



Review Article

Enhancing Agricultural Resilience Through Climate-Smart Practices: A Case Study of Smallholder Farmers in Horro Guduru Wallaga Zone, Hababo Guduru Woreda

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Abstract

Climate variability and environmental stressors, including erratic rainfall, recurrent drought, and soil degradation, increasingly threaten the sustainability of smallholder agriculture in Ethiopia, where rain-fed farming remains the main source of livelihood and food security. Although climate-smart agriculture (CSA) is widely promoted as a strategy to increase productivity, build resilience, and reduce greenhouse gas emissions, evidence on its effects at the local level remains limited. This study therefore investigates how CSA practices enhance the resilience of smallholder farmers in Hababo Guduru Woreda, Horro Guduru Wallaga Zone, and Oromia Regional State, Ethiopia. A mixed-methods research design was employed, combining quantitative and qualitative approaches. Primary data were collected through household surveys, key informant interviews, and focus group discussions with smallholder farmers, development agents, and local officials. Quantitative data were analysed using descriptive and inferential statistics, while qualitative data were analysed thematically. The findings reveal that the adoption of CSA practices, such as soil and water conservation, improved crop varieties, agroforestry, crop diversification, and organic fertilizer use, improves crop productivity, soil health, and household food security while reducing vulnerability to climate shocks. Policy support, farmer training and extension services, and access to financial incentives and credit were identified as key enablers of CSA uptake, whereas limited access to climate information, inputs, and capital constrained wider adoption. The study concludes that CSA is an effective pathway for strengthening agricultural resilience among smallholder farmers in the study area. It recommends that local and national stakeholders strengthen extension and training programs, expand access to finance and climate information, and integrate CSA into agricultural development policies to promote climate-resilient agriculture.

Keywords

Climate-Smart Agriculture, Resilience, Smallholder Farmers, Food Security, Hababo Guduru, Ethiopia

1. Introduction

1.1. Background of the Study

Agriculture is the cornerstone of Ethiopia's economy, employing more than 70% of the population and playing a pivotal role in

the nation's GDP and exports. Yet, this vital sector faces severe challenges from climate change, including erratic rainfall, land degradation, and rising temperatures. These factors jeopardize the productivity and sustainability of smallholder farming. The

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Received: 1 September 2026; **Accepted:** 29 September 2026; **Published:** 21 October 2026



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Horro Guduru Wallaga Zone, especially Hababo Guduru Woreda, is frequently hit by weather-related shocks, resulting in diminished yields and heightened food insecurity. Climate-smart agriculture (CSA) is a ground-breaking response to these urgent problems. By integrating strategies for adapting to and mitigating climate change while enhancing productivity, CSA offers a pathway towards long-term agricultural sustainability. This study seeks to investigate the transformative role of CSA in bolstering the resilience of smallholder farmers in the region, highlighting its potential to secure both livelihoods and food security for the future.

1.2. Statement of the Problem

Smallholder farmers in Hababo Guduru Woreda face escalating vulnerabilities due to climatic variability. Despite the implementation of national policies that advocate for Climate Smart Agriculture (CSA), adoption rates remain alarmingly low. This is primarily attributed to significant knowledge gaps, inadequate extension services, and financial limitations. Furthermore, the lack of localized evidence regarding the effectiveness of CSA in enhancing resilience poses a critical barrier to developing targeted interventions and formulating effective policies.

1.3. Research Questions

- 1) What varieties of (climate-smart agricultural) CSA practices are currently being adopted by smallholder farmers in Hababo Guduru Woreda?
- 2) In what ways do these (climate-smart agricultural) CSA practices impact agricultural productivity and resilience?

1.4. Objectives of the Study

1.4.1. General Objective

To examine how climate-smart agricultural practices enhance agricultural resilience among smallholder farmers in Hababo Guduru Woreda.

1.4.2. Specific Objectives

- 1) To identify CSA practices used in the study area.
- 2) To analyze the impact of CSA on crop yield and farmer income.
- 3) To assess the constraints and opportunities for scaling up CSA.

1.4.3. Significance of the Study

This research seeks to provide compelling empirical evidence on the advantages of CSA for smallholder farmers in Ethiopia. The insights gained will serve as a vital resource for policymakers, development partners, and local extension agents, empowering them to facilitate increased CSA adoption and significantly strengthen agricultural resilience in the region.

2. Literature Review

2.1. Introduction

This chapter reviews key concepts, theoretical frameworks, and empirical findings related to agricultural resilience and climate-smart practices. It establishes the foundation for understanding the significance of climate-smart agriculture (CSA) within the context of smallholder farming in Ethiopia. The review is organized into thematic areas, including resilience theory, climate-smart agricultural concepts, global and Ethiopian CSA experiences, barriers to adoption, and knowledge gaps.

2.2. Concept of Agricultural Resilience

Agricultural resilience refers to the ability of agricultural systems, particularly smallholder farms, to absorb, adapt to, and transform in response to climatic and non-climatic shocks [1]. This concept extends beyond short-term adaptation, emphasizing long-term sustainability, food security, and risk reduction. Resilience comprises three core elements. Absorptive capacity is the ability to withstand minor shocks, for example through the use of drought-tolerant crops. Adaptive capacity is the capability to adjust practices over time, such as by implementing agroforestry. Transformative capacity is the potential for long-term systemic change, such as the development of irrigation systems.

2.3. Overview of Climate-Smart Agriculture (CSA)

2.3.1. Increase Productivity and Incomes

Increasing agricultural productivity and incomes is the first pillar of climate-smart agriculture (CSA). For smallholder farmers in Hababo Guduru Woreda, who depend largely on rain-fed farming, this pillar is closely tied to food security and household welfare. Yields are often low because of erratic rainfall, declining soil fertility, and limited access to improved inputs, which keeps incomes low and leaves households with little capacity to recover from climate shocks.

2.3.2. Enhance Resilience to Climate Variability

CSA practices address these constraints in several ways. Soil and water conservation measures, such as terracing, soil bunds, and water harvesting, reduce erosion and runoff and keep moisture and nutrients in the root zone, which stabilizes yields in both dry spells and heavy rains. Improved and drought-tolerant crop varieties give better returns on the same land, especially when planted on time and managed with recommended practices.

2.3.3. Reduce Greenhouse Gas emissions, Where Possible

CSA is a framework that is customized to fit local demands rather than a single technology or method. The following are important instances of CSA practices:

Table 1. Components of Agricultural Resilience (Diagram showing interlinked capacities — absorptive, adaptive, and transformative).

CSA Practice	Function
Conservation agriculture	Improves soil health and water retention
Agroforestry	Increases biodiversity and shade
Drought-resistant seeds	Enhances yield under dry conditions
Crop diversification	Reduces climate risk
Integrated livestock	Improves farm nutrient cycling

2.4. Global Experiences with Climate-Smart Agriculture (CSA)

Countries around the world, including Kenya, India, and Bangladesh, have successfully integrated CSA into their national development plans. For example, Kenya's Climate-Smart Agriculture Strategy (2017–2026) offers a framework for CSA implementation in semi-arid and desert areas [5].

Case Example – India: The "National Initiative on Climate Resilient Agriculture (NICRA)" has enabled thousands of farmers to adopt water-saving technologies and implement risk-reducing cropping systems [6]. CSA in Ethiopia: Ethiopia adopted the Climate-Resilient Green Economy (CRGE) strategy in 2011, which aims to promote climate-resilient development [7]. CSA is a key component of this strategy, particularly in the agricultural sector [1,2].

2.5. CSA Practices and Adoption Trends

Climate-smart agriculture (CSA) practices have been shown to improve yields by up to 40% in pilot areas [9]. However, adoption rates remain low—below 25%—in many rural zones due to a lack of awareness, necessary tools, and access to markets.

2.6. Empirical Evidence

Many researchers have examined how smallholder farmers respond to climate shocks. For instance: - Kassie et al. [3] found that integrated soil fertility management significantly boosts maize yields during drought years. - Mekonnen & Gebremedhin [4] noted that farmers who adopted CSA practices were more likely to recover from drought within two growing seasons. Common Benefits Identified: - Improved soil fertility

- Diversified income sources - Better access to water - Enhanced food security

2.7. Theoretical Framework

This study is guided by the Sustainable Livelihoods Framework (SLF) and Resilience Thinking. These frameworks analyze how households utilize various capital assets (natural, human, financial, etc.) to achieve resilience under stress.

2.8. Research Gap

While several studies on CSA exist in Ethiopia, few have specifically focused on the Horro Guduru Wallaga Zone or Hababo Guduru Woreda. There is a need to: - Localize findings based on agro ecological conditions - Explore farmer perceptions of CSA - Analyze measurable improvements in resilience outcomes

2.9. Summary of Literature Review

The literature indicates that CSA is a critical strategy for improving agricultural resilience in the face of climate change. However, adoption is highly context-specific and often hindered by socio-economic and institutional barriers. This study builds on existing knowledge but narrows its focus to a specific and under-researched geographic area in Oromia.

3. Research Methodology

3.1. Introduction

This chapter presents the research design, population and sampling procedures, data sources, data collection methods, data analysis techniques, and ethical considerations used in the study. It aims to ensure the reliability, validity, and academic rigor needed to address the study's objectives.

3.2. Description of the Study Area

Hababo Guduru. Approximately 310 kilometers west of Addis Ababa, in Ethiopia's Horro Guduru area, is Woreda.

The area has the following characteristics:

- 1) Altitude: 1,800–2,400 meters above sea level
- 2) Rainfall: 900–1,200 mm annually
- 3) Temperature: 13°C–28°C
- 4) Main Crops: Teff, maize, sorghum, and wheat,
- 5) Livestock: Cattle, goats, sheep, and poultry

The relevance of Climate Smart Agriculture (CSA) in this region is significant, as it is characterized by rain-fed agriculture, making it highly vulnerable to climate shocks such as drought and irregular rainfall.

3.3. Research Design

This study employs a mixed-methods approach, which integrates both quantitative and qualitative methods. This design facilitates data triangulation and provides a comprehensive understanding of CSA adoption and resilience outcomes.

Table 2. CSA adoption and resilience outcomes.

Methodology Type	Purpose
Quantitative	Statistical analysis of adoption, yield, income
Qualitative	Farmer perceptions, barriers, case narratives

3.4. Target Population

The target population consists of smallholder farming households in Hababo Guduru Woreda. These households mostly use family labour to run farms that are smaller than two hectares.

The key groups included in this study are:

- 1) Farmers practicing Climate Smart Agriculture (CSA)
- 2) Farmers who have not yet adopted CSA
- 3) Agricultural extension officers
- 4) Local cooperatives and development agents

3.5. Sampling Procedure and Sample Size

A multistage sampling technique was employed for this study:

- 1) Purposive selection of Hababo Guduru Woreda due to its climate vulnerability.
- 2) Random selection of five Kebeles from the Woreda.
- 3) Systematic random sampling of 150 smallholder farmers, with 30 selected from each kebele.

Sample Size Determination

Using Yamane's [8] formula for sample size determination:

To effectively manage resources while ensuring representation, a final sample of 150 farmers was selected, keeping in mind time and cost constraints.

3.6. Data Sources

Table 3. Types of Data used.

Source Type	Examples
Primary	Household survey, FGDs, key informant interviews

Source Type	Examples
Secondary	CSA project reports, CSA policy frameworks, CSA-Ethiopia reports [9], journal articles, meteorological data

3.7. Data Collection Tools and Techniques

A. Household Survey Questionnaire

Structured tools covering:

- 1) Socioeconomic characteristics
- 2) Climate-smart practices adopted
- 3) Changes in crop yields and income
- 4) Perceived climate risks

B. Focus Group Discussions (FGDs)

conducted with 8–12 farmers in each kebele to investigate:

- 1) Local perceptions of climate risks
- 2) Indigenous practices and awareness of climate-smart agriculture (CSA)
- 3) Gender perspectives on CSA adoption

C. Key Informant Interviews (KIIs)

Conducted with:

- 1) Agricultural experts
- 2) Development agents (DAs)
- 3) Representatives from the woreda agriculture office

D. Field Observation

used to verify data through the observation of tangible proof of: CSA techniques (such as water harvesting pits and mulching)

Instances of land degradation or improvements

3.8 Data Analysis Techniques

Quantitative Data

- 1) Entered in SPSS v26 [11].
- 2) The mean, frequency, and standard deviation are examples of descriptive statistics.

Inferential statistics:

- 1) Chi-square tests (for association between CSA use and demographic variables).
- 2) T-tests (comparing yields of CSA vs. non-CSA farmers).
- 3) Regression analysis (to predict factors influencing CSA adoption).

Qualitative Data.

- 1) Thematic analysis using coding derived from FGDs and KIIs
- 2) NVivo software utilized for organizing and interpreting text data [10]

3.9. Validity and Reliability

- 1) Pre-testing of questionnaires conducted in a neighboring kebele to refine questions
- 2) Training provided to enumerators to ensure consistency

- 3) Triangulation of data sources (surveys, FGDs, and observations) to enhance credibility

3.10. Ethical Considerations

- 1) Informed consent obtained from all participants
- 2) Confidentiality assured through anonymous responses
- 3) Participation was entirely voluntary, and anyone might stop at any moment.
- 4) Ethical clearance secured from [Your University Department] prior to fieldwork

4. Results and Analysis

4.1. Introduction

This chapter presents and analyzes the data collected during the field research. It provides an in-depth understanding of the factors influencing the adoption of Climate-Smart Agriculture (CSA) practices, and how these practices affect agricultural resilience in Hababo Guduru Woreda. The chapter is divided into two main sections: demographic analysis and CSA adoption analysis. Tables, graphs, and charts are included to illustrate the findings.

4.2. Demographic Profile of Respondents

4.2.1. Age Distribution

The age of the respondents ranged from 25 to 65 years, with the majority falling within the 35-50 year age group. This is reflective of the active farming population in the region.

Table 4. Age Distribution of Respondents (Bar graph showing the frequency distribution by age group).

Age Group (Years)	Frequency	Percentage (%)
25-34	30	20
35-50	75	50
51-65	40	26.7
66+	5	3.

4.2.2. Gender Distribution

Out of 150 respondents, 70% were male and 30% were female, reflecting the typical gender roles in smallholder farming in Ethiopia, where men often control land and major agricultural decisions.

Table 5. Gender Distribution of Respondents (Pie chart showing male and female respondents).

Gender	Frequency	Percentage (%)
Male	105	70
Female	45	30

4.2.3. Education Level

The majority of respondents had basic education, with primary school as the highest level attained by 60% of the respondents. Only 15% had completed secondary education or higher.

Table 6. Education Level of Respondents, (Bar graph depicting education levels).

	Frequency	Percentage (%)
No formal education	20	13.3
Primary school	90	60
Secondary education	20	13.3
Tertiary education	20	13.3

4.3. Climate-Smart Agriculture Adoption

4.3.1. Awareness and Knowledge of CSA

Among the 150 respondents, 85% were aware of Climate-Smart Agriculture (CSA). However, only 45% had adopted one or more CSA practices. The remaining 55% had heard of CSA but had not implemented any practices, citing lack of knowledge, resources, and extension support as key barriers.

4.3.2. Types of CSA Practices Adopted

The most commonly adopted CSA practices among the respondents were:

Table 7. CSA Practices Adopted by Respondents (Stacked bar graph representing adoption of different CSA practices).

CSA Practice	Adopted (%)
Conservation Agriculture	60
Agroforestry	50
Crop Diversification	45
Drought-Resistant Seeds	35
Water Harvesting Techniques	30
Integrated Livestock Systems	25

4.3.3. Reasons for CSA Adoption

Farmers who adopted CSA practices cited several motivations, including:

- 1) Increased crop yields during drought (78%).
- 2) Improved soil fertility and water retention (70%).
- 3) Higher income levels due to diversification (55%).
- 4) Government and NGO support through training and material provision (50%).

4.3.4. Challenges to CSA Adoption

Despite the benefits, 55% of farmers expressed reluctance to fully adopt CSA practices due to the following barriers:

Table 8. Barriers to CSA Adoption (Bar graph showing the percentage of farmers citing each barrier).

Barrier	Frequency (%)
Lack of extension support	50
Limited access to	45
Lack of awareness about CSA	40
High initial costs of CSA technologies	35
Land tenure insecurity	25

4.3.5. Comparative Analysis: CSA vs Non-CSA Farmers

A t-test was conducted to compare the yields and income levels between CSA adopters and non-adopters.

Yield Analysis

Table 9. Yield Comparison between CSA and Non-CSA Farmers (Bar chart showing yield differences between CSA and non-CSA groups).

Group	Average Yield (kg/ha)	Standard Deviation
CSA Adopters	2,500	350
Non-CSA Adopters	1,700	400

- 1) The mean yield for CSA adopters is significantly higher than for non-adopters ($p < 0.05$), indicating that CSA adoption results in improved productivity.

Income Analysis

Table 10. Income Comparison between CSA and Non-CSA Farmers (Bar chart illustrating income differences between CSA and non-CSA groups).

Groups	Average Annual Income (ETB)	Standard Deviation
CSA Adopters	15,000	2,500
Non-CSA Adopters	10,500	3,000

- 2) CSA adopters also reported a higher average annual income, with the difference being statistically significant ($p < 0.05$).

4.4. Discussion of Findings

4.4.1. Impact of CSA on Agricultural Resilience

The findings from the survey and statistical analysis show a strong correlation between CSA adoption and improved resilience. Farmers practicing CSA, particularly conservation agriculture and drought-resistant seeds, reported better crop yields, income levels, and overall resilience during climate-related shocks.

4.4.2. Socioeconomic Factors Affecting CSA Adoption

- 1) Education: Farmers with higher levels of education were more likely to adopt CSA due to better awareness and understanding of its benefits.
- 2) Gender: Male farmers had a higher adoption rate of CSA, which can be linked to traditional gender roles and access to land and resources.
- 3) Extension Services: Availability of extension services was a key determinant of CSA adoption. Farmers who received training and technical support were more likely to adopt and benefit from CSA.

4.5. Summary of Chapter

This chapter presented detailed demographic data, CSA adoption rates, and key findings regarding the impact of CSA practices on agricultural resilience. It also discussed the barriers to adoption and comparative performance between CSA and non-CSA farmers. These results highlight the importance of targeted extension services and training in promoting CSA practices in Hababo Guduru Woreda.

5. Conclusions and Recommendations

5.1. Introduction

This chapter presents and analyzes the data collected during the field research, providing an in-depth understanding of the factors influencing the adoption of Climate-Smart Agriculture (CSA) practices and their effects on agricultural resilience in Hababo Guduru Woreda. The chapter is divided into two main sections: demographic analysis and CSA adoption analysis. Tables, graphs, and charts are included to illustrate the findings.

5.2. Demographic Profile of Respondents

5.2.1. Age Distribution

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Among the 150 respondents, 70% were male and 30% were female, reflecting the typical gender roles in smallholder farming in Ethiopia, where men often control land and make major agricultural decisions.

Table 12. Gender Distribution of Respondents (Pie chart showing male and female respondents).

Percentage (%)	Gender	Frequency
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Table 13. Education Level of Respondents.

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(Stacked bar graph representing adoption of different CSA practices).

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The mean yield for CSA adopters is significantly higher than for non-adopters ($p < 0.05$), indicating that CSA adoption results in improved productivity.

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CSA adopters also reported a higher average annual income, with the difference being statistically significant ($p < 0.05$).

5.4. Discussion of Findings

5.4.1. Impact of CSA on Agricultural Resilience

The findings from the survey and statistical analysis show a strong correlation between CSA adoption and improved resilience. Farmers practicing CSA, particularly through conservation agriculture and the use of drought-resistant seeds reported better crop yields, higher income levels, and overall resilience during climate-related shocks.

5.4.2. Socioeconomic Factors Affecting CSA Adoption

- 1) Education: Farmers with higher education levels were more likely to adopt CSA due to better awareness and understanding of its benefits.
- 2) Gender: Male farmers had a higher adoption rate of CSA, which is linked to traditional gender roles and access to land and resources.
- 3) Extension Services: The availability of extension services is crucial for facilitating CSA adoption.

Abbreviations

CSA	Climate-Smart Agricultural
GDP	Growth Domestic Plan
FAO	Food Association Organization
CRGE	Climate-Resilient Green Economy
NICRA	National Initiative on Climate Resilient Agriculture
SLF	Sustainable Livelihoods Framework
SPSS	Statistical Package for the Social Sciences
FGDs	Focus Group Discussions
DAs	Development Agents
KIIs	Key Informant Interviews
FGDs	Focus Group Discussions

Author Contributions

Gamachu Busa Meskele: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Project administration, Resources, Software Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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