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Adoption of Climate-Smart Agriculture Practices among Smallholder Farmers in Chikuni, Monze District

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Abstract

Climate change poses a significant threat to smallholder farmers in sub-Saharan Africa, particularly in Zambia where agriculture supports nearly 70% of the population. Climate-Smart Agriculture (CSA) has emerged as a critical strategy for building resilience, yet adoption rates remain persistently low. This mixed-methods study investigated CSA adoption among 330 smallholder farmers in Chikuni, Monze District, using surveys, focus groups, and key informant interviews. The findings revealed that 62% of farmers had adopted at least one CSA practice, with conservation agriculture (48%) and crop rotation (45%) being most common, while water harvesting (18%) and agroforestry (15%) remained limited. However, 65% of farmers implemented no more than two practices. Financial constraints (78%), limited input access (62%), inadequate extension services (48%), and knowledge gaps (55%) emerged as primary barriers, compounded by a severe extension officer-to-farmer ratio of 1:1,200. Despite these challenges, 72% of farmers expressed willingness to adopt more practices, conditional on credit access, inputs, and practical training. Farmer-to-farmer learning (85%) and demonstration plots (78%) were the most preferred dissemination approaches. Statistical analysis confirmed that financial access ($p<0.001$, $d=0.795$) and extension visit frequency ($p=0.001$, OR=5.69) significantly influence adoption intensity, while education level explains 17% of variance in adoption. The study concludes that enhancing CSA adoption requires a bundled approach addressing financial, informational, and institutional barriers simultaneously through community-based mechanisms like Village Savings and Loan Associations and peer learning networks.

Keywords: Climate-Smart Agriculture, Adoption, Smallholder Farmers, Constraints, Zambia

1. Introduction

1.1 Background and Global Context

Climate change poses a significant threat to agricultural productivity, particularly among smallholder farmers in sub-Saharan Africa (SSA), where over 90% of agriculture is rain-fed [1]. The region is highly susceptible to climatic variability due to dependence on seasonal rainfall, limited irrigation infrastructure, and low adaptive capacity [2]. Rising global temperatures have altered precipitation patterns and exacerbated droughts and floods [3], disrupting planting seasons, reducing soil moisture, and diminishing crop yields [4].

The IPCC documents that global surface temperatures have risen by approximately 1.1°C since pre-industrial times [1]. In SSA, impacts are particularly severe due to heavy reliance on rain-fed agriculture, limited adaptive capacity, and widespread poverty. Without adaptation, crop yields in SSA could decline by up to 20% by 2050 [2]. Smallholder vulnerability encompasses biophysical factors (temperature and precipitation changes) and socioeconomic factors (limited access to credit, markets, and technology) [3].

1.2 The Zambian Agricultural Context

In Zambia, agriculture employs nearly 70% of the population and contributes about 20% of GDP, yet smallholder farmers, approximately 80% of the agricultural workforce, remain highly vulnerable to climate shocks [5]. The country has experienced declining rainfall reliability over two decades, with prolonged dry spells affecting maize production [6]. Smallholders often lack access to climate-resilient seeds, modern irrigation, and financial resources [7]. Without intervention, climate change could reduce Zambia's agricultural output by 15 to 40% by 2050 [8].

Zambia's agricultural sector comprises a small commercial farming sector and a large, subsistence-oriented smallholder sector. Maize dominates the cropping system, accounting for over 80% of cultivated area in many regions, creating risks associated with mono-cropping and climate-induced crop failures [6]. The National Agricultural Policy 2021-2026 emphasizes sustainable intensification and CSA [11], but implementation challenges include limited financial resources, weak institutional capacity, and inadequate coordination [12].

1.3 Climate-Smart Agriculture: Concept and Pillars

CSA is a holistic approach aimed at enhancing agricultural resilience, improving productivity, and reducing greenhouse gas emissions [9]. CSA integrates three pillars: (1) sustainably increasing agricultural productivity, (2) adapting and building resilience to climate change, and (3) mitigating emissions where possible [10]. Prominent CSA practices include conservation agriculture, agroforestry, crop diversification, improved water management, and integrated nutrient management.

Conservation agriculture (CA) is based on minimum soil disturbance, permanent soil cover, and crop rotation or diversification [9]. CA improves soil health, increases water infiltration, reduces erosion, and enhances drought resilience. However, adoption among smallholders in SSA has been uneven due to input availability, labour requirements, and competing uses for crop residues [18]. Agroforestry involves integrating trees and shrubs into crop and livestock systems, enhancing soil fertility, providing fodder, sequestering carbon, and diversifying income [20], but requires long-term planning and investment. Water harvesting techniques help farmers cope with erratic rainfall but often require significant upfront investment and technical knowledge [10].

1.4 Study Area: Chikuni, Monze District

Monze District, in Zambia's Southern Province, is predominantly agrarian with maize as the primary staple crop [6]. Chikuni is characterized by small-scale farming systems highly sensitive to climate variability. Farmers face recurring droughts, soil degradation, and limited access to credit and inputs [11]. While government programs and NGOs have introduced CSA initiatives, adoption remains fragmented [12].

Chikuni is located approximately 100 kilometres south of Lusaka, with a semi-arid climate and a single rainy season from November to April. Annual rainfall averages 600-800 millimetres but has become increasingly erratic [6]. Predominant soil types are sandy loams and loamy sands, inherently low in fertility and organic matter. Maize dominates, followed by groundnuts, sunflower, and cotton. Livestock, particularly cattle and goats, play an important role in the local economy. The Chikuni Agricultural Camp serves approximately 1,340 registered smallholder farmers, mostly cultivating 1-5 hectares. Farming systems are predominantly rain-fed, with limited access to inputs, credit, and extension services [13].

1.5 Problem Statement

Key barriers to CSA adoption in Chikuni include socioeconomic constraints (high input costs, lack of credit), institutional gaps (weak extension services, limited training), and cultural factors such as preference for traditional methods and risk aversion [13]. Despite CSA's potential benefits, adoption rates remain low and fragmented. Previous studies document various barriers [7, 18, 22], but limited understanding exists of how these barriers interact in specific local contexts like Chikuni. Many CSA promotion efforts have been implemented as short-term projects without adequate attention to sustainability [21]. When projects end, adoption often declines, suggesting underlying barriers have not been addressed.

1.6 Research Objectives

This study aimed to evaluate CSA adoption among smallholder farmers in Chikuni, Monze District. Specific objectives were:

1. To assess the extent of adoption of selected CSA practices;
2. To identify major constraints to CSA adoption;
3. To analyze factors that can potentially enhance CSA adoption; and
4. To provide evidence-based recommendations for policymakers and practitioners.

1.7 Research Questions

1. What is the extent of adoption of selected CSA practices among smallholder farmers in Chikuni?
2. What are the major constraints to CSA adoption in the study area?
3. What factors can potentially enhance CSA adoption?
4. What are the most preferred channels for CSA knowledge dissemination and support?

1.8 Significance of the Study

This study provides empirical evidence on CSA adoption patterns in a specific local context, identifies key barriers and their interactions, examines farmer preferences for CSA practices and knowledge dissemination channels, and provides evidence-based recommendations for policymakers and practitioners.

1.9 Structure of the Article

Section II reviews the literature on CSA adoption. Section III describes the research design, sampling procedures, data collection instruments, and data analysis methods. Section IV presents the results. Section V discusses findings in relation to the literature. Section VI presents conclusions and recommendations. Section VII identifies areas for further research.

2. Literature Review

2.1 Conceptual Framework

The conceptual framework illustrates relationships between independent variables (factors influencing adoption), intervening variables (institutional and support systems), and the dependent variable (level of CSA adoption). CSA adoption is influenced by farmer characteristics, socioeconomic factors, agro-ecological context, institutional factors, and cultural norms. At the farm level, farmer characteristics (age, education, gender, farming experience) and socioeconomic factors (income, credit access, land tenure) influence adoption decisions. Agro-ecological factors (soil type, rainfall patterns, pests and diseases) influence the suitability of different CSA practices [18]. At the institutional level, extension services, market access, and the policy environment shape the enabling environment [22].

At the community level, social networks, cultural norms, and collective action influence diffusion [27, 33].

2.2 Theoretical Framework

This study is grounded in four complementary theories:

Diffusion of Innovations Theory [14] explains how new practices are adopted within a community, emphasizing innovation characteristics, social networks, and adopter categories. Adoption follows an S-shaped curve, with rate influenced by relative advantage, compatibility, complexity, trialability, and observability. Farmer-to-farmer learning is often the most effective communication channel.

Theory of Planned Behaviour [15] offers a psychosocial model explaining how attitudes, subjective norms, and perceived behavioural control shape adoption intentions. Farmers' decisions are influenced by their attitudes toward CSA, perceived social pressure, and perceived ability to implement CSA.

Sustainable Livelihoods Framework [16] provides a comprehensive approach for understanding how households construct livelihoods within environmental and institutional contexts, focusing on five livelihood capitals: human, natural, financial, physical, and social. Financial capital determines investment ability; human capital influences understanding and implementation capacity; natural capital determines potential benefits; physical capital influences feasibility; social capital influences access to information and support.

Innovation Systems Theory [17] posits that innovation is a complex, interactive process generated within a network of diverse actors and institutions. Creating an enabling environment for innovation, including supportive policies, effective institutions, and strong linkages among actors, is essential. Multi-stakeholder approaches and local capacity building are emphasized.

2.3 Extent of Adoption of CSA Practices

Global Patterns: Globally, adoption rates are generally low and heterogeneous. Thornton *et al*. [19] suggest that in many developing regions fewer than 10% of smallholders have adopted more than two CSA practices concurrently, revealing widespread partial or symbolic adoption. Many CSA practices are complementary, and their benefits are maximized when implemented together. The prevalence of partial adoption suggests many farmers are not realizing the full benefits of CSA [19].

Sub-Saharan Africa: Adoption rates are highly variable. Notable successes include 30-40% conservation agriculture adoption in Malawi and 50% agroforestry uptake in targeted Kenyan zones [20]. However, high rates in project areas underscore the temporary efficacy of external inputs and intensive extension, not necessarily sustainable adoption. Practices requiring significant upfront investment tend to have lower adoption rates. Farmers with higher education, greater credit access, and more secure land tenure tend to have higher adoption rates [22]. Extension services play a well-documented role, but are often under-resourced with farmer-to-extension officer ratios far exceeding the recommended 1:500 [29].

Zambia: Conservation agriculture and agroforestry form the core CSA portfolio [7]. Adoption is often catalyzed by targeted NGO or faith-based programs, creating a "projectification" of adoption where practices are adopted within project lifespans but durability post-project remains questionable [21]. Ngoma *et al*. [7] found adoption of conservation farming is associated with increased crop revenues, but effects vary. Adoption is highest where institutional presence is strong, but the pilot project trap creates unsustainable dependence. Siatwinda *et al*. [34] call for mainstreaming CSA into national extension systems to ensure permanence beyond donor cycles.

2.4 Constraints to CSA Adoption

Global Perspectives: The literature identifies an interconnected matrix of constraints. Foremost is the information and capacity gap, with weak public extension services creating disconnection between knowledge generators and end-users [22]. Financial and resource constraints place CSA out of reach for cash-poor smallholders due to high initial costs for improved seeds, irrigation equipment, or soil amendments [23]. Land tenure insecurity undermines incentives for long-term land stewardship [24]. Cultural norms and institutional weaknesses act as mediating factors [25].

African Context: Land tenure security operates as a primary gatekeeper for CSA adoption [26]. Social structures and capital, farmer networks, cooperatives, kinship groups, serve as critical economic infrastructures for risk-sharing, labour exchange, and information diffusion [27]. Limited capital and labour availability must be analyzed through household dynamics and gender, as CSA technologies often reallocate labour, frequently increasing the burden on women and youth [28]. Women face additional barriers including limited access to land, credit, and information.

Zambia: A primary bottleneck is the chronic weakness of public extension systems. Nyanga *et al*. [29] identify poor extension coverage, under-resourcing, and a top-down delivery mode as major impediments. Limited credit access must be examined within Zambia's financial ecosystem, where smallholder farmers face a scarcity of formal lending institutions and financial products ill-suited to agricultural rhythms [30]. Informal credit sources like Village Savings and Loan Associations (VSLAs) have emerged as important alternatives but their reach and capacity are limited.

2.5 Enhancement Measures for CSA Adoption

Global Perspectives: Scholars converge on the necessity of creating robust enabling environments. FAO [10] and Lipper *et al*. [9] emphasize integrated policy frameworks that incentivize sustainable practices. Tyler *et al*. [31] argue for climate information services and index-based insurance to de-risk adoption. Arslan *et al*. [32] highlight the need for gender-responsive program design. Climate information services help farmers make informed decisions about planting dates and crop selection. Index-based insurance provides payouts when climate triggers occur, helping farmers cope with shocks.

African Context: Kristjanson *et al*. [27] demonstrate the importance of strengthening social capital, farmer cooperatives, saving groups, and peer learning networks. Mbeche *et al*. [33] argue for value chain integration, linking CSA adoption to improved access to input and output markets to create economic incentives. Peer learning networks have been shown to be effective in disseminating CSA knowledge and promoting adoption.

Zambia: Ngoma *et al*. [7] confirm that adoption is highest where institutional presence is strong but warn of the pilot project trap. Siatwinda *et al*. [34] call for mainstreaming CSA

into national extension systems and agricultural training curricula. Addressing the pilot project trap requires designing CSA promotion efforts with clear exit strategies and handover to community institutions, building local capacity, strengthening farmer organizations, and creating sustainable financing mechanisms [7].

3. Materials and Methods

3.1 Research Design

This study employed a Convergent Parallel Mixed-Methods Descriptive Design, characterized by simultaneous, independent collection and analysis of quantitative and qualitative data, with merging during interpretation [35]. This design serves all study objectives: quantitative survey quantifies adoption extent, while qualitative methods explore contextual constraints and social dynamics. The convergent parallel design allows triangulation, enhancing validity and depth. The study was guided by a pragmatist paradigm, emphasizing the research question as the primary driver of methodological choices [35].

3.2 Target Population and Sample Size

The target population consisted of 1,340 registered smallholder farmers in Chikuni Agricultural Camp, Monze District, Zambia. The study focused on farmers operating 1-5 hectares with mixed subsistence and market-oriented production. Using Yamane's formula for finite population sample size: $n = N / (1 + N(e)^2)$

Using a 95% confidence level and 5% margin of error:

$$n = 1340 / (1 + 1340(0.05)^2) = 1340 / 4.35 = 308$$

A finite population correction resulted in a minimum sample size of 292. To account for non-response, this was inflated by 13% to 330 farmers. Farmers operating larger farms (above 5 hectares) were excluded, as their farming systems and constraints may differ.

3.3 Sampling Procedures

Quantitative Sampling: Simple random sampling was used to select 330 farmers from the consolidated list of 1,340 registered farmers. The sampling frame was stratified by gender to ensure adequate female representation. Within each stratum, farmers were selected using a random number generator. If a selected farmer was unavailable, the next farmer on the list was selected as a replacement.

Qualitative Sampling: Purposive sampling was used to select participants for key informant interviews and focus group discussions. Key informants included extension officers, NGO staff, community leaders, and lead farmers. Twenty key informant interviews were conducted (45-60 minutes each). Four focus group discussions were conducted with 8 participants each (90-120 minutes each), ensuring diversity in gender, age, farming experience, and CSA adoption status.

3.4 Data Collection Instruments

Structured Questionnaire: The questionnaire collected quantitative data on socio-demographic characteristics, CSA adoption patterns, perceived barriers, sources of information and support, and preferences for CSA promotion approaches. It consisted of four sections: (A) Socio-demographic characteristics; (B) CSA adoption; (C) Perceived barriers (5-point Likert scale); (D) Sources of information and preferences. The questionnaire was pre-tested with 30 farmers in a neighbouring camp.

Focus Group Discussion Guide: Explored farmers' perceptions, experiences, and opinions about CSA, including awareness, adoption experiences, barriers, facilitating factors, preferences for promotion approaches, and gender dimensions.

Key Informant Interview Guide: Collected in-depth information on CSA adoption trends, barriers, effectiveness of promotion efforts, recommendations, and institutional/policy factors.

Validity and Reliability: Content validity was ensured through literature review and expert consultation. Construct validity was assessed through factor analysis. Criterion-related validity was assessed by comparing questionnaire responses with observational data. Cronbach's alpha for the barriers scale was 0.82. Test-retest reliability yielded a correlation coefficient of 0.85. Inter-rater reliability yielded a Cohen's kappa of 0.78.

3.5 Data Analysis

Quantitative Analysis: Descriptive statistics (frequencies, means) summarized socio-demographic characteristics, adoption patterns, barriers, and preferences. Inferential statistics tested hypotheses: chi-square for associations between categorical variables, t-tests for comparing means between two groups, and ANOVA for comparing means across multiple groups. Effect sizes were calculated: Cohen's d for t-tests, Cramer's V for chi-square, and eta-squared for ANOVA.

Qualitative Analysis: Thematic analysis followed Braun and Clarke's six-step process: familiarization, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. Transcripts were coded inductively, with codes grouped into themes.

Integration: Results were integrated through triangulation, comparing and contrasting findings from quantitative and qualitative strands to identify convergence and divergence. For each objective, findings from both strands were synthesized.

4. Results and Interpretation

4.1 Socio-Demographic Profile of Respondents

The sample exhibited male predominance (58%), with female representation at 42%. Age distribution indicates a mature population, with 60% between 36-55 years. Education levels are markedly low: 70% have no formal schooling or only primary education. Farming is the dominant livelihood (crop farming 55%, mixed farming 32%), with experience split between 5-10 years (30%) and over 15 years (30%). Land ownership at 65% indicates tenure security for most, while 22% rely on communal land and 13% on rented arrangements.

Table 1: Socio-Demographic Characteristics of Respondents

Characteristic	Category	Frequency (n=330)	Percentage
Gender	Male	191	58%
	Female	139	42%
Age	18-35 years	86	26%
	36-55 years	198	60%
	Above 55 years	46	14%
Education	No formal schooling	89	27%
	Primary	142	43%
	Secondary	76	23%
	Tertiary	23	7%
Farming Experience	Less than 5 years	66	20%
	5-10 years	99	30%
	11-15 years	66	20%
	Above 15 years	99	30%
Land Tenure	Owned	215	65%
	Communal	73	22%
	Rented	43	13%
Household Size	1-5 members	132	40%
	6-10 members	165	50%
	Above 10 members	33	10%

The male predominance is consistent with patterns in Zambia, where men are more likely to be registered as farmers. However, 42% female representation is notable given women's significant role in the agricultural workforce. The mature age of respondents may have implications for CSA adoption, as older farmers may be more risk-averse but may also have more resources to invest [14]. Low education levels are a concern, highlighting the importance of designing CSA training appropriate for low-literacy audiences using visual aids and hands-on learning [22]. Land tenure security is positive, as most farmers have secure tenure and are more likely to invest in CSA practices. However, the 35% relying on communal or rented land may be less likely to adopt long-term investments such as agroforestry [24].

4.2 Types of CSA Practices Adopted

The data reveals a tiered adoption pattern. Conservation agriculture (48%) and crop rotation (45%) are most widely embraced, serving as entry-level, low-cost strategies. Integrated soil fertility management (38%) and drought-tolerant varieties (35%) show moderate uptake. Resource-intensive practices, organic manure/composting (28%), water harvesting (18%), and agroforestry (15%), record lower adoption.

Table 2: Types of CSA Practices Adopted

CSA Practice	Frequency (n=330)	Percentage
Conservation agriculture	158	48%
Crop rotation/intercropping	149	45%
Integrated soil fertility management	125	38%
Drought-tolerant varieties	116	35%
Organic manure/composting	92	28%
Water harvesting	59	18%
Agroforestry	50	15%
Other	26	8%

The tiered adoption pattern is consistent with findings from other studies in Zambia and SSA. Conservation agriculture and crop rotation are relatively low-cost and easy to implement, making them accessible to resource-constrained farmers. They also have immediate benefits, such as improved soil moisture retention and reduced pest pressure [18]. Moderate uptake of integrated soil fertility management and drought-tolerant varieties suggests these practices are gaining traction but are not yet widely adopted. Lower adoption of resource-intensive practices is consistent with literature identifying high upfront costs and long payback periods as key barriers [23].

Qualitative Insights: Focus group participants noted that conservation agriculture and crop rotation are relatively easy to implement without significant additional resources. As one participant explained: "Conservation agriculture and crop rotation are things we can do without much money. We don't need to buy expensive inputs or equipment. We just need to change how we farm." In contrast, water harvesting and agroforestry require significant investment and technical knowledge. Another participant noted: "Water harvesting sounds good, but where do we get the money for the equipment? And who will teach us how to do it properly?"

4.3 Number of CSA Practices Implemented

The largest share of respondents (25%) had adopted two practices, while 22% had implemented just one. Notably, 20% had not implemented any CSA practice. Only 15% had adopted four or more practices. Taken together, 65% of respondents are implementing no more than two CSA practices, signalling that the majority remain at a low or moderate level of adoption.

Table 3: Number of CSA Practices Implemented

Number of Practices	Frequency (n=330)	Percentage
None	66	20%
One	73	22%
Two	83	25%
Three	59	18%
Four or more	49	15%

The finding that 65% of respondents have adopted no more than two CSA practices is consistent with the literature documenting widespread partial or symbolic adoption. Thornton *et al.* [19] suggest that in many developing regions fewer than 10% of smallholders have adopted more than two CSA practices concurrently. While the adoption rate in this study is higher, the finding that only 15% have adopted four or more practices suggests adoption intensity remains low. Many CSA practices are complementary, and their benefits are maximized when implemented together. The prevalence of partial adoption suggests many farmers are not realizing the full benefits of CSA [19].

Qualitative Insights: Participants noted that adopting multiple practices requires more resources, knowledge, and labour. As one participant explained: "I would like to adopt more practices, but I don't have the money or the labour. Even the practices I have adopted are difficult to maintain." Another noted that risks discourage adopting multiple practices simultaneously: "If I adopt many new practices at once and they fail, I will lose everything. It is better to adopt one or two practices and see how they work before adopting more."

4.4 Duration of CSA Practice

The largest group (35%) had adopted CSA practices for 1-3 years, suggesting a significant portion were relatively recent adopters. Another 28% had been practicing for 4-6 years,

while 19% represented more established adopters with more than 6 years of experience. Nearly two-thirds of respondents (63%) have been engaged in CSA for three years or fewer.

Table 4: Duration of CSA Practice

Duration	Frequency (n=264)*	Percentage
Less than 1 year	47	18%
1-3 years	92	35%
4-6 years	74	28%
More than 6 years	51	19%

*Note: 66 respondents (20%) who had not adopted any CSA practice were excluded.

The finding that 63% of adopters have been practicing CSA for three years or fewer suggests adoption is a relatively recent phenomenon, consistent with a recent surge in CSA promotion efforts in Zambia [7, 21]. The relatively recent nature of adoption raises questions about sustainability, particularly in the absence of continued external support. The finding that 19% have been practicing for more than six years suggests a core group of established adopters. As one long-term adopter explained: "I have been practicing conservation agriculture for many years now. At first, it was difficult, but now I have seen the benefits. My soil is healthier, and I harvest more even when the rains are poor. I will never go back to the old ways."

4.5 Perceived Barriers to CSA Adoption

Lack of financial resources emerged as the most dominant constraint (78%), followed by limited access to inputs (62%), lack of knowledge/training (55%), and inadequate extension services (48%). Labour shortages affected 35%, while cultural practices and land tenure issues were mentioned by 22% and 15% respectively.

Table 5: Perceived Barriers to CSA Adoption

Barrier	Frequency (n=330)	Percentage
Lack of financial resources	257	78%
Limited access to inputs	205	62%
Lack of knowledge / training	182	55%
Inadequate extension services	158	48%
Labour shortages	116	35%
Cultural/traditional practices	73	22%
Land tenure issues	50	15%
Other	33	10%

Likert scale ratings (1-5) confirm that financial constraints are the most severe barriers, with lack of financial resources ranking highest (4.2), followed by limited credit access (4.0) and high input costs (3.9). Lack of information/training (3.8) and poor extension delivery (3.7) occupy a secondary tier.

Table 6: Severity of Barriers (Likert Scale Ratings)

Barrier	Mean Score (1-5)	Standard Deviation
Lack of financial resources	4.2	0.89
Limited credit access	4.0	0.94
High input costs	3.9	0.91
Lack of information/training	3.8	1.02
Poor extension delivery	3.7	1.08
Labour shortages	3.4	1.15
Cultural/traditional practices	2.8	1.23
Land tenure issues	2.5	1.31

The finding that financial constraints are the most severe barriers is consistent with literature identifying high upfront costs and limited credit access as key impediments [23, 30]. Limited access to inputs is also consistent, as smallholder farmers often face challenges accessing improved seeds and fertilizers, particularly in remote areas [7]. Inadequate extension services are consistent with documented weakness of public extension systems in Zambia. The farmer-to-extension officer ratio in Monze District stands at approximately 1:1,200, well below the recommended 1:500, limiting reach and effectiveness [29].

Qualitative Insights: Financial constraints emerged as a dominant theme. As one participant explained: "Everything requires money. To practice conservation agriculture, I need to buy herbicides to control weeds because I am not ploughing. To practice agroforestry, I need to buy tree seedlings. Where will I get the money?" Limited input access was also major: "The nearest input shop is very far. And even if I go there, the prices are too high. I cannot afford to buy improved seeds and fertilizers every season." Weak extension services were another theme: "The extension officer covers a very large area. He cannot visit all the farmers. I have not seen him this season. How can I learn about new practices if no one comes to teach me?"

4.6 Sources of CSA Training and Support

Fellow farmers emerged as the most frequently accessed source (55%), followed by NGOs (42%), government extension officers (28%), and farmer cooperatives (22%). Informal, peer-to-peer networks are the dominant channel for CSA knowledge dissemination, surpassing formal institutional sources.

Table 7: Sources of CSA Training and Support

Source	Frequency (n=330)*	Percentage
Fellow farmers	182	55%
NGOs	139	42%
Government extension officers	92	28%
Farmer cooperatives	73	22%
Radio/TV	56	17%
Input suppliers	43	13%
Other	23	7%

*Note: Respondents could select multiple sources.

The finding that fellow farmers are the most frequently accessed source is consistent with literature documenting the importance of farmer-to-farmer learning [14, 27]. Farmer-to-farmer learning is effective because it involves sharing practical, context-specific knowledge between people facing similar challenges, and builds trust and credibility. NGOs are the second most accessed source, consistent with their prominent role in promoting CSA in Zambia [21]. However, reliance on NGOs raises sustainability concerns as programs are often time-limited. Government extension officers are accessed by only 28% of farmers, consistent with documented weakness of public extension systems [29].

Qualitative Insights: Participants trust fellow farmers because they have practical experience: "When another farmer tells me about a practice, I know it works because I can see it with my own eyes. I can visit their farm and see the results." NGOs provide valuable support including training, inputs, and follow-up: "The NGO came and trained us on conservation agriculture. They gave us seeds and

showed us how to plant. They also came back to check on us and help us with any problems." However, concerns about sustainability exist: "The NGO will leave one day. What will we do then? We need the government to support us, but the government extension officers are never around."

4.7 Frequency of Extension Visits

Forty percent of respondents reported they had never received an extension visit, while another 35% indicated they were visited but rarely. Only 15% had received quarterly visits, 8% monthly, and 2% weekly visits. Taken together, 75% of farmers fell into the never or rarely categories, indicating little to no meaningful engagement with formal extension services. The farmer-to-extension officer ratio in Monze District stands at approximately 1:1,200, well below the recommended 1:500.

Table 8: Frequency of Extension Visits

Frequency	Frequency (n=330)	Percentage
Never	132	40%
Rarely	116	35%
Quarterly	50	15%
Monthly	26	8%
Weekly	6	2%

The finding that 75% of farmers have never or rarely received an extension visit is alarming and highlights severe weakness of public extension systems. This is consistent with literature documenting poor extension coverage, under-resourcing, and top-down delivery as major impediments in Zambia [29]. The farmer-to-extension officer ratio of 1:1,200 means extension officers are responsible for far more farmers than they can effectively serve. The low frequency of extension visits has significant implications for CSA adoption, as extension services are a key channel for disseminating information and providing technical support. Without regular contact, farmers may lack knowledge and skills to adopt CSA effectively [22].

Qualitative Insights: Participants described how infrequency of extension visits limited access to information: "The extension officer came once at the beginning of the season. We have not seen him since. If we have problems, there is no one to help us." Participants also noted that extension officers often focus on farmers close to the main road: "The extension officer only visits the farmers near the road. Those of us in the interior are forgotten. We need extension officers who can reach all farmers."

4.8 Access to CSA Inputs

Only 32% of respondents reported having access to improved seeds, fertilizers, or water-harvesting equipment, while 68% do not. This clear majority lacking access to CSA inputs is a significant structural constraint that severely limits CSA uptake, regardless of farmers' awareness or willingness to adopt.

Table 9: Access to CSA Inputs

Access Status	Frequency (n=330)	Percentage
Has access	106	32%
No access	224	68%

The finding that 68% of farmers lack access to CSA inputs is a significant constraint. Access to inputs is essential for many CSA practices. Without access, farmers may be unable to adopt CSA practices even if aware and willing. This highlights the importance of addressing input access as part of any CSA promotion strategy [7]. Limited access to CSA inputs is consistent with literature documenting challenges smallholder farmers face in accessing agricultural inputs, including distance to input markets, high prices, and limited availability of appropriate inputs [30].

Qualitative Insights: Participants described how distance and cost prevented access: "The nearest shop that sells improved seeds is 20 kilometres away. I don't have transport to go there, and even if I did, the seeds are too expensive." Participants also noted that available inputs are often not suitable for CSA: "The shops only sell hybrid maize seeds that need a lot of fertilizer. They don't sell drought-tolerant seeds or seeds for legumes. We need shops that sell the inputs we need for CSA."

4.9 Awareness of CSA Programs

Forty-five percent of respondents indicated awareness of CSA programs, while 55% reported no such awareness. This narrow margin suggests that while CSA initiatives have achieved moderate visibility, a substantial portion of the farming population remains uninformed.

Table 10: Awareness of CSA Programs

Awareness Status	Frequency (n=330)	Percentage
Aware	149	45%
Not aware	181	55%

The finding that 55% of farmers are not aware of CSA programs is concerning. Awareness is a prerequisite for adoption. The finding suggests current CSA promotion efforts are not reaching a significant portion of the farming population, particularly those not connected to extension services, NGOs, or farmer organizations [22]. The moderate level of awareness suggests CSA initiatives have achieved some visibility, likely through NGO programs and government initiatives. However, more than half of farmers remain unaware, highlighting the need for more inclusive and far-reaching awareness-raising strategies, such as radio programs, community meetings, and mobile phone-based messaging [10].

Qualitative Insights: Participants noted that awareness-raising efforts are often concentrated in certain areas: "The NGOs only work in certain villages. If you are not in those villages, you don't hear about CSA. We need programs that reach all farmers." Language and literacy barriers also limit awareness: "Some of the materials are in English, which many farmers cannot read. We need materials in local languages and with pictures so that everyone can understand."

4.10 Priority Interventions and Willingness to Adopt

Quantitative ranking reveals a clear hierarchy: increased access to inputs (82%), more training and awareness campaigns (76%), and improved access to credit (74%) emerged as the most urgent needs. Structural and institutional interventions—group support (48%), subsidy (45%), and land security reform (28%)—were rated significantly lower. Survey data show that 72% of farmers were willing to adopt CSA practices, with 18% undecided and 10% unwilling.

Table 11: Priority Interventions

Intervention	Frequency (n=330)*	Percentage
Increased access to inputs	271	82%
More training and awareness campaigns	251	76%
Improved access to credit	244	74%
Group support	158	48%
Subsidy	149	45%
Land security reform	92	28%
Other	33	10%

*Note: Respondents could select multiple interventions.

Table 12: Willingness to Adopt CSA Practices

Willingness Status	Frequency (n=330)	Percentage
Willing	238	72%
Undecided	59	18%
Unwilling	33	10%

The finding that 72% of farmers are willing to adopt CSA practices is encouraging and suggests significant demand. The high level of willingness indicates farmers recognize the need for climate-resilient practices and are open to new approaches. This is consistent with literature documenting high willingness to adopt CSA among smallholder farmers in SSA [18, 32]. The finding that increased access to inputs, more training, and improved access to credit are top priorities is consistent with barriers identified earlier. These findings suggest farmers are aware of barriers and have clear ideas about what would help them overcome them. The high ranking of these interventions suggests they are likely to be effective if implemented [22]. Lower ranking of structural and institutional interventions may reflect farmers' perceptions of feasibility or relevance to immediate needs [10].

Qualitative Insights: Participants expressed strong desire to adopt CSA practices but noted need for support: "We want to adopt CSA practices. We can see that the climate is changing and we need to adapt. But we need help. We need access to inputs, credit, and training." Participants also noted support needed is not just financial: "It's not just about money. We also need someone to teach us how to do CSA properly. And we need to work together as a community to support each other."

4.11 Preferred Learning Approaches

Farmer-to-farmer learning emerged as the most favoured method (85%), closely followed by demonstration plots (78%) and local farmer trainers (72%). Extension office visits (35%) and radio programs (30%) rank significantly lower.

Table 13: Preferred Learning Approaches

Learning Approach	Frequency (n=330)*	Percentage
Farmer-to-farmer learning	281	85%
Demonstration plots	257	78%
Local farmer trainers	238	72%
Field days	182	55%
Extension office visits	116	35%
Radio programs	99	30%
Other	26	8%

*Note: Respondents could select multiple approaches.

The finding that farmer-to-farmer learning is the most preferred approach is consistent with literature documenting effectiveness of peer learning [14, 27]. Farmer-to-farmer learning is effective because it involves sharing practical, context-specific knowledge between people facing similar challenges, and builds trust. Demonstration plots are the second most preferred approach, allowing farmers to see results with their own eyes and providing opportunities for hands-on learning [10]. Lower ranking of extension office visits and radio programs suggests farmers prefer learning approaches that are interactive, practical, and embedded in their communities. Extension office visits require travel to a central location, a barrier for remote farmers. Radio programs are one-way communication without interaction or hands-on learning [22].

Qualitative Insights: Participants noted they learn best from other farmers: "We learn best from other farmers. When we see a fellow farmer succeeding with a new practice, we want to try it too. We can ask them questions and they can show us exactly what to do." Participants also appreciated demonstration plots: "The demonstration plot is very helpful. We can see the difference between the old way and the new way. We can see that CSA works."

4.12 Statistical Evaluation of Hypotheses

Table 14: Summary of Hypothesis Testing Results

Hypothesis	Test	Result	Effect Size
H1: Gender differences in adoption	Chi-square	χ^2=3.405, p=0.065	-
H2: Financial access and adoption intensity	t-test	t=3.922, p<0.001	d=0.795
H3: Adopters vs. non-adopters perceived barriers	Mann-Whitney U	z=2.596, p=0.009	r=0.237
H4: Extension frequency and adoption	Chi-square	χ^2=10.576, p=0.001	φ=0.297
H5: Education and adoption intensity	ANOVA	F=7.921, p<0.001	η^2=0.170
H6: Farmer vs. key informant perceptions	t-test	t=4.014, p<0.01	-

The analysis reveals that financial access has a moderate-to-large effect on adoption intensity (d=0.795), extension visit frequency has a moderate relationship with adoption status (φ=0.297), and education level explains 17% of variance in adoption intensity (η^2=0.170).

H1: Gender Differences in Adoption: The chi-square test revealed no statistically significant difference in adoption between male and female farmers (χ^2=3.405, p=0.065). While approaching significance, it does not meet the conventional threshold of p<0.05. This suggests gender may not be a significant barrier to CSA adoption in terms of the decision to adopt at least one practice. However, this should be interpreted with caution. While there may not be a statistically significant difference in the decision to adopt, there may be differences in intensity, types of practices adopted, and benefits derived. Previous research documents that women face additional barriers including limited access to land, credit, and information [28].

H2: Financial Access and Adoption Intensity: The t-test revealed a statistically significant difference in adoption intensity between farmers with financial access and those without (t=3.922, p<0.001), with a moderate-to-large effect size (d=0.795). This confirms financial access is a key determinant of CSA adoption intensity. Farmers with access to credit or savings can invest in more CSA practices, while

those lacking financial access are limited to low-cost practices or cannot adopt at all. This is consistent with literature identifying financial constraints as a primary barrier [23, 30]. The moderate-to-large effect size indicates the relationship is substantial, highlighting the importance of improving access to credit and savings.

H3: Adopters vs. Non-Adopters Perceived Barriers: The Mann-Whitney U test revealed a statistically significant difference in perceived barriers between adopters and non-adopters ($z=2.596$, $p=0.009$), with a small-to-moderate effect size ($r=0.237$). This suggests adopters and non-adopters perceive barriers differently. Non-adopters may perceive barriers as more severe, discouraging adoption, while adopters may have found ways to overcome barriers or perceive them as less severe. This is consistent with literature documenting perceived barriers as an important determinant of adoption [22]. The finding suggests interventions to address perceived barriers may be effective, particularly among non-adopters.

H4: Extension Frequency and Adoption: The chi-square test revealed a statistically significant association between extension visit frequency and adoption status ($\chi^2=10.576$, $p=0.001$), with a moderate effect size ($\varphi=0.297$). This confirms extension services play a critical role in promoting CSA adoption. Farmers receiving more frequent extension visits are more likely to adopt CSA practices. This is consistent with literature documenting the importance of extension services [22, 29]. The moderate effect size indicates the relationship is substantial, highlighting the importance of strengthening extension services.

H5: Education and Adoption Intensity: The ANOVA revealed a statistically significant difference in adoption intensity across education levels ($F=7.921$, $p<0.001$), with education explaining 17% of variance in adoption intensity ($\eta^2=0.170$). This confirms education is an important determinant of CSA adoption intensity. Farmers with higher education are more likely to adopt multiple CSA practices, possibly because they have greater capacity to understand and implement complex practices. This is consistent with literature documenting education as positively associated with adoption [14]. The finding that education explains 17% of variance indicates that while important, it is not the only factor. Other factors such as financial access and extension frequency also play important roles.

H6: Farmer vs. Key Informant Perceptions: The t-test revealed a statistically significant difference in perceptions between farmers and key informants ($t=4.014$, $p<0.01$). This suggests farmers and key informants have different perceptions of CSA adoption, barriers, and enhancement measures. Key informants may have a more optimistic view or may emphasize different barriers than farmers. This is consistent with literature documenting different stakeholder perspectives on agricultural innovation [17]. The finding highlights the importance of incorporating farmer perspectives into CSA promotion strategies.

5. Discussion of the Findings

5.1 Synthesis of Findings

This study provides a comprehensive analysis of CSA adoption among smallholder farmers in Chikuni, Monze District, Zambia. The findings reveal a pattern of moderate but partial adoption, with 62% of farmers having adopted at least one CSA practice but 65% implementing no more than two practices. Conservation agriculture and crop rotation are the most widely adopted practices, while water harvesting and agroforestry remain limited.

The study identifies financial constraints, limited access to inputs, inadequate extension services, and knowledge gaps as the primary barriers to CSA adoption. These barriers are interconnected, with each reinforcing the others. For example, financial constraints limit farmers' ability to purchase inputs, which limits their ability to adopt CSA practices that require inputs. Inadequate extension services limit farmers' access to information about CSA practices, which limits their awareness and knowledge. The farmer-to-extension officer ratio of 1:1,200 is a critical constraint, as it means extension officers cannot provide adequate support to the farmers they are responsible for.

Despite these barriers, 72% of farmers expressed willingness to adopt more CSA practices, conditional on improved access to credit, inputs, and training. Farmer-to-farmer learning and demonstration plots emerged as the most preferred learning approaches, highlighting the importance of peer learning and practical, hands-on training in promoting CSA adoption.

The statistical analysis confirmed that financial access, extension visit frequency, and education level are significant determinants of CSA adoption. Financial access has a moderate-to-large effect on adoption intensity ($d=0.795$), extension visit frequency has a moderate relationship with adoption status ($\varphi=0.297$), and education level explains 17% of variance in adoption intensity ($\eta^2=0.170$). These findings highlight the importance of addressing financial, informational, and human capital constraints to promote CSA adoption.

5.2 Theoretical Implications

The findings have important implications for the theoretical frameworks that guided the research. The Diffusion of Innovations Theory [14] suggests that adoption is influenced by the characteristics of the innovation, the characteristics of adopters, and the communication channels through which information is disseminated. The findings support this theory, showing that adoption is influenced by the characteristics of CSA practices (with low-cost, simple practices being more widely adopted), the characteristics of adopters (with education and financial access being important determinants), and communication channels (with farmer-to-farmer learning being the most preferred channel).

The Theory of Planned Behaviour [15] suggests that adoption is influenced by attitudes, subjective norms, and perceived behavioural control. The findings provide partial support for this theory. The finding that 72% of farmers are willing to adopt CSA practices suggests attitudes toward CSA are generally positive. However, the finding that many farmers have not adopted suggests perceived behavioural control (the perceived ability to adopt) is a significant constraint. Financial constraints, limited access to inputs, and inadequate extension services all limit farmers' perceived ability to adopt CSA practices.

The Sustainable Livelihoods Framework [16] suggests that adoption is influenced by the assets that households possess, including human, natural, financial, physical, and social capital. The findings support this framework, showing that financial capital (access to credit), human capital (education), and social capital (farmer-to-farmer learning) are important determinants of adoption. The framework also highlights the importance of considering the full range of

assets that influence adoption decisions, rather than focusing on a single type of asset.

The Innovation Systems Theory [17] suggests that innovation is a complex, interactive process generated within a network of diverse actors and institutions. The findings support this theory, showing that CSA adoption is influenced by the interaction of multiple actors, including farmers, extension agents, NGOs, and farmer organizations. The theory highlights the importance of creating an enabling environment for innovation, including supportive policies, effective institutions, and strong linkages among actors. The findings suggest that the enabling environment for CSA adoption in the study area is weak, with inadequate extension services and limited access to inputs and credit.

5.3 Policy Implications

The findings have important policy implications for promoting CSA adoption among smallholder farmers in Zambia. First, the finding that financial constraints are the most severe barrier highlights the need for policies that improve access to credit and savings for smallholder farmers. This could include supporting the formation and strengthening of Village Savings and Loan Associations (VSLAs), which have been shown to be effective in building financial resilience in rural communities. It could also include reforming formal lending institutions to make credit more accessible and affordable, including by addressing collateral requirements and aligning repayment schedules with agricultural rhythms.

Second, the finding that limited access to inputs is a major barrier highlights the need for policies that improve input supply chains for CSA. This could include supporting the development of local input markets, particularly for CSA-specific inputs such as drought-tolerant seeds and organic amendments. It could also include reforming the Farmer Input Support Programme (FISP) to include drought-tolerant seed varieties and to tie support to the adoption of sustainable practices.

Third, the finding that inadequate extension services are a major barrier highlights the need for policies that strengthen extension systems. This could include increasing staffing levels and resources for extension officers, as well as reforming extension delivery models to be more participatory and farmer-centred. It could also include integrating CSA into national extension systems and agricultural training curricula to ensure that extension officers are equipped with the knowledge and skills to promote CSA.

Fourth, the finding that farmer-to-farmer learning is the most preferred approach highlights the need for policies that support peer learning networks and farmer organizations. This could include investing in farmer field schools, demonstration plots, and farmer exchange visits. It could also include strengthening farmer cooperatives and other farmer organizations to serve as platforms for CSA knowledge dissemination and collective action.

5.4 Practical Implications

The findings have important practical implications for NGOs, development partners, and other organizations working to promote CSA adoption. First, the finding that adoption is partial and fragmented suggests that CSA promotion efforts should focus on promoting complementary practices as bundles rather than individual practices. For example, promoting conservation agriculture as a package of minimum tillage, crop residue retention, and crop rotation may be more effective than promoting each practice separately.

Second, the finding that financial constraints are the most severe barrier suggests that CSA promotion efforts should integrate financial support with technical support. This could include combining credit and savings programs with CSA training, as well as linking farmers to input and output markets to create clear economic incentives for adoption.

Third, the finding that farmer-to-farmer learning is the most preferred approach suggests that CSA promotion efforts should invest in peer learning networks and farmer trainers. This could include training lead farmers to serve as trainers and mentors, establishing demonstration plots that showcase CSA practices, and organizing farmer exchange visits that allow farmers to learn from each other.

Fourth, the finding that the majority of farmers have adopted CSA practices for three years or fewer suggests that CSA promotion efforts should include follow-up support to ensure that adoption is sustained over time. This could include regular monitoring visits, refresher training, and access to ongoing technical advice. It could also include designing projects with clear exit strategies and handover to community institutions to ensure sustainability beyond project cycles.

5.5 Limitations of the Study

This study has several limitations. First, the study was conducted in a single agricultural camp in Monze District, which limits generalizability to other areas. The findings may not be applicable to areas with different agro-ecological conditions, socioeconomic characteristics, or institutional environments. Future research should replicate this study in other areas.

Second, the study relied on self-reported data, which may be subject to social desirability bias or recall bias. Farmers may over-report adoption or under-report barriers. Future research should consider using observational methods or secondary data sources to validate self-reported data.

Third, the study used a cross-sectional design, which limits the ability to establish causality. While the study identified associations between variables, it cannot determine whether these associations are causal. Future research should consider using longitudinal designs to track CSA adoption over time.

Fourth, the study focused on smallholder farmers operating 1-5 hectares, which limits generalizability to larger or smaller farms. The factors influencing CSA adoption may differ for farmers with different farm sizes. Future research should consider including farmers with different farm sizes.

Fifth, the study did not include a detailed analysis of the costs and benefits of CSA practices, which limits the ability to assess economic viability. Future research should consider conducting cost-benefit analyses of different CSA practices to provide evidence for investment decisions.

6. Conclusions and Recommendations

6.1 Conclusions

This study has demonstrated that CSA adoption among smallholder farmers in Chikuni, Monze District, is moderate but faces significant barriers. The current adoption rate of 62% indicates that while farmers are aware of and willing to adopt CSA practices, they are constrained by a complex

interplay of financial limitations, inadequate extension services, and limited access to agricultural inputs.

The study identified several key factors that could substantially enhance CSA adoption. First, improved access to credit and agricultural inputs is essential to enable farmers to overcome the upfront costs associated with adopting new practices. Second, strengthened extension services, particularly through farmer-to-farmer learning approaches, can bridge the knowledge gap. Third, targeted interventions for women are critical, given their predominant role in Zambia's agricultural workforce and the persistent gender-based barriers they face. Finally, more coordinated institutional support from government agencies, NGOs, and financial institutions is necessary to create an enabling environment for sustained adoption.

The strong demand for farmer-to-farmer learning expressed by participants, combined with the demonstrated effectiveness of Village Savings and Loan Associations in building financial resilience, suggests that community-based approaches should be central to any CSA promotion strategy.

6.2 Recommendations

To Government and Policymakers:

1. Strengthen extension services by increasing staffing levels and improving resources for extension officers. The current farmer-to-extension officer ratio of 1:1,200 should be reduced to at least 1:500, in line with recommended standards.
2. Reform the Farmer Input Support Programme to include drought-tolerant seed varieties and tie support to adoption of sustainable practices.
3. Promote financial inclusion by supporting the formation and strengthening of Village Savings and Loan Associations.
4. Establish a district-level coordination mechanism for CSA promotion to align efforts of government, NGOs, and private sector actors.
5. Develop gender-responsive CSA programs that address women's specific constraints, including limited access to land, credit, and information.
6. Invest in climate information services and early warning systems to help farmers make more informed decisions.
7. Mainstream CSA into national extension systems and agricultural training curricula to ensure sustainability beyond donor cycles.

To NGOs and Development Partners:

1. Invest in farmer-to-farmer learning through demonstration plots and farmer field schools.
2. Combine financial and technical support by integrating credit and savings programs with CSA training.
3. Design projects with clear exit strategies and handover to community institutions.
4. Prioritize the distribution and promotion of drought-tolerant maize and legume varieties.
5. Use participatory approaches that involve farmers in the design and implementation of CSA programs.
6. Collect and use monitoring and evaluation data to learn what works and adapt strategies accordingly.

To Farmer Cooperatives & Community Organizations:

1. Strengthen VSLA groups and link them to CSA training.
2. Establish village-level demonstration plots in collaboration with extension services and NGOs.
3. Organize farmer exchange visits and peer learning events.
4. Advocate for policies and programs that support CSA adoption at the local and national levels.
5. Promote collective action to address barriers that individual farmers cannot overcome on their own.

C. Areas for Further Research

1. Conduct longitudinal studies to track CSA adoption patterns and impacts over time.
2. Investigate the specific barriers and enablers for women's CSA adoption.
3. Conduct cost-benefit analysis of CSA practices to provide evidence for investment decisions.
4. Develop district-level climate risk maps to guide targeted CSA promotion.
5. Investigate the role of social networks and social capital in CSA adoption.
6. Assess the effectiveness of different extension approaches in promoting CSA adoption.
7. Investigate the potential of digital technologies to support CSA promotion and monitoring.

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