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Assessing the Effectiveness of Drought Adaptation Strategies Employed by Small-Scale Maize Farmers in the Msekera Catchment Area of Chipata District, Eastern Province of Zambia

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Abstract

Climate change, especially frequent droughts, is threatening small-scale maize farming in Zambia, particularly in the Msekera Catchment Area of Chipata District. Although farmers are encouraged to use strategies like conservation agriculture, early-maturing maize, crop diversification, and agroforestry, their real impact has not been well studied. Many of these strategies are introduced without much farmer involvement, leading to low adoption and poor sustainability. Most studies also overlook the unique conditions in Msekera. This research therefore assesses how effective these drought adaptation strategies are, how widely they are used, their benefits, and the challenges farmers face. Using surveys, interviews, and field visits, the study aims to provide evidence to support locally relevant, farmer-led adaptation policies that improve resilience among maize farmers in drought-prone areas of Eastern Zambia.

Keywords: Drought Adaptation Strategies, Climate Resilience, Resilience Mechanisms, and Catchment Area

1. Introduction

Climate change is worsening global food insecurity, especially for smallholder farmers who rely on rain-fed agriculture. Maize, a key staple crop, is highly vulnerable to heat and drought, with IPCC projections showing yields could decline by up to 24% by 2030. Climate-smart agriculture (CSA) including drought-tolerant crops, conservation tillage, irrigation, and digital weather services has improved resilience in countries like India and Mexico when adapted to local contexts. In Africa, where agriculture supports over 60% of people, maize yields may drop 10–25% with rising temperatures. Although countries like Kenya and Ethiopia promote CSA and indigenous practices, adoption remains low due to poverty, weak institutions, limited credit, and insecure land tenure, highlighting the need for locally driven, sustainable adaptation efforts.

Maize, Zambia's main staple, supplies 60–70% of daily calories and is grown by 90% of smallholders, but droughts and erratic rainfall in areas like the Msekera Catchment of Chipata District have reduced yields and worsened food insecurity. Farmers struggle with limited access to drought-tolerant seeds, credit, and extension services, while high input costs and poor infrastructure add to the challenge. Although NGOs promote conservation farming and early planting, adoption remains low due to financial limits, cultural barriers, and weak institutional support. This study examines how effective current drought adaptation strategies are in Msekera, identifies barriers to adoption, and provides policy insights to enhance farmer resilience and support Zambia's Vision 2030 and the Sustainable Development Goals.

1.1 Statement of the Problem

Small-scale maize farmers in the Msekera Catchment of Eastern Zambia face growing drought risks due to climate change. Though strategies such as conservation farming, crop diversification, and early-maturing maize have been promoted, their success varies, with many farmers abandoning them because of high labor needs, low returns, or poor fit with local conditions. Most programs are top-down and lack farmer involvement, leading to low adoption. Since few studies focus specifically on Msekera, this research aims to fill that gap by assessing the effectiveness, challenges, and scalability of local drought adaptation strategies.

1.2 Specific Objectives
1. To establish the drought adaptation strategies currently being used by small-scale maize farmers in Msekera Catchment.
2. To assess the effectiveness of adaptation strategies currently adopted in enhancing farmers' resilience to drought.
3. To examine the socio-economic, institutional, and environmental factors influencing the adoption and performance of these adaptation strategies.

1.3 Research Questions
1. What drought adaptation strategies are currently being employed by small-scale maize farmers in the Msekera Catchment Area?
2. How effective are these strategies in enhancing farmers' resilience and sustaining maize production under drought conditions?
3. What are the major socio-economic, institutional, and environmental barriers to the adoption and effective implementation of drought adaptation strategies in the study area?

1.4 Theoretical Framework
This study is based on the Sustainable Livelihoods Framework (SLF), which explains how small-scale maize farmers in drought-prone areas adapt and sustain their livelihoods under stress. Developed by DFID (1999), the SLF focuses on five assets human, natural, financial, physical, and social capital that interact to shape livelihood strategies. In Msekera, limited financial and physical capital, such as credit and farm tools, hinders effective drought adaptation. The framework's people-centered approach highlights that vulnerability is influenced not only by climate but also by governance, markets, and institutions, making it ideal for analyzing why some farmers adopt certain strategies while others do not.

1.5 Significance of the Study
This study provides local evidence to help improve drought resilience among small-scale maize farmers in Zambia. By focusing on the Msekera Catchment Area, it identifies which adaptation strategies work best, guiding better policies and climate-smart farming programs. It also offers insights to improve farmer training, support inclusive NGO projects, and expand academic understanding of adaptation choices. Overall, the research promotes stronger collaboration, better policies, and greater community resilience to drought.

1.6 Scope of study
This study focuses on the Msekera Catchment Area in Chipata District, Eastern Province, which depends on rain-fed farming and faces frequent droughts. The area is ideal for examining how small-scale maize farmers adapt to drought because it experiences erratic rainfall and hosts many agricultural programs. Maize is chosen as the main crop since it is Zambia's staple food and highly sensitive to climate change. The study targets small-scale farmers with less than five hectares of land who rely on family labor, excluding commercial farmers with more resources. This focus ensures findings are relevant to the most vulnerable rural households affected by drought.

2. Literature Review
2.1 Types of Drought Adaptation Strategies Adopted by Small-Scale Maize Farmers
This section examines drought adaptation strategies used by smallholder maize farmers globally, in Africa, and in Zambia's Eastern Province. Worldwide, farmers adopt practices such as conservation agriculture, drought-tolerant seeds, mulching, intercropping, and livelihood diversification to cope with erratic rainfall. In Africa, agroforestry, minimum tillage, and water harvesting methods like zai pits and tied ridges improve soil moisture and resilience, though challenges like insecure land tenure, gender inequality, poor infrastructure, and weak policies hinder progress. In Zambia, especially in the Msekera Catchment Area, farmers use early-maturing maize, conservation agriculture, crop diversification, agroforestry, and rainwater harvesting, though adoption remains uneven due to limited resources, labor shortages, and poor access to extension services. Overall, the success of drought adaptation depends not just on technologies but also on financial, institutional, and social support systems that enable smallholder farmers to sustain these practices and build long-term resilience.

2.2 Effectiveness of Drought Adaptation Strategies in Enhancing Resilience
This thematic area examines how drought adaptation strategies affect yields, food security, income, and long-term resilience among smallholder maize farmers, focusing on experiences from Sub-Saharan Africa and Eastern Zambia. Globally, effective adaptation depends on combining technical, social, and institutional support farmers benefit most when they have access to resources, information, and credit. Practices like conservation agriculture, drought-tolerant seeds, and water harvesting improve yields and resilience, though their success varies with access to extension services and supportive policies. In Africa, programs such as the CASU and DTMA have boosted maize productivity, yet poor farmers often face barriers like limited finance, labor, or information. In Zambia's Msekera Catchment, conservation agriculture, early-maturing maize, and climate-smart agriculture programs have improved soil health and food security, but uneven access to inputs and services limits their reach. Overall, adaptation is most effective when it integrates technology, strong institutions, social inclusion, and local participation to ensure all farmers especially the poorest can benefit and build lasting resilience to drought.

2.3 Socio-Economic, Institutional, and Environmental Determinants of Strategy Adoption and Performance
In Msekera Ward, small-scale maize farmers' ability to adapt to drought depends on their income, education, land security, access to credit, and support from institutions like cooperatives and extension services. Wealthier and educated farmers with secure land and financial resources can use advanced methods such as irrigation and conservation farming, while poorer and less educated ones depend on low-cost strategies like early planting and mulching. Women face added challenges due to limited land rights and exclusion from credit and training programs. Weak institutions, poor coordination, and limited extension support further reduce farmers' ability to adopt sustainable practices. Combined with environmental problems such as

erratic rainfall, soil degradation, and land insecurity, these factors make drought adaptation difficult. Strengthening local institutions, improving access to resources, and ensuring gender-inclusive support are key to helping farmers build lasting resilience and food security.

2.4 Establishing the Research Gap

The literature shows that while global and regional studies identify drought adaptation strategies like conservation agriculture, drought-tolerant seeds, and agroforestry, there is limited understanding of how these strategies are selected, applied, and adapted to local conditions, especially in the Msekera Catchment of Eastern Zambia. Most studies are descriptive or anecdotal, with inconsistent methods and little assessment of long-term effectiveness or sustainability. Research often focuses on external interventions rather than farmer-led innovations, and socio-economic factors such as gender, youth, and land access are underexplored, limiting inclusivity. Institutional and political barriers, and how they interact to affect adaptation, are rarely analyzed, leaving gaps in understanding resilience mechanisms. This study addresses these gaps through a context-specific, mixed-methods investigation to evaluate the adoption, effectiveness, and scalability of drought adaptation strategies among smallholder maize farmers in Msekera, aiming to inform locally relevant and inclusive climate resilience interventions.

3. Methodology

3.1 Research Design

The study used a descriptive case study design to examine how small-scale maize farmers in the Msekera Catchment of Chipata District respond to recurrent droughts. This approach allowed an in-depth look at which adaptation strategies farmers use, why and how they adopt them, their effectiveness, and the socio-economic and institutional factors affecting implementation. The design suited the study's objectives of identifying strategies, assessing their impact on resilience, and understanding adoption barriers. Its flexibility also allowed the use of both qualitative and quantitative methods to capture farmers' experiences and adaptive practices within their specific local context.

3.2 Target Population

The study focused on 100 smallholder maize farming households in Chipata District, Eastern Zambia, selected because they rely on maize as their main livelihood and are highly vulnerable to climate stresses like recurrent droughts, erratic rains, and pests. While the district has over 47,000 smallholder households, this sample provides a manageable yet representative group for examining coping strategies, socio-economic challenges, and institutional influences on drought adaptation. The households reflect local diversity in gender, income, land access, and extension service exposure, making them ideal for understanding how local conditions shape adaptation practices and generating insights that could inform broader interventions in similar drought-prone areas.

3.3 Sampling Design

The study used purposive sampling to select maize farmers in Chipata District with direct experience of farming and climate-related challenges, focusing on those who have cultivated maize for at least five years. This method targets information-rich participants and, combined with maximum variation sampling, ensures inclusion of diverse respondents across wards, genders, and socio-economic backgrounds. This approach captures a wide range of adaptation strategies, experiences, and challenges, with local extension officers helping identify eligible participants to enhance the relevance and credibility of the data.

3.4 Sample Size Determination

The study used purposive sampling to select 100 small-scale maize farmers in Chipata District, focusing on depth of information about adaptation strategies rather than large numbers. While qualitative research often reaches saturation with 12–30 participants, a larger sample of 100 was chosen to capture diverse experiences, farming contexts, and resilience practices, ensuring richer and more valid data. The size was manageable for data collection and analysis and included both men and women to ensure gender balance and inclusivity.

3.5 Data Collection Methods

The study used semi-structured interviews and focus group discussions to collect data from farmers. Interviews allowed in-depth exploration of individual experiences and decision-making about climate adaptation, while focus groups captured collective views and community perspectives on common strategies. Both methods were recorded, transcribed, and translated as needed, covering topics like changes in rainfall and temperature, crop yields, adaptation strategies used, institutional support, and challenges faced.

3.6 Data Analysis

The study used thematic analysis to organize and interpret qualitative data from interviews and focus groups, identifying patterns and deeper meanings in farmers' responses. Data were transcribed, coded manually and with STATA, and descriptive statistics summarized demographics like age, gender, and farm size. Following Braun and Clarke's six-step approach, the analysis generated and reviewed themes to produce a comprehensive narrative explaining the effectiveness of drought adaptation strategies among small-scale maize farmers in Chipata District.

4. Presentation of Findings and Discussion Results

4.1 Presentation of Results on Background Characteristics of Respondents

Socio-demographic factors such as age, gender, education, land size, and access to agricultural support influence how farmers adopt and implement drought adaptation strategies. Data from the Msekera Catchment show a diverse population with variations in these characteristics.

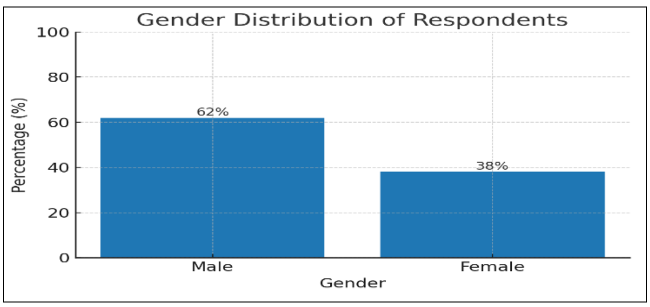

Fig 4.1.1: Shows gender distribution of respondents

The study found that 62% of respondents were male and 38% female, reflecting rural Zambian trends where men often own land while women play key roles in farm labor and adaptation decisions. Households averaged six members, with larger, male-headed households having more labor available for adaptation activities like mulching, rainwater harvesting, and conservation agriculture.

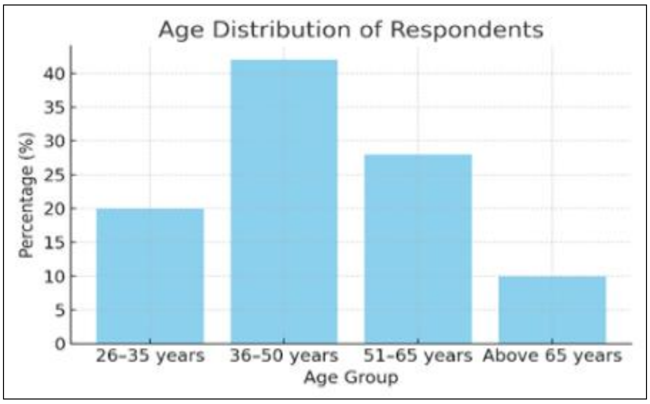

Fig 4.1.2: Shows age distribution of respondents

Most respondents were middle-aged, with 42% aged 36–50, actively engaged in farming and adapting to both traditional and modern drought strategies. Those 51–65 years (28%) had more experience but were less likely to adopt labor-intensive practices, while 26–35-year-olds (20%) were younger, energetic, and open to new technologies. Only 10% were over 65, mainly relying on indigenous knowledge and family labor. Overall, the population balances experience and willingness to innovate in drought adaptation.

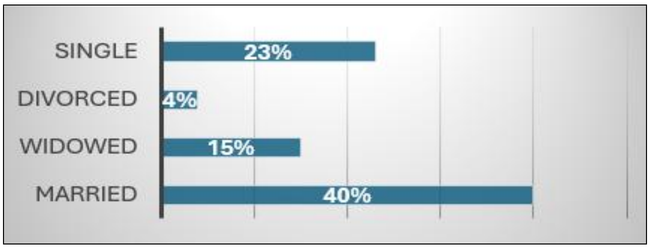

Fig 4.1.3: Shows marital status of respondents

Most respondents (74%) were married, benefiting from shared labor and pooled resources, which supported greater adoption of drought adaptation strategies. Widowed (15%) and divorced (4%) households faced labor and financial constraints, limiting their ability to implement intensive practices, while single respondents (23%) showed moderate adoption depending on personal resources and support networks. Marital status therefore influenced household resilience and capacity to cope with drought.

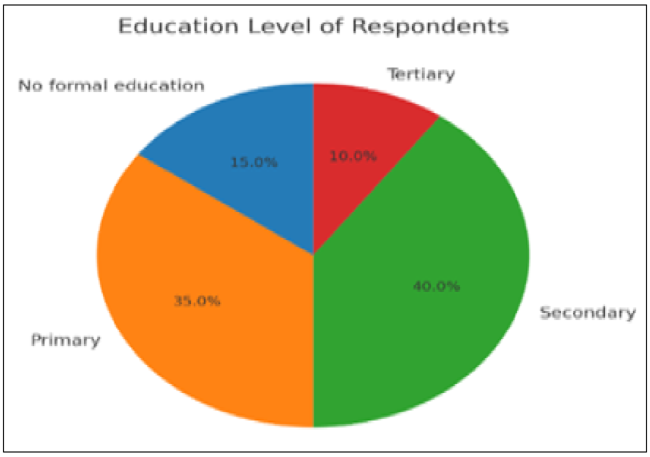

Fig 4.1.4: Education level Representation of Respondents

Respondents had varied education levels: 35% completed primary school, 40% secondary, 10% tertiary, and 15% had no formal education. Higher education was linked to better understanding of agricultural innovations and greater use of extension services, while those with little or no education faced challenges accessing technical knowledge. Education thus influenced awareness, adoption, and effective use of drought adaptation strategies.

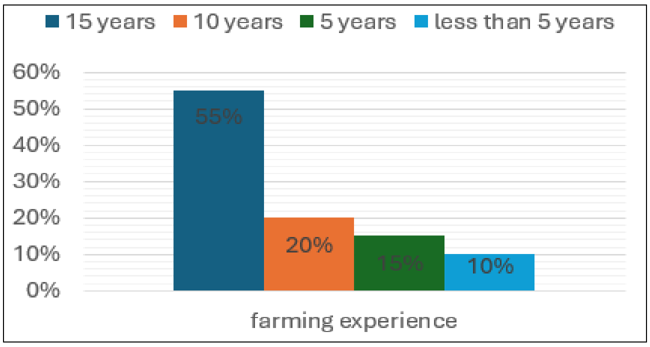

Fig 4.1.5: Shows farming experience of respondents

Most respondents (55%) had over 15 years of farming experience, relying heavily on indigenous knowledge like early planting, crop diversification, and traditional water harvesting. Formal education complemented this experience, enabling farmers to adopt modern strategies such as conservation agriculture and drought-tolerant seeds. Combining traditional wisdom with scientific methods proved important for effective and sustainable adaptation.

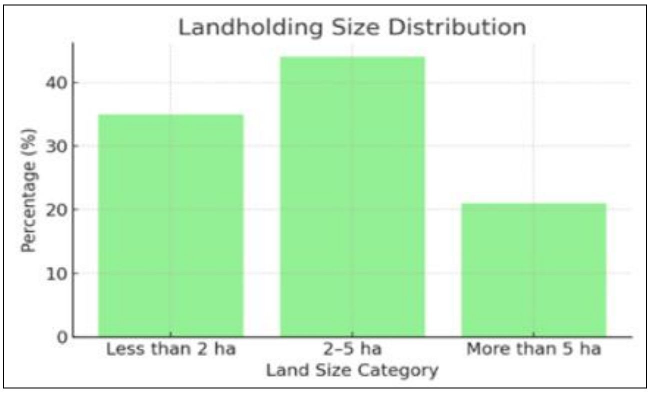

Fig 4.1.6: Shows Landholding sizes

Secure land tenure encouraged investment in long-term adaptation practices like agroforestry and irrigation, while farmers on borrowed land favored short-term strategies. Land sizes varied, with 44% farming 2–5 hectares, 35% under 2 hectares, and 21% over 5 hectares; larger landholders were more able to diversify crops and test drought-tolerant varieties.

4.2 Adaptation to Climate Change

Small-scale maize farmers in the Msekera Catchment adopt various drought coping strategies including drought-tolerant maize, irrigation, mulching, and crop rotation though adoption levels vary based on access, cost, and perceived effectiveness.

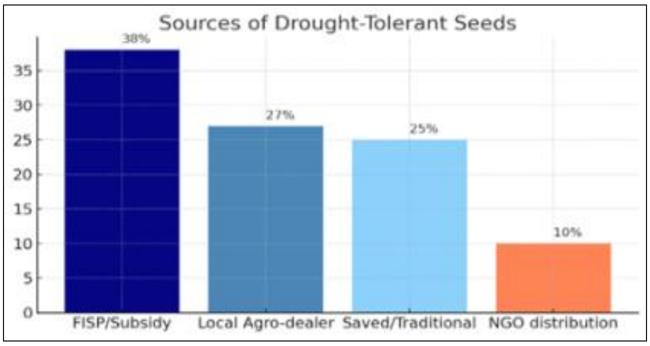

Fig 4.2.1: Shows sources of drought tolerant seed

Access to drought-tolerant maize seeds in Msekera is mainly supported by FISP (38%) and local agro-dealers (27%), but 25% of farmers still rely on saved seeds due to cost and availability constraints, while NGOs provide only limited support (10%), showing that subsidies improve adoption but do not reach all smallholders.

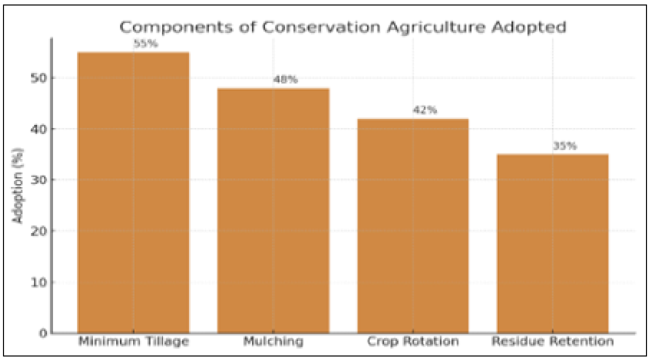

Fig 4.2.2: Shows the adopted components of conservation agriculture

The study found that among conservation agriculture practices in Msekera, minimum tillage was most adopted (55%) for saving labor and conserving soil moisture, followed by mulching (48%) for erosion control, crop rotation (42%) for soil fertility and pest management, and residue retention (35%), which was limited by competing use as livestock feed. Adoption levels varied based on resource availability and livelihood priorities, reflecting common challenges in Sub-Saharan Africa.

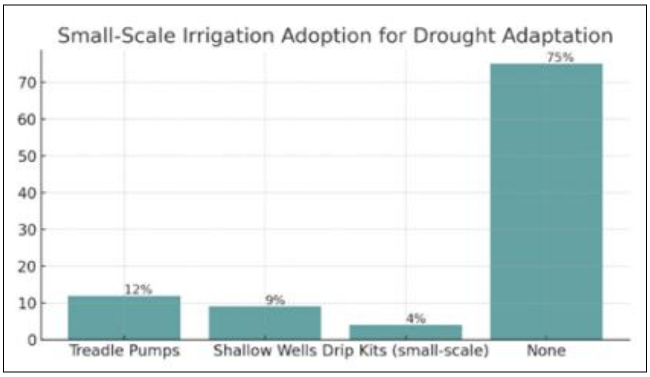

Fig 4.2.2: Shows small scale irrigation adoption

The study showed that most farmers (75%) relied entirely on rain-fed agriculture, making them vulnerable to erratic rainfall. Small-scale irrigation was limited: 12% used treadle pumps, 9% relied on shallow wells, and only 4% had drip kits. Overall, irrigation remains largely underutilized due to cost, accessibility, and labor constraints.

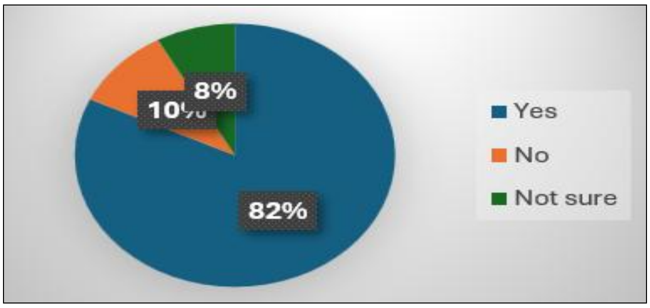

Fig 4.3.4: Illustrates Observed Climate Change

The study found that 82% of farmers in the Msekera Catchment Area noticed changes in climate over the past five years, showing strong awareness of shifting weather patterns. Ten percent had not observed changes, and 8% were unsure, highlighting some gaps in knowledge. This suggests widespread recognition of climate change but indicates a need for further farmer education and awareness programs.

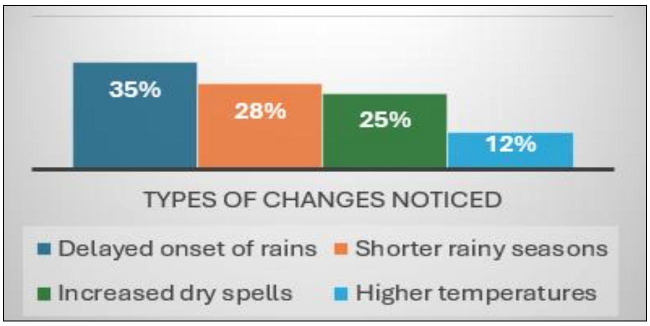

Fig 4.3.5: Shows Types of Changes Noticed

The study found that farmers in the Msekera Catchment Area mainly noticed delayed rains (35%), shorter rainy seasons (28%), and increased dry spells (25%), with some observing higher temperatures (12%). This shows that rainfall variability is the primary climate challenge affecting maize farming in the area.

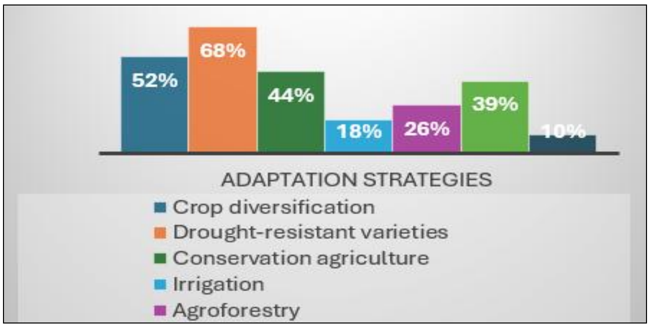

Fig 4.3.6: Indicates Adaptation Strategies

The study showed that farmers mainly used drought-resistant maize (68%) and crop diversification (52%) to cope with climate risks. Conservation agriculture (44%) and adjusting planting dates (39%) had moderate adoption, while agroforestry (26%) and irrigation (18%) were less common due to labor, cost, and resource constraints. Other strategies, like mixed farming, were reported by 10%, highlighting a variety of approaches to manage climate challenges.

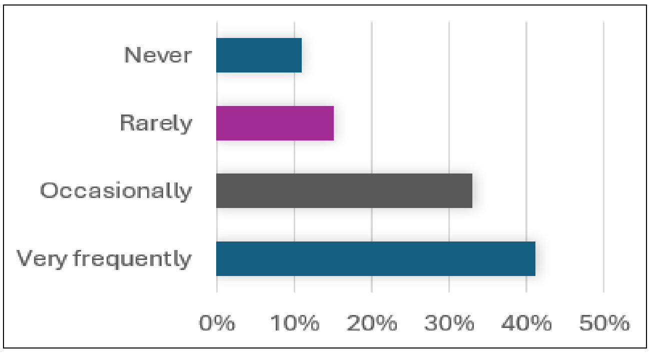

Fig 4.3.7: Indicates Frequency of Strategy Use

The study found that 41% of farmers used adaptation strategies consistently every season, 33% applied them occasionally, 15% used them rarely, and 11% never used any measures. This shows that while many farmers are proactive, resource constraints and knowledge gaps limit consistent adoption for some households.

4.3 Impact of Climate Change on Maize Production

This section shows that small-scale maize farmers in the Msekera Catchment Area are experiencing climate impacts like droughts, unpredictable rainfall, high temperatures, and occasional floods, which reduce maize yields and threaten food security, highlighting their vulnerability and the need for effective adaptation strategies.

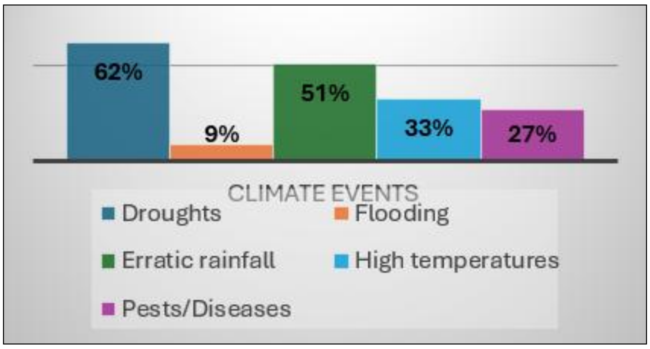

Fig 4.3.1: Illustrates Climate Events

Figure 4.3.1 shows that maize farmers in the study area face multiple climate-related challenges: droughts (62%) are the most severe, followed by erratic rainfall (51%), high temperatures (33%), pests and diseases (27%), and floods (9%), highlighting the diverse risks affecting crop growth and yields.

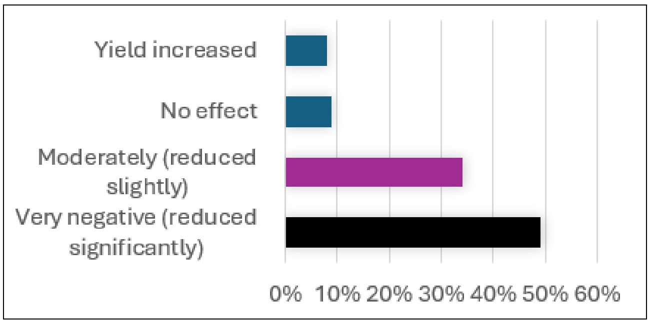

Fig 4.3.2: Indicates Impact on Yield

Figure 4.3.2 shows that climate change has mostly reduced maize yields: 49% of farmers reported very negative effects, 34% saw moderate decreases, 9% experienced no change, and 8% had increased yields, reflecting both vulnerability and the influence of local conditions or adaptation measures.

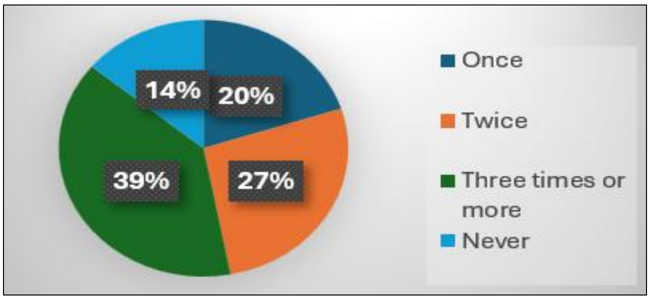

Fig 4.3.3: Illustrates Severe Drought/Flood Experience

Figure 4.3.3 shows that severe droughts or floods are increasingly frequent in the area: 39% of farmers experienced them three times or more in five years, 27% twice, 20% once, and 14% never, indicating rising climate extremes that threaten maize production.

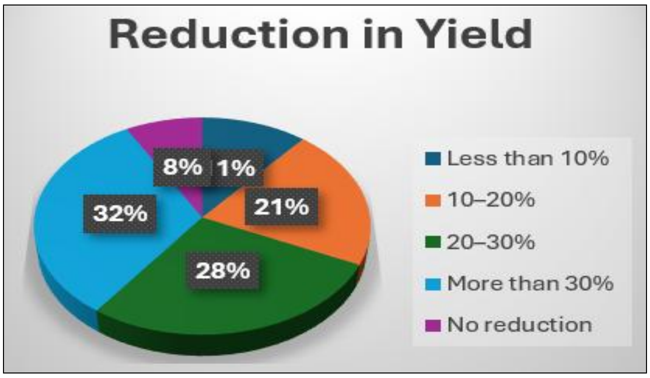

Fig 4.3.4: Illustrates Reduction in Yield

Figure 4.3.4 shows that climate change has significantly reduced maize yields in the past five years: 32% of farmers lost over 30% of their harvest, 28% lost 20–30%, 21% lost 10–20%, 11% lost less than 10%, and 8% saw no reduction, highlighting widespread negative impacts on food security.

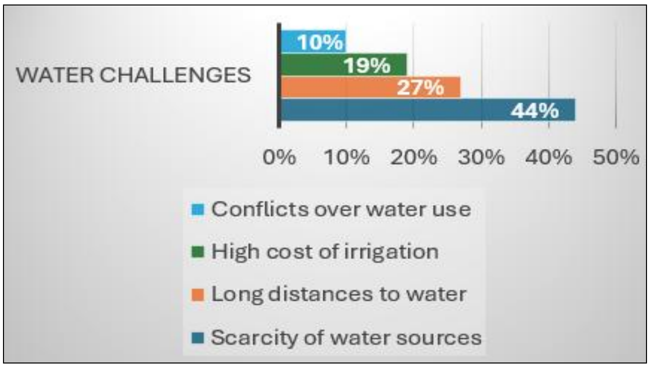

Fig 4.3.5: Indicates Water Challenges

Figure 4.3.5 shows that water-related challenges significantly affect maize farming: 44% of farmers struggle with scarce water sources, 27% travel long distances for water, 19% face high irrigation costs, and 10% experience water conflicts, emphasizing the importance of water access for sustaining production.

4.4 Response to Shocks and Recovery

This section explains how small-scale maize farmers in the Msekera Catchment Area cope with climate shocks like droughts, floods, and erratic rainfall, focusing on the strategies they use, their effectiveness, the support received, and long-term adjustments to sustain maize production and build resilience.

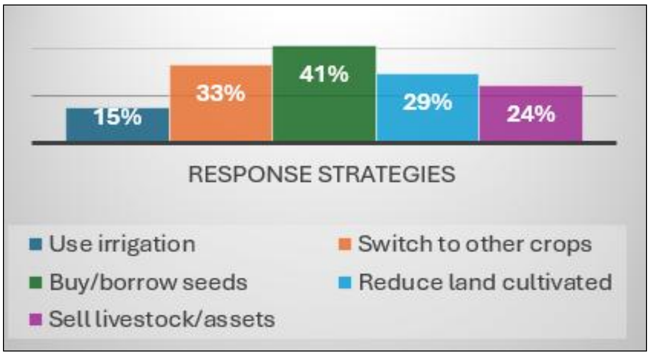

Fig 4.4.1: Shows Response Strategies

Figure 4.4.1 shows that farmers mainly cope with climate shocks by using drought-resistant seeds (41%) and switching to drought-tolerant crops (33%). Fewer reduce land cultivated (29%), sell assets (24%), or use irrigation (15%), highlighting a reliance on low-cost, accessible strategies rather than infrastructure-heavy solutions.

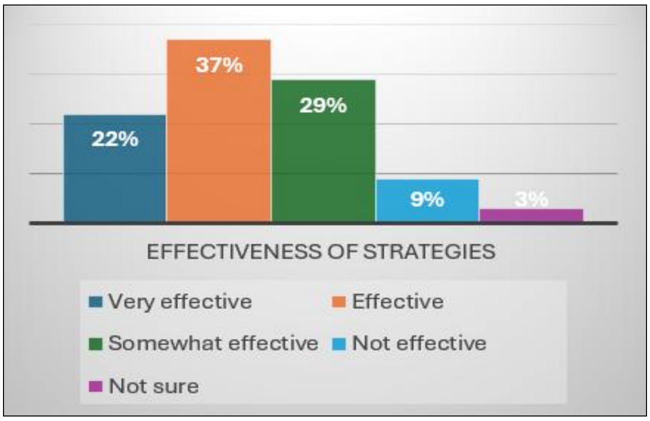

Fig 4.4.2: Illustrates Effectiveness of Strategies

Figure 4.4.2 shows that most farmers find their coping strategies useful, with 37% rating them effective and 22% very effective, while 29% saw partial success. Only 9% found them ineffective, and 3% were unsure, indicating overall usefulness but potential for improvement.

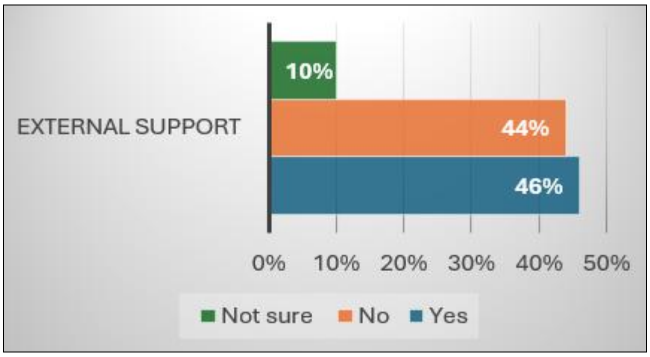

Fig 4.4.3: Indicates External Support

Figure 4.4.3 shows that 46% of farmers received external support from government programs, NGOs, or cooperatives, 44% had no support, and 10% were unsure, highlighting unequal access to assistance for coping with climate shocks.

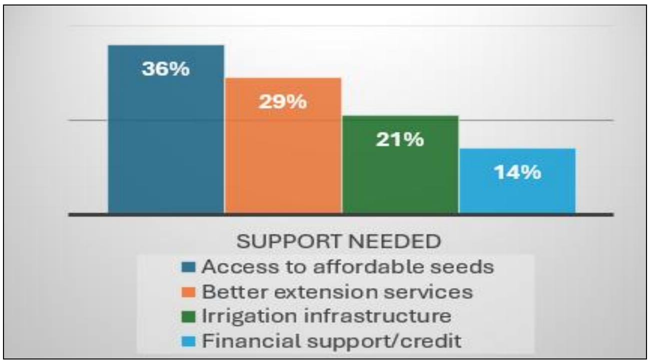

Fig 4.4.4: Demonstrates Support Needed

Figure 4.4.4 shows that farmers prioritize support to cope with climate shocks: 36% want affordable seeds, 29% need better extension services, 21% seek irrigation infrastructure, and 14% require financial support, highlighting the key areas to strengthen their resilience.

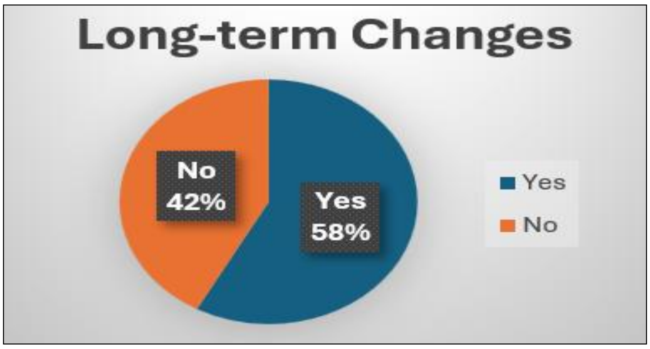

Fig 4.4.5: Illustrates Long-term Changes

Figure 4.4.5 shows that 58% of farmers have made long-term changes to their farming practices to adapt to climate change, while 42% have not, indicating moderate adoption and a need for further support to promote sustainable adaptation.

4.5 Confidence and Future Outlook

This section examines farmers' confidence in sustaining maize production amid climate change, their willingness to adopt new adaptation strategies, the support provided by cooperatives and networks, and the interventions they see as necessary to maintain productivity and food security.

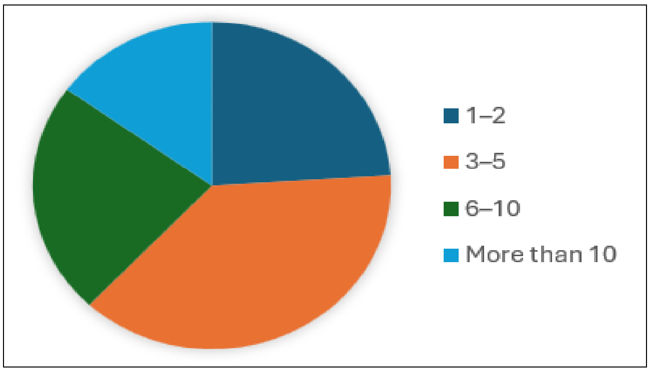

Fig 4.5.1: Shows Number of Long-term Changes Made

Figure 4.5.1 shows that most farmers have made some long-term changes to their maize farming practices in response to climate change, with 38% making 3–5 changes, 24% making 1–2, 23% making 6–10, and 15% making over 10 changes, indicating varying levels of adaptation effort.

Fig 4.5.2: Indicates Cooperative Membership

Figure 4.5.2 shows that 47% of farmers belong to cooperatives, gaining collective support and resources, while 53% operate independently, potentially limiting their access to cooperative benefits.

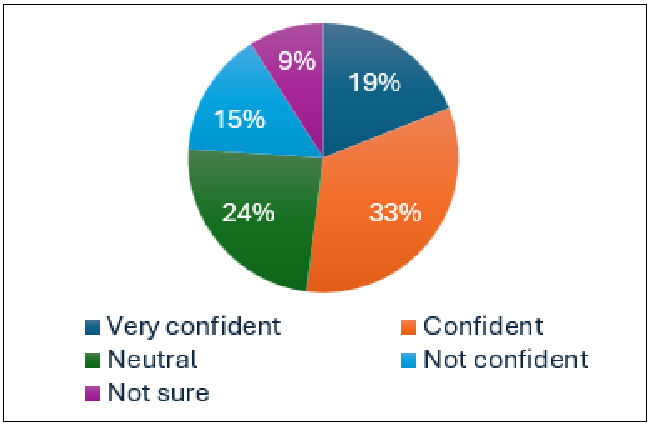

Fig 4.5.3: Illustrates Confidence in Continued Maize Farming

Figure 4.5.3 shows that just over half of farmers (52%) are confident or very confident in continuing maize farming under climate change, 24% are neutral, and 24% feel not confident or unsure, indicating a mix of optimism and vulnerability.

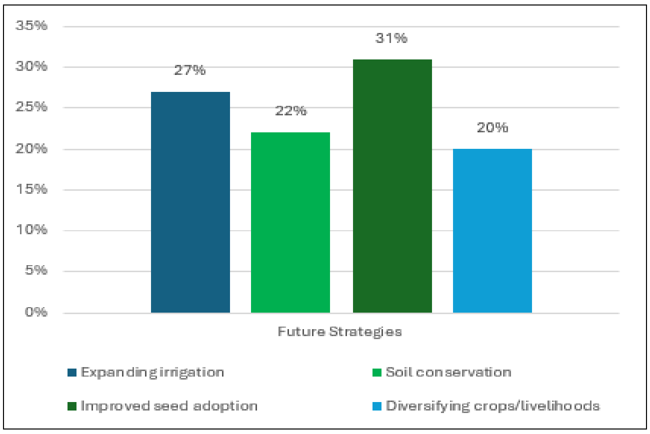

Fig 4.5.4: Demonstrates Future Strategies

Figure 4.5.4 shows that farmers plan to strengthen resilience through improved seed varieties (31%), expanded irrigation (27%), soil conservation practices (22%), and crop and livelihood diversification (20%), reflecting a mix of technological, ecological, and risk-spreading strategies.

4.6 Discussion of Research Findings

The study found that small-scale maize farmers in the Msekera Catchment face recurring droughts, erratic rainfall, pests, and occasional floods, all of which reduce yields and threaten food security. Farmers adopt diverse adaptation strategies, including drought-tolerant maize, conservation agriculture, crop diversification, and small-scale irrigation, but adoption varies across villages and households depending on resources, land, and gender. Male-headed households often use resource-intensive practices, while female-headed households rely on lower-cost methods. Access to climate information, income diversification, and financial support also strongly influence adaptation effectiveness. Despite farmers' efforts, systemic barriers such as gender inequality, poor infrastructure, insecure land tenure, and limited institutional support constrain the scale and sustainability of these strategies. The findings highlight that effective adaptation in Msekera requires integrated, context-specific, and gender-sensitive approaches combining technology, knowledge, finance, and institutional support to strengthen resilience, ensure food security, and reduce rural vulnerability.

5.1 Conclusion

The study found that small-scale maize farmers in the Msekera Catchment actively use multiple drought adaptation strategies, including drought-tolerant maize, conservation agriculture, crop diversification, small-scale irrigation, and indigenous practices like early planting. While these strategies show potential in mitigating the impacts of erratic rainfall and recurrent droughts, their effectiveness is limited by socio-economic, institutional, and environmental constraints. Wealth, land access, credit, and extension support influence which strategies farmers can adopt, with resource-poor and female-headed households facing greater barriers. Successful adaptations are those that are affordable, technically feasible, culturally compatible, and supported by strong institutions. Integrating traditional knowledge with modern practices, providing timely climate information, and promoting inclusive, context-specific interventions are essential. The study concludes that building climate resilience in Msekera requires coordinated technical, socio-economic, and institutional efforts, long-term monitoring, and policies that ensure equitable access to resources, empowering all farmers to sustain maize production and household food security under increasing climate variability.

5.2 Recommendations

Effective and sustainable drought adaptation requires integrated, inclusive, and context-sensitive approaches rather than isolated technical solutions. Adaptation strategies must address socio-economic inequalities, gender disparities, institutional capacity, and environmental sustainability. Combining low-cost practices like mulching and intercropping with resource-intensive technologies such as irrigation and improved seeds ensures all farmers, including women and poorer households, can benefit. Integrating indigenous knowledge with scientific tools, tailoring interventions to local agro-ecological and socio-economic conditions, and providing timely climate information enhance adoption and resilience. Strengthening extension services, farmer cooperatives, rural credit access, and participatory learning mechanisms further supports scalability. Policies must also ensure ecological alignment, promote sustainability, and encourage knowledge exchange. Overall, building climate resilience depends on multi-level, coordinated efforts that empower farmers, reduce structural barriers, and safeguard food security and rural livelihoods. Finally, at the policy level, drought adaptation frameworks must integrate environmental sustainability and agro-ecological realities into their design. Strategies that are technically sound but ecologically misaligned risk creating new vulnerabilities. For example, expanding irrigation without considering water availability and watershed dynamics may cause long-term harm. Policies should, therefore, promote practices that are ecologically restorative, such as agroforestry, soil fertility management, and conservation agriculture, alongside risk-reducing measures like insurance and social protection.

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