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Enhancing Agricultural Resilience through Sustainable Practices: Assessing the Effectiveness of Climate Change Adaptation Strategies for Smallholder Farmers in Zambia

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Abstract

Climate change poses a serious threat to agricultural productivity and rural livelihoods in Zambia, particularly among smallholder farmers who depend on rain-fed agriculture. This study assessed the effectiveness of current climate change adaptation strategies in enhancing agricultural resilience among smallholder farmers in Kalomo District, Southern Province. A descriptive cross-sectional design employing both quantitative and qualitative approaches was adopted. Data were collected from 72 smallholder farmers using structured questionnaires, key informant interviews, and focus group discussions, and analyzed using descriptive statistics and thematic analysis. The main adaptation strategies identified included the use of early-maturing and drought-tolerant crop varieties, conservation agriculture, crop diversification, agroforestry, and livelihood diversification. Findings revealed that early-maturing crops (68%) and drought-tolerant varieties (49%)

were the most effective strategies in stabilizing yields under erratic rainfall conditions. Conservation agriculture and agroforestry practices improved soil fertility, moisture retention, and long-term productivity, while income diversification provided a buffer against climate-induced income shocks. Socioeconomic factors such as education level, income, farm size, gender, and access to credit significantly influenced the adoption of adaptation strategies. Farmers generally perceived climate change as a growing threat and demonstrated a willingness to adopt climate-smart practices, though constraints such as limited financial resources, inadequate extension services, and weak institutional support persist. The study concludes that integrated and community-based approaches, supported by extension services and policy interventions, are essential for strengthening agricultural resilience and promoting sustainable livelihoods in Kalomo District.

Keywords: Climate Change Adaptation, Smallholder Farmers, Agricultural Resilience, Socioeconomic Determinants

1. Introduction

Climate change has emerged as one of the most pressing global challenges of the 21st century, threatening food security, ecosystem stability, and human livelihoods. The Intergovernmental Panel on Climate Change (IPCC, 2022) reports that the global mean temperature has already increased by approximately 1.1°C above pre-industrial levels, resulting in intensified droughts, floods, and heatwaves that directly affect agricultural productivity. Agriculture, being both a contributor to and victim of climate change, accounts for nearly 24 percent of global greenhouse gas emissions, mainly through land-use change, livestock production, and fertilizer use (FAO, 2023). The consequences of these climatic shifts are particularly severe for smallholder farmers in developing countries, whose livelihoods depend heavily on rain-fed agriculture and natural resources. Across the Sub-Saharan African (SSA) region, climate change has become a major constraint to agricultural development and rural livelihoods. The region's agriculture is highly vulnerable due to its dependence on rainfall, limited technological innovation, and weak adaptive capacity (Niang *et al.*, 2014). Studies indicate that average temperatures in SSA have increased by 0.7°C to 1.0°C since 1970, with projections suggesting a rise of 2–3°C by 2050 if no mitigation measures are implemented (AfDB, 2021). Droughts, erratic rainfall, and land degradation have led to reduced yields in staple crops such as maize, sorghum, and millet, thereby intensifying food insecurity (Makate *et al.*, 2019). Smallholder farmers, who form the backbone

of the region's food systems, are disproportionately affected due to limited access to finance, irrigation, and climate information services (Hassan & Nhemachena, 2008). Consequently, adaptation has become a vital survival strategy for sustaining agricultural production under changing climatic conditions.

In Zambia, climate change poses a growing threat to the country's socio-economic stability, given that agriculture supports more than 70 percent of the population, most of whom are smallholder farmers (Baudoin, 2017). The Ministry of Agriculture (MoA, 2022) and the Zambia Meteorological Department (ZMD, 2023) report that average national temperatures have increased by 1.3°C since 1960, while rainfall has declined by approximately 15 percent in the southern and western regions. These changes have led to recurrent droughts, flash floods, and dry spells, resulting in declining crop productivity, livestock losses, and increased rural poverty. The Southern Province, where Kalomo District is located, has been among the hardest hit, experiencing prolonged dry spells and soil moisture stress that threaten staple food production. The 2018/2019 drought, for example, reduced maize yields in the province by nearly 40 percent (FAO, 2023). To counter these impacts, Zambia has introduced several climate change adaptation strategies aimed at enhancing agricultural resilience. These include conservation agriculture (CA), crop diversification, use of early-maturing and drought-tolerant crop varieties, agroforestry, and rainwater harvesting (Tembo, Bernard, & Sihubwa, 2024). The Conservation Farming Unit (CFU) and various non-governmental organizations have promoted CA as a sustainable land management practice that improves soil structure, water retention, and yields, especially under drought conditions. Similarly, the government's National Policy on Climate Change (NPCC, 2016) and National Agriculture Investment Policy (NAIP, 2014–2024) have emphasized the integration of climate-smart agriculture (CSA) into rural development programs. Despite these efforts, the adoption and effectiveness of adaptation strategies vary significantly across regions and among farming households due to socioeconomic, institutional, and behavioral factors (Muyabe, Silombe, & Phiri, 2025; Sichoongwe & Wang, 2023^[51]). In Kalomo District, agriculture is the primary livelihood activity, yet it is increasingly challenged by erratic rainfall patterns, declining soil fertility, and recurrent droughts. Smallholder farmers rely heavily on rain-fed maize and groundnut production, with limited access to irrigation and financial support. Although several adaptation initiatives have been introduced—such as conservation agriculture and agroforestry—there is limited empirical evidence on how effective these strategies are in enhancing agricultural resilience and sustaining livelihoods under climate stress. Furthermore, farmers' perceptions, attitudes, and socioeconomic conditions significantly influence the success or failure of these interventions (Phiri *et al.*, 2025)^[45]. Understanding these factors is therefore essential for designing context-specific and sustainable adaptation strategies that can strengthen resilience and improve agricultural productivity in vulnerable districts like Kalomo. Given this context, this study seeks to evaluate the effectiveness of current adaptation strategies in enhancing agricultural resilience, identify the socioeconomic determinants influencing farmers' adoption of these

strategies, and assess farmers' perceptions toward climate change adaptation in Kalomo District. By combining insights from both behavioral and resource-based frameworks, the study contributes to evidence-based policy formulation and provides practical recommendations for promoting sustainable, climate-resilient agriculture in Zambia's semi-arid regions.

1.1 Statement of Problem

Agriculture remains a cornerstone of Zambia's economy, contributing significantly to employment, food security, and rural livelihoods. According to the National Agriculture Investment Policy, the agricultural sector is one of the most critical drivers of economic growth and poverty reduction, employing over 70 percent of the rural population (Baudoin, 2017; Ministry of Agriculture [MoA], 2022). However, the sector's productivity is increasingly threatened by climate variability and change, manifested through prolonged droughts, erratic rainfall, and rising temperatures (Phiri *et al.*, 2025)^[45]. These climatic shifts have led to reduced crop yields, soil degradation, and recurrent food insecurity, especially among smallholder farmers who rely primarily on rain-fed agriculture for their livelihoods (Hachigonta, Hellmuth, & Zermoglio, 2013). Although several climate change adaptation strategies—such as conservation agriculture, crop diversification, use of drought-tolerant seed varieties, and agroforestry have been promoted by the government and development partners, their effectiveness in enhancing agricultural resilience remains uncertain at the local level (Tembo, Bernard, & Sihubwa, 2024). Many smallholder farmers in semi-arid regions like Kalomo District continue to face challenges such as limited access to financial resources, inadequate extension services, and weak institutional support, which hinder the successful adoption and sustained use of adaptation measures (FAO, 2023; ZMD, 2023). Additionally, socio-economic factors such as education, income, gender, and farm size play a crucial role in influencing farmers' adaptive capacity and decision-making (Sichoongwe & Wang, 2023)^[51]. Despite growing policy attention on climate-smart agriculture, empirical evidence on how these adaptation strategies perform in strengthening agricultural resilience at the household level remains limited in Zambia. Previous studies have mainly focused on adoption rates rather than the effectiveness and perception of implemented practices in different agro-ecological contexts (Muyabe, Silombe, & Phiri, 2025). Consequently, there is a critical need to assess how well current adaptation interventions are working for smallholder farmers, identify key socio-economic determinants of adaptation, and understand farmers' perceptions of these strategies. This study therefore seeks to fill this knowledge gap by evaluating the effectiveness of existing climate change adaptation practices and proposing sustainable pathways for improving resilience among smallholder farmers in Kalomo District.

1.2 Objectives

1.2.1 Specific Objectives

1. To evaluate the effectiveness of the current adaptation strategies in enhancing agricultural resilience.
2. To identify socioeconomic factors determinants of farmer's adaptation to climate change impact.
3. To determine the farmer's perception to climate change adaptation strategies.

1.3 Research Questions

Based on the specific objectives, the study was guided by the following research questions:

1. How effective are the current climate change adaptation strategies in enhancing agricultural resilience among smallholder farmers in Kalomo District?
2. What are the key socioeconomic factors that determine farmers' adaptation to the impacts of climate change in Kalomo District?
3. What are the perceptions of smallholder farmers toward the climate change adaptation strategies being implemented in Kalomo District?

2. Literature Review

This chapter reviews relevant literature on climate change and adaptation in agriculture at the global, regional (Sub-Saharan Africa), and local (Zambia and Kalomo District) levels. It highlights empirical findings and theoretical perspectives related to the effectiveness of adaptation strategies, socioeconomic determinants of adoption, and farmers' perceptions. The chapter concludes with the theoretical framework guiding the study and a discussion of knowledge gaps that the research seeks to address.

Globally, climate change is recognized as one of the most profound challenges to sustainable development, posing significant risks to food security, environmental stability, and human livelihoods. The Intergovernmental Panel on Climate Change (IPCC, 2022) reports that average global temperatures have already increased by about 1.1°C above pre-industrial levels, primarily due to greenhouse gas (GHG) emissions from human activities such as deforestation, fossil fuel combustion, and industrial agriculture. This temperature rise has accelerated the frequency and intensity of droughts, floods, and heatwaves, leading to widespread soil degradation, water scarcity, and declining agricultural productivity (IPCC, 2022; FAO, 2023). Agriculture both contributes to and suffers from climate change. According to the Food and Agriculture Organization (FAO, 2023), the agricultural sector is responsible for nearly 24 percent of total global GHG emissions, mainly through methane from livestock, nitrous oxide from fertilizers, and carbon dioxide from land-use change. Simultaneously, the sector is one of the most climate-sensitive, as crop and livestock production directly depend on climatic variables such as temperature, rainfall, and soil moisture. Vermeulen, Challinor, and Thornton (2018) observed that changes in temperature and rainfall patterns are already affecting global food systems, with reduced yields in major cereals such as maize, wheat, and rice across Africa, Asia, and Latin America. In developing regions where agriculture is largely rain-fed, yield losses of 10–30 percent have been recorded due to heat stress, erratic rainfall, and pest outbreaks (IPCC, 2022). In South Asia, for example, studies in India and Bangladesh show that rising temperatures and erratic monsoons have led to lower productivity in rice and wheat systems, forcing farmers to adopt adaptive practices such as crop diversification, drought-resistant varieties, and integrated water management (Shah *et al.*, 2020). Similarly, in Latin America, prolonged dry spells and extreme rainfall events have disrupted agricultural calendars, increased soil erosion, and reduced productivity in key export crops like coffee, soybeans, and sugarcane (Vermeulen *et al.*, 2018). Climate variability is also affecting livestock production, as heat

stress reduces animal fertility and milk yields while increasing disease prevalence (Thornton *et al.*, 2019). To address these challenges, climate-smart agriculture (CSA) has emerged as a global framework for sustainable adaptation and mitigation. CSA integrates three key objectives: increasing productivity, enhancing resilience (adaptation), and reducing or removing GHG emissions (mitigation) (FAO, 2023). Practices under CSA include conservation farming, agroforestry, integrated crop-livestock systems, efficient irrigation technologies, and precision agriculture. According to Thornton *et al.* (2019), such practices have shown measurable success in improving resource efficiency and reducing vulnerability to climate shocks. For instance, conservation agriculture has improved soil moisture retention and reduced erosion in dryland systems, while agroecological practices such as mixed cropping and organic nutrient recycling have enhanced biodiversity and soil health across tropical and subtropical regions (Altieri & Nicholls, 2017).

However, the effectiveness and scalability of global adaptation strategies vary greatly depending on institutional support, policy environment, and farmers' access to knowledge and finance. Lipper *et al.* (2018) emphasize that the successful implementation of CSA requires strong institutional coordination, access to climate information, and financial mechanisms such as climate insurance and carbon credit schemes. In many developing countries, smallholder farmers face barriers including high input costs, limited extension services, and poor access to credit, which restrict their capacity to adopt modern adaptation technologies. Consequently, while global frameworks for adaptation exist, their on-ground effectiveness is often determined by local governance systems, infrastructure, and socioeconomic conditions.

2.1.1 Climate Change and Agriculture in Sub-Saharan Africa

In Sub-Saharan Africa (SSA), climate change has become a major driver of agricultural instability and food insecurity. The region's agricultural systems are predominantly rain-fed, with over 95 percent of cropland dependent on seasonal rainfall (FAO, 2023). This heavy reliance makes smallholder farmers particularly vulnerable to rainfall variability, droughts, and floods, which have intensified in frequency and severity over recent decades (Niang *et al.*, 2014; IPCC, 2022). Empirical evidence indicates that average temperatures across SSA have risen between 0.7°C and 1.0°C since 1970, and projections suggest an increase of 2–3°C by 2050 if global mitigation remains insufficient (Niang *et al.*, 2014). Such warming trends are expected to reduce agricultural productivity, alter cropping calendars, and exacerbate pest and disease outbreaks, posing significant threats to food systems and rural livelihoods. The African Development Bank (AfDB, 2021) estimates that climate-induced losses could reduce agricultural GDP by up to 8 percent annually in low-income African economies by mid-century. Climate change impacts are already being observed across the region. Extended dry spells in southern Africa, erratic rainfall in East Africa, and flooding in West Africa have disrupted production of staple crops such as maize, sorghum, millet, and groundnuts. Thornton *et al.* (2019) found that rain-fed maize yields in southern Africa could decline by up to 30 percent by 2050 under high-emission scenarios. Livestock production is also affected as rangelands degrade and water resources become scarcer,

forcing pastoralists to migrate and increasing conflict over grazing land (Serdeczny *et al.*, 2017). These impacts compound existing structural vulnerabilities such as poverty, limited access to credit, poor infrastructure, and dependence on subsistence farming. As a result, millions of rural households face recurrent food insecurity, threatening to reverse developmental gains made over the past two decades (Mubaya *et al.*, 2017). To respond to these threats, many SSA countries have implemented a range of adaptation programs and climate-smart agricultural (CSA) initiatives. For instance, Kenya, Malawi, Tanzania, and Zimbabwe have prioritized interventions such as conservation agriculture, irrigation expansion, agroforestry, livelihood diversification, and early warning systems (Makate, Makate, & Mango, 2019). In Zimbabwe, adoption of conservation agriculture has increased maize yields, improved soil organic matter, and enhanced water-use efficiency, demonstrating its effectiveness in mitigating drought impacts (Makate *et al.*, 2019). In Kenya, Bryan *et al.* (2013) observed that access to agricultural extension services and climate information significantly influenced farmers' adoption of multiple adaptation strategies. Similarly, studies in Malawi and Tanzania revealed that integrating livelihood diversification and agroforestry into smallholder farming systems improved household resilience by providing additional income and food sources during climatic shocks (Mubaya *et al.*, 2017). Moreover, regional initiatives such as the Comprehensive Africa Agriculture Development Programme (CAADP) and the African Climate-Smart Agriculture Alliance (ACSAA) have been instrumental in promoting coordinated policy frameworks for climate adaptation. These programs emphasize sustainable intensification, knowledge sharing, and regional cooperation to enhance food security and resilience (AfDB, 2021). In addition, African governments are increasingly aligning their Nationally Determined Contributions (NDCs) under the Paris Agreement with agricultural adaptation priorities, reflecting growing recognition of the sector's central role in climate action (IPCC, 2022). Despite these advances, the adoption and effectiveness of adaptation strategies in SSA remain limited by a range of socioeconomic and institutional barriers. Many smallholder farmers lack access to credit, insurance, markets, and modern inputs, which constrains their ability to invest in resilient technologies (Hassan & Nhemachena, 2008; Mubaya *et al.*, 2017). The availability and reliability of climate information services are also inadequate, reducing farmers' capacity for timely decision-making. Weak extension systems, limited policy coherence, and low investment in agricultural research and infrastructure further impede the scaling up of proven adaptation practices (Makate *et al.*, 2019). An additional challenge is the mismatch between national policy frameworks and local realities. Top-down climate initiatives often fail to incorporate indigenous knowledge systems and community-based adaptation approaches that have sustained rural livelihoods for generations (Nhemachena & Hassan, 2007). Integrating indigenous practices such as traditional weather forecasting, mixed cropping, and water harvesting into modern adaptation planning could enhance the cultural relevance and long-term sustainability of interventions. Hassan and Nhemachena (2008) emphasize that successful adaptation in Africa depends on improving farmers' knowledge, strengthening institutional linkages, and combining scientific innovation with local experiential

wisdom.

2.1.2 Climate Change and Agriculture in Zambia

At the national level, Zambia faces significant and escalating challenges in adapting its agricultural systems to the impacts of climate change. Over the past six decades, national climate records indicate that average temperatures have increased by approximately 1.3°C, with a consistent trend of declining and erratic rainfall, particularly in the Southern and Western Provinces (Ministry of Agriculture [MoA], 2022; Zambia Meteorological Department [ZMD], 2023). These climatic changes have been accompanied by an increased frequency of droughts, flash floods, dry spells, and pest infestations, which have led to widespread crop failures, livestock mortality, and food insecurity (Phiri, Tembo, & Nanyangwe, 2025). For example, the 2018/2019 drought severely reduced maize production in the Southern Province by nearly 40%, highlighting the vulnerability of rain-fed agriculture to climate variability (FAO, 2023). Agriculture remains the backbone of Zambia's economy and the primary livelihood source for the rural population. The sector employs over 70 percent of the country's workforce, most of whom are smallholder farmers cultivating less than five hectares of land under rain-fed conditions (Baudoin, 2017; MoA, 2022). Despite its importance, the sector contributes less than 10 percent to national GDP due to persistent productivity constraints and environmental stressors (World Bank, 2021). The country's agro-ecological zones ranging from the high rainfall areas of Northern Province to the semi-arid regions of Southern Province exhibit diverse vulnerabilities to climate change. Southern Province, which includes Kalomo District, is among the most affected areas, experiencing recurrent droughts, declining soil fertility, and limited water availability for both crops and livestock (ZMD, 2023).

To address these challenges, Zambia has adopted a series of adaptation strategies that promote climate resilience among smallholder farmers. Commonly promoted interventions include conservation agriculture (CA), crop diversification, use of drought-tolerant and early-maturing crop varieties, agroforestry, and rainwater harvesting (FAO, 2023; Muyabe, Silombe, & Phiri, 2025). Conservation agriculture, in particular, has been widely promoted by the Conservation Farming Unit (CFU), the Food and Agriculture Organization (FAO), and various non-governmental organizations. According to Tembo, Bernard, and Sihubwa (2024), farmers practicing CA in the Southern Province have experienced improved soil fertility, moisture retention, and crop yields compared to conventional ploughing systems. Similarly, agroforestry the integration of trees such as *Faidherbia albida* in crop fields has enhanced soil structure and provided shade for livestock, while livelihood diversification (e.g., small-scale livestock rearing, gardening, and off-farm businesses) has emerged as a coping mechanism during extreme weather events (Chomba, Banda, & Musukwa, 2020). Government and development partners have also introduced institutional and policy measures aimed at strengthening agricultural adaptation. These include the National Policy on Climate Change (NPCC, 2016), the National Adaptation Plan of Action (NAPA, 2007), and the National Agriculture Investment Policy (NAIP, 2014–2024), which collectively promote climate-smart agriculture (CSA) and sustainable land management practices (Baudoin, 2017). Zambia's inclusion of agriculture as a priority sector in its Nationally

Determined Contributions (NDCs) under the Paris Agreement further underscores its commitment to building a climate-resilient agricultural sector (ZMD, 2023). These policies advocate for capacity building, institutional coordination, and technology transfer to empower smallholder farmers with adaptive knowledge and tools. Despite these policy advances, the adoption and effectiveness of adaptation practices remain uneven across regions and communities. Studies by Muyabe, Silombe, and Phiri (2025) and Sichoongwe and Wang (2023) ^[51] indicate that socioeconomic and institutional barriers such as limited access to agricultural credit, weak extension services, high input costs, and gender disparities continue to constrain widespread adoption. Many smallholder farmers lack the financial capacity to purchase improved seed varieties or invest in irrigation infrastructure, making them highly dependent on external assistance. Gender inequalities further compound these challenges, as women farmers who make up nearly half of Zambia's agricultural labor force often face restricted access to land ownership, extension training, and productive resources (FAO, 2023).

Moreover, most adaptation initiatives in Zambia are donor-driven and short-term, implemented through pilot projects without sufficient integration into local government structures or long-term funding strategies (Phiri *et al.*, 2025) ^[45]. Once external support phases out, adoption rates decline due to the absence of technical follow-up and financial incentives. Additionally, gaps remain in climate information dissemination, as many rural farmers rely on traditional forecasting methods rather than scientific weather predictions (MoA, 2022). The lack of localized data and early warning systems hinders timely decision-making and increases vulnerability to extreme weather events. In Kalomo District, these challenges are particularly pronounced. The district's semi-arid conditions, coupled with sandy soils and erratic rainfall, make it a climate "hotspot" where smallholder farmers struggle to maintain productivity (FAO, 2023). Limited access to extension services, weak market linkages, and declining soil fertility further exacerbate vulnerability. Nonetheless, evidence from field projects and local studies shows that integrating conservation agriculture with livelihood diversification and agroforestry can significantly enhance household resilience and reduce dependency on rain-fed maize monoculture (Muyabe *et al.*, 2025) ^[36].

2.2 Climate Change Adaptation and Agricultural Resilience

Agricultural resilience refers to the ability of farming systems to anticipate, absorb, and recover from climatic shocks while maintaining or improving productivity, ecosystem services, and livelihoods (IPCC, 2022; FAO, 2023). In the context of climate change, resilience is achieved through effective adaptation strategies that enable farmers to cope with increased weather variability, resource degradation, and socio-economic pressures. Adaptation measures such as conservation agriculture, crop and livelihood diversification, use of improved and drought-tolerant seed varieties, agroforestry, and rainwater management have been identified as crucial pathways for building climate-resilient agricultural systems (FAO, 2023; World Bank, 2021). These strategies are designed not only to mitigate immediate climatic risks but also to strengthen the long-term sustainability and productivity of

agroecosystems. Globally, the concept of resilient agriculture has evolved within the broader framework of Climate-Smart Agriculture (CSA), which seeks to simultaneously achieve three objectives: increased productivity, enhanced resilience (adaptation), and reduced greenhouse gas emissions (mitigation) (Thornton, Ericksen, & Herrero, 2019). Practices such as minimum tillage, integrated pest management, efficient irrigation, and agroecological intensification have been shown to improve soil structure, water retention, and biodiversity, leading to higher productivity even under erratic climatic conditions (Altieri & Nicholls, 2017). For example, studies in India and Brazil have demonstrated that integrating crop-livestock systems and using organic soil amendments improve resilience to droughts and floods while maintaining ecosystem integrity (Lipper *et al.*, 2018). These global lessons underscore the potential for scaling such approaches in Sub-Saharan Africa, where agricultural systems face similar vulnerabilities.

In Sub-Saharan Africa (SSA), adaptation strategies have been implemented to counter the adverse impacts of temperature rise, prolonged dry spells, and unpredictable rainfall. Conservation agriculture (CA), in particular, has gained prominence as a sustainable land management practice due to its emphasis on minimum soil disturbance, permanent soil cover, and crop rotation. Research in Zimbabwe, Malawi, and Zambia has shown that CA improves soil organic matter, enhances water-use efficiency, and stabilizes maize yields during drought periods (Makate, Makate, & Mango, 2019; Tembo, Bernard, & Sihubwa, 2024). The FAO (2023) further notes that CA contributes to soil carbon sequestration and erosion control, enhancing both environmental and economic resilience. Similarly, agroforestry systems that integrate trees with crops such as *Faidherbia albida* and *Gliricidia sepium* help replenish soil fertility through nitrogen fixation, reduce evapotranspiration, and provide shade, fuelwood, and fodder, all of which contribute to household adaptation capacity (Chomba, Banda, & Musukwa, 2020). Crop diversification and livelihood diversification are also essential components of resilience-building. Crop diversification reduces production risk by spreading exposure across multiple crops with different climate tolerances, thereby enhancing food and income security (Phiri, Tembo, & Nanyangwe, 2025). For example, farmers in Southern Africa who combine maize with drought-tolerant crops such as sorghum, millet, and cowpeas experience more stable yields and income even during dry seasons (Hachigonta, Hellmuth, & Zermoglio, 2013). Meanwhile, livelihood diversification through small livestock rearing, petty trade, or off-farm employment provides an additional buffer against income shocks caused by climate-induced crop failures (Bryan *et al.*, 2013). These measures not only strengthen economic resilience but also enhance social resilience by empowering communities through diversified knowledge and asset bases.

In Zambia, conservation agriculture and agroforestry have been key pillars of national adaptation programs. The Conservation Farming Unit (CFU), in collaboration with the Ministry of Agriculture and development partners, has spearheaded large-scale promotion of CA in the Southern, Eastern, and Central Provinces, reaching thousands of smallholder farmers (MoA, 2022). Tembo *et al.* (2024) found that farmers practicing CA recorded improved maize

and groundnut yields compared to those using conventional ploughing, mainly due to increased soil moisture retention and reduced erosion. Similarly, Chomba *et al.* (2020) observed that agroforestry practices in Southern Province enhanced soil fertility and reduced dependency on chemical fertilizers, thereby lowering production costs while promoting sustainability. In Kalomo District, anecdotal evidence suggests that integrating CA with crop diversification and small livestock production has helped households recover faster from prolonged droughts (Muyabe, Silombe, & Phiri, 2025). However, while these adaptation strategies have proven effective in certain contexts, their adoption and sustainability remain constrained by various socioeconomic and institutional factors. Chisanga and Musaba (2021) argue that the uptake of conservation agriculture and other CSA practices in Zambia is still limited due to high labor demands, lack of access to farm inputs, and skepticism among farmers regarding long-term benefits. Additionally, many adaptation projects are externally funded and short-lived, leading to challenges in continuity once donor support ends (Phiri *et al.*, 2025) ^[45]. Market inefficiencies, poor rural infrastructure, and limited access to agricultural finance further hinder widespread adoption, especially among marginalized groups such as women and youth (Sichoongwe & Wang, 2023) ^[51]. Building agricultural resilience therefore requires a context-specific and participatory approach that integrates local knowledge with scientific innovation. FAO (2023) and IPCC (2022) recommend that adaptation interventions should be tailored to local agro-ecological conditions, involve farmers in co-designing solutions, and strengthen institutional linkages across policy, research, and extension systems. Investing in capacity building, climate information services, and inclusive financial mechanisms—such as weather-indexed insurance and microcredit—can further enhance resilience. Moreover, embedding gender-sensitive and community-driven approaches ensures equitable participation and sustainable impacts.

2.3 Climate Change and Smallholder Agriculture in Zambia

Climate change has a profound impact on smallholder farmers because they depend heavily on predicted weather patterns for their livelihoods due to limited resources to adapt to climate-changing environmental conditions such as soil degradation and erosion, water scarcity, increased incidence of pests and diseases, extreme temperatures, and unpredicted weather patterns. Many of the farmers depended on tacit knowledge of their area and their agriculture to cope with the changed climatic situations, which usually followed a 'business as usual' approach their agriculture. This was because agriculture choices made by smallholder farmers in rural Zambia were driven by market availability rather than weather and climate change this approach towards agriculture has resulted in small scale farmers getting adversely affected by the effects of changed climatic patterns, leaving them vulnerable to climatic perturbations (Turap *et al.*, no date). Most farmers have showed awareness of climate change and its impacts, and have such adopted strategies to enhance crop. This study aims to evaluate the effectiveness of the adopted strategies in enhancing climate change resilience. The impact of climate change has been extensively documented, highlighting

reduced crop yields and increased vulnerability of farming systems (Porter *et al.*, 2014). Small holder farmers have been disproportionately affected by increase and change in weather patterns such floods, high temperature and extreme cold. Adverse climate change impacts are considered to be particularly strong in countries located in tropical Africa that depend on agriculture as their main source of livelihood (Tazeze, Haji and Ketema, 2012). Climate change affects agricultural production and productivity of the rural community both directly and indirectly. It directly affects agriculture by affecting the weather variables, which are important inputs for agricultural production, such as temperature, solar radiation, rainfall, wind speed and humidity and indirectly through disease and pest outbreaks as well as favoring the development of climate related diseases like malaria that affect the work force. Climate change also affects the complex interactions between crop and pathogens leading to increased outbreak of pests and diseases (Sani, Haji and Goshu, 2016). In southern Africa, among the countries worst affected by droughts are Zambia and Zimbabwe. Both countries, signatories to the United Nations Convention on Climate and Desertification, are facing the adverse effects of climate, which compromises growth in the agricultural sector, and perpetuates subsequent degradation of the environment as rural households try and meet their livelihood needs. (Chipo *et al.*, 2010). Why are small-scale farmers at risk from global warming? There is currently no agreed-upon definition for climate vulnerability, resilience, or adaptive capacity. However, the basic ecological definition of resilience holds true here: Farmers can prosper in an environment that is adaptable to climate change while maintaining the same baseline agroecological conditions. On the other hand, a susceptible system is one in which the sustainability of smallholder farms is jeopardized by state changes in climate factors. Farmers may have some degree of coping capacity (e.g., assets that might be depleted in a given year to overcome a climate shock), but resilience is ultimately driven by their adaptive capacity, or their capability to thrive in changing conditions. (Burney *et al.*, 2014). According to rainfall, Zambia's three agro-ecological regions (AER) have different projected effects from climate change. Historically the western and southern parts of Zambia have an excellent grain growing area, however, rainfall in these two parts of the country (AER I) has been low, irregular, and poorly distributed for the previous 20 years. With evenly spaced rainfall and rich soil, the central region (AER IIa & b) is both the most populated and has the greatest potential for agriculture. The northern part of the country (AER III) receives the highest rainfall but has poorer soils. About 65% of this region is underutilized. (Arslan *et al.*, 2015). Despite considerable agricultural potential, Zambia's agriculture has been very low due to climate.

The agricultural sector in Zambia accounts for approximately 20% of GDP. 64% of Zambians live in rural areas where rain-fed subsistence agriculture is the dominant economic activity. Maize is the most important staple crop; over half the calories consumed in Zambia are from maize, although this proportion is decreasing. (Arslan *et al.*, 2015). According to the United Nations Development Programme (UNDP), climate change is expected to reduce crop yields in Africa by up to 30% by 2050. Africa is one of the continents in the world that has been severely affected by climate change, which presents with an increase in temperatures and

changing precipitation patterns that affect economic sectors such as energy and agriculture. Zambia is one of the countries in southern Africa whose agriculture sector has severely been hit by the effects of climate change such as rising temperatures and changing weather patterns resulting in drought, heatwaves, and flooding. The yearly drought, heatwaves and flooding, in Zambia, cause low crop yields, crop failures, crop pests, and plant diseases, among others. Zambia's economy is heavily dependent on agriculture, which employs over 70% of the population and contributes about 20% to the country's Gross Domestic Product (Nanyangwe and Tembo, 2024). We find that farmers located in areas where the cropping season's rainfall has been highly variable have 15 percent lower maize yields. Similarly, farmers located in areas where maximum temperatures during the growing season exceed 30 degrees Celsius have approximately 25 percent lower yields. Both rainfall variability and hotter temperatures are expected to increase under climate change, underlining the importance of policies to buffer food security from the estimated effects of climate change (FAO and of the United Nations, 2016).

2.4 Farmers' Perception of Climate Change Impact and Adaptation

Over the past few decades, various climate changes have been observed globally, such as atmospheric warming and shifts in precipitation patterns. The Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (2013) suggests that increasing temperatures and altered precipitation could significantly reduce rain-fed crop production in some African nations. Climate projections for southern African countries by 2050 indicate the region will face changing precipitation patterns, temperature increases of at least 1-2°C, and more frequent extreme weather events. Although different climate models consistently predict rising temperatures, they offer significantly different forecasts for rainfall. Despite these discrepancies, climate change is widely seen as a major challenge to agricultural development in the region. (Hachigonta *et al.* 2013). According to a study conducted by the Indaba Agricultural Policy Research Institute on the farmers' perception, it found that farmers in various locations of Zambia have reported a decrease in water levels in streams, rivers, lakes, and wells. It remains unclear whether this is a result of climate change, as even in areas where rainfall hasn't noticeably declined, farmers have observed lower water levels. They also noted that women, who are typically responsible for collecting water, now spend more time on this task. This was highlighted as the most significant gender-specific impact of climate in the discussions. Moreover, the reduction in water availability has implications for household food security, as it has become more difficult to maintain gardens during the dry season, which are crucial for food and dietary diversity (Cullingworth, 2015). Several other empirical studies have also identified a significant rise in temperature and humidity in Ethiopia over the years (Deressa *et al.*, 2008). Nhemachena and Hassan (2007) investigated farmers' perceived long-term increase in temperature and noted that the region was becoming drier, with altered timing of rains and more frequent droughts. Similarly, Maddison, (2006) conducted a survey across seven African countries, revealing that a significant number of farmers believe temperatures have already risen and precipitation has

decreased in these countries (Chalchisa and Sani, 2016). Therefore, farmers are concerned about their low production, food security, unpredicted weather patterns, and generally all impacts of climate change as this greatly affects their well-being.

2.5 Climate Change Adaptation Strategies

Adaptation can be defined as the adjustment in ecological, social or economic systems in response to observed or anticipated changes in climate stimuli and their effects and impacts in order to alleviate negative impacts of change or take advantage of new opportunities (Wo, no 2010). The Intergovernmental Panel on Climate Change (IPCC) defines human adaptation as "the process of adjusting to actual or expected climate variability and its effects to moderate harm or exploit beneficial opportunities" (Atube *et al.*, 2021) [6]. Adaptation can be viewed as reducing the severity of many impacts when adverse conditions prevail. In addition, adaptation reduces the level of damage that might have otherwise occurred. The success of adaptation depends critically on the availability of necessary resources, not only financial and natural resources, but also knowledge, technical capability, and institutional resources (Tazeze, Haji and Ketema, 2012). Climate change is a fact of life. Hence this research aims to evaluate the effectiveness of climate change adaptation strategies in enhancing resilience by smallholder farmers. Reduced severity and expense of climate change consequences are achieved by adaptation to the changing climate. Farmers that implement adaptation strategies can protect themselves from losses brought on by rising temperatures and falling precipitation caused by climate change (Tazeze, Haji and Ketema, 2012). However, because of variations in rainfall patterns and amounts, it was discovered that farmers' application of these strategies varied from one agroecological zone to the next. For instance, studies have indicated that the most important adaptation strategies in semi-arid, temperate, and humid agrological zones are deploying enhanced crop varieties and shifting the planting date. Others have replaced some crop species because they are more adapted to drier conditions. For example, sorghum and millet have replaced maize in certain parts of East Africa, according to research by Thornton *et al.* (2007).

3. Methodology

3.1 Research Design

This study adopted a descriptive and cross-sectional survey design utilizing a mixed-methods approach that integrates both quantitative and qualitative research techniques. The descriptive design was employed to systematically describe the existing climate change adaptation strategies and their effectiveness among smallholder farmers in Zambia. According to Kothari (2014), a descriptive design is suitable for studies that aim to present an accurate profile of events, persons, or situations as they naturally occur without manipulating variables. This design was therefore appropriate for identifying, documenting, and explaining the various sustainable agricultural practices and adaptation measures farmers have implemented in response to changing climatic conditions. The cross-sectional approach was chosen because data were collected from respondents at a single point in time. This method is widely used in social and environmental studies where researchers seek to capture current attitudes, behaviors, and practices without engaging

in long-term observation or experimental control (Creswell & Creswell, 2018). In this study, the cross-sectional survey made it possible to obtain a “snapshot” of farmers’ adaptation behaviors, perceptions, and socioeconomic characteristics within one agricultural season. It also provided an efficient means of comparing different adaptation strategies across diverse agro-ecological zones of Zambia. Furthermore, a mixed-methods approach was adopted to strengthen the validity and depth of the study. Quantitative data collected through structured questionnaires enabled statistical analysis of relationships between socioeconomic factors such as income, education, and farm size and adaptation behavior. Qualitative data, gathered through key informant interviews and focus group discussions, enriched this analysis by providing contextual explanations of the social, institutional, and environmental factors influencing adoption decisions. As Creswell and Plano Clark (2017) argue, the integration of qualitative and quantitative methods allows researchers to triangulate findings, thereby enhancing reliability and producing more comprehensive insights than either approach alone.

Additionally, the survey design was underpinned by the pragmatic philosophical paradigm, which prioritizes research questions and outcomes over rigid methodological boundaries. Pragmatism allows flexibility in data collection and analysis, accommodating both numerical measurement and interpretive exploration (Morgan, 2014). Within this paradigm, the researcher was able to evaluate the effectiveness of adaptation strategies not only through measurable indicators such as adoption rates and yield improvements but also through farmers lived experiences and perceptions of climate risk.

3.2 Study Area

The study was conducted in Kalomo District, located in Southern Province of Zambia. Kalomo lies approximately between 16° 15' S and 27° 00' E, about 350 km south of Lusaka, and is bordered by Choma to the north and Zimba to the south. Administratively, the district falls under Agro-Ecological Region IIa, characterized by moderate rainfall and a mixture of semi-arid to sub-humid climatic conditions (Ministry of Agriculture [MoA], 2022). The soils are predominantly sandy loams and loamy sands, derived from granite and quartzite parent material, which are moderately fertile but highly susceptible to erosion and nutrient leaching when exposed to intensive cultivation or heavy rainfall (Hachigonta *et al.*, 2013). These edaphic conditions make the district representative of broader challenges facing smallholder farmers across Southern Zambia, where declining soil fertility and recurrent droughts constrain productivity. Agriculture forms the backbone of the district’s economy, engaging more than 80 percent of the population (Central Statistical Office [CSO], 2020). The majority of farmers are smallholders cultivating 1–5 hectares of land under rain-fed conditions. The principal crops include maize, sorghum, groundnuts, cowpeas, and sunflower, complemented by livestock rearing (cattle, goats, and poultry) which provides both draught power and household income diversification. Cash crops such as tobacco and cotton are also grown on a smaller scale, depending on market access and input availability (Tembo *et al.*, 2024).

Kalomo District has experienced increasing climatic variability over the past two decades, manifested through

delayed onset of rains, early cessation, and frequent mid-season dry spells. These shifts have led to periodic crop failures and pasture shortages, thereby undermining household food security and income stability (Phiri *et al.*, 2025) [45]. (Muyabe *et al.*, 2025) [36]. Kalomo District was therefore purposively selected as the study site because it represents a typical smallholder farming environment highly vulnerable to climate change but also actively engaged in adaptation initiatives.

3.3 Target Population

The target population for this study comprised smallholder farmers in Kalomo District who are actively engaged in rain-fed agricultural production and depend primarily on farming as their main source of livelihood. These farmers typically cultivate between 0.5 and 5 hectares of land using family labor and limited mechanization, which aligns with the national classification of smallholder farmers in Zambia (Ministry of Agriculture [MoA], 2022). They were targeted because they represent the most vulnerable group to the adverse effects of climate change due to their high dependence on natural rainfall, low access to irrigation facilities, and limited adaptive capacity. As noted by Phiri *et al.* (2025) [45] and Tembo *et al.* (2024), smallholders in Southern Zambia face increasing production risks from recurrent droughts, erratic rainfall, and declining soil fertility, which necessitates the adoption of climate-smart agricultural (CSA) practices. The study population also included male- and female-headed households, reflecting the gendered dimensions of adaptation since women play significant roles in seed selection, soil conservation, and food production (Sichoongwe & Wang, 2023) [51].

3.3.1 Inclusion and Exclusion Criteria

To ensure that the study population accurately represented smallholder farmers actively involved in agricultural production and adaptation activities, clear inclusion and exclusion criteria were established prior to data collection. These criteria enhanced the reliability, validity, and consistency of the data gathered across the sampled communities in Kalomo District.

Inclusion Criteria

Participants were included in the study if they met the following conditions:

1. Smallholder farmers: Only farmers owning or cultivating between 0.5 and 5 hectares of land were eligible to participate, consistent with Zambia’s definition of a smallholder farmer (Ministry of Agriculture [MoA], 2022).
2. Residence in the study area: Farmers who had resided in Kalomo District for at least three consecutive years were included to ensure familiarity with local climatic conditions and farming practices (Phiri *et al.*, 2025) [45].
3. Engagement in rain-fed agriculture: Participants were required to be actively involved in rain-fed crop or mixed farming systems, since the study focused on the effects of climate variability on rain-dependent agriculture.
4. Experience with adaptation practices: Farmers who had adopted or attempted to adopt at least one climate change adaptation strategy (such as conservation agriculture, crop diversification, or drought-tolerant seed use) were included. This ensured that the study

captured informed perceptions on the effectiveness of adaptation strategies (Tembo *et al.*, 2024).

5. Willingness to participate: Only respondents who provided informed consent and voluntarily agreed to participate were included in the study.

Exclusion Criteria

Certain individuals were excluded from the study to maintain the focus and integrity of the data:

1. Commercial or large-scale farmers: Farmers operating more than 5 hectares of land or involved in fully mechanized commercial agriculture were excluded, as their adaptation strategies, capital resources, and risk profiles differ significantly from those of smallholders (Zamasiya *et al.*, 2017) [60].
2. New residents: Individuals who had lived in Kalomo for less than three years were excluded to avoid responses from participants with limited exposure to the district's climatic conditions and agricultural dynamics.
3. Non-agricultural residents: Households not engaged in any form of farming (e.g., traders, civil servants, or artisans) were excluded because they fall outside the target population.
4. Minors and dependents: Individuals below the age of 18 years were excluded, in compliance with ethical research standards on informed consent and capacity to participate (Creswell & Creswell, 2018).
5. Incomplete responses: Questionnaires with significant missing data or inconsistencies were excluded during data cleaning to preserve data accuracy and validity.

These inclusion and exclusion criteria ensured that the study focused specifically on experienced smallholder farmers who could provide reliable insights into local climate change adaptation practices, effectiveness, and constraints. The criteria also helped eliminate bias arising from participants with different socio-economic or institutional circumstances.

3.4 Sampling Procedure and Sample Size Determination

3.4.1 Sampling procedure

The study employed a multi-stage sampling procedure that combined both purposive and simple random sampling techniques to ensure representation across Kalomo District's major agricultural zones. According to Kothari (2014), multi-stage sampling is suitable for geographically dispersed populations where sampling proceeds through successive stages, each narrowing the unit of analysis. In the first stage, Kalomo District was purposively selected because it represents a typical smallholder farming area in Zambia's semi-arid region where climate variability has had significant effects on agriculture. The use of simple random sampling at the household level ensured that each smallholder farmer had an equal and independent chance of being included in the study, thereby minimizing selection bias (Creswell & Creswell, 2018; Saunders *et al.*, 2019).

3.4.2 Sample size determination

The sample size was determined using Yamane's (1967) formula, which provides a statistically sound method for calculating sample size from a known population with a specified precision level. The formula is expressed as:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = sample size

N = total population size

e = margin of error (assumed at 10% for this study)

According to records from the Ministry of Agriculture in Kalomo District (MoA, 2022), the number of active smallholder farming households in the selected agricultural blocks was approximately 550. Substituting into Yamane's formula:

$$n = \frac{550}{1 + 550(0.1)^2} = \frac{550}{1 + 5.5} = \frac{550}{6.5} = 84.6$$

Therefore, the computed sample size was approximately 85 respondents. However, due to logistical and resource constraints, a final sample of 72 smallholder farmers was used, which still met the minimum threshold for representativeness recommended by Israel (2013) and Krejcie and Morgan (1970) for populations under 1,000. This sample size was adequate for both descriptive and inferential statistical analysis since it allowed for variability in gender, age, education, and farm size among respondents. To complement household data, key informants including agricultural extension officers, local cooperative leaders, and representatives from NGOs were purposively selected based on their expertise and involvement in climate adaptation initiatives. This approach allowed the study to triangulate quantitative data from farmers with qualitative insights from institutional actors, enhancing the overall validity and depth of findings (Bryman, 2016; Creswell & Plano Clark, 2017).

3.5 Data Collection Methods

The study utilized both primary and secondary data collection methods to ensure a comprehensive and reliable understanding of the effectiveness of climate change adaptation strategies among smallholder farmers in Kalomo District. This mixed-methods approach was adopted to capture both the measurable aspects of adaptation behavior and the qualitative dimensions of farmers' perceptions and experiences (Creswell & Plano Clark, 2017).

3.5.1 Primary Data

Primary data were collected directly from respondents using structured questionnaires, key informant interviews, and focus group discussions (FGDs). The structured questionnaire served as the main instrument for collecting quantitative data from smallholder farmers. It comprised both closed- and open-ended questions divided into sections covering demographic characteristics, climate change awareness, adaptation strategies, and perceived effectiveness of these practices. The questionnaire was administered through face-to-face interviews, allowing enumerators to clarify questions and assist respondents with limited literacy, which increased response accuracy (Kothari, 2014). In addition to household surveys, key informant interviews (KIIs) were conducted with agricultural extension officers, cooperative leaders, and representatives of non-governmental organizations such as the Conservation Farming Unit (CFU) and World Vision Zambia. These informants provided expert insights on the institutional, technical, and policy frameworks influencing climate

change adaptation in Kalomo District (FAO, 2023). Focus group discussions were also held with selected farmers to capture group perspectives, community-level challenges, and shared experiences on adaptation. Each FGD consisted of 6–10 participants and was guided by a semi-structured discussion outline to encourage participation and thematic exploration (Bryman, 2016).

3.5.2 Secondary Data

Secondary data were obtained from existing reports, scholarly articles, and institutional publications to complement the primary findings. These included data from the Ministry of Agriculture, Zambia Meteorological Department (ZMD), and Food and Agriculture Organization (FAO), as well as recent academic studies on climate-smart agriculture and rural adaptation in Zambia. These documents provided contextual information on climate patterns, national adaptation policies, and agricultural performance in Southern Province (Hachigonta *et al.*, 2013; MoA, 2022). Reviewing secondary sources ensured a broader understanding of climate trends and policy interventions while enabling comparison with local findings.

3.6 Data Analysis

Data analysis involved the use of both quantitative and qualitative analytical techniques consistent with the mixed-methods design of the study. Quantitative data collected through structured questionnaires were first coded, cleaned, and entered into the Statistical Package for the Social Sciences (SPSS) version 26 and Microsoft Excel for statistical computation and visualization. Descriptive statistics such as frequencies, percentages, means, and standard deviations were employed to summarize respondents' socio-demographic characteristics, types of adaptation strategies adopted, and levels of perceived effectiveness (Kothari, 2014; Saunders, Lewis, & Thornhill, 2019). These measures provided a clear overview of patterns and distributions within the sample. Inferential statistical techniques including correlation analyses were used to examine the relationships between farmers' socioeconomic factors (e.g., income, education, farm size, and gender) and the adoption of climate-smart agricultural practices. Such tests helped determine whether the observed associations were statistically significant, thereby providing empirical evidence to support or reject the study hypotheses (Creswell & Creswell, 2018). Qualitative data from key informant interviews and focus group discussions (FGDs) were analyzed using thematic analysis, which entailed transcription, categorization, and interpretation of recurring ideas and perceptions. Themes such as perceived climate risks, barriers to adaptation, institutional support, and gender roles were identified and triangulated with quantitative findings to enrich the interpretation (Braun & Clarke, 2019; Creswell & Plano Clark, 2017). This integration of numerical and narrative evidence allowed for a comprehensive understanding of farmers' adaptive behaviors, motivations, and constraints. Data triangulation enhanced the validity and reliability of the results by cross-checking consistency across different sources and methods (Bryman, 2016). Findings were presented through tables, graphs, and charts, accompanied by detailed narrative explanations linking results to the research objectives and literature. The analytical process ultimately provided insights into the effectiveness of current adaptation strategies, the influence of socioeconomic determinants, and

farmers' perceptions of climate-smart practices, thereby forming the empirical foundation for the discussion and policy recommendations in later chapters.

3.7 Reliability and Validity

To ensure reliability, the study emphasized consistency in both the design and implementation of data collection tools. The questionnaire was pre-tested with ten smallholder farmers in a non-sampled agricultural camp within Kalomo District to identify and correct unclear or ambiguous questions. This pilot testing enhanced the instrument's internal consistency and improved the clarity of the questions (Kothari, 2014). Data collectors were trained and given standardized instructions to ensure uniform administration across all sites, thereby reducing interviewer bias. Using identical procedures in all selected areas strengthened the reproducibility and dependability of the responses (Saunders, Lewis, & Thornhill, 2019). Validity was maintained through expert review, triangulation, and cross-verification of responses. Content validity was ensured by having the instruments reviewed by academic supervisors and agricultural experts to confirm alignment with research objectives (Creswell & Creswell, 2018). Triangulation of data from questionnaires, key informant interviews, and focus group discussions improved both construct and internal validity by allowing cross-checking of findings from multiple sources (Creswell & Plano Clark, 2017). Additional data cleaning and consistency checks further improved credibility. Collectively, these measures enhanced the accuracy, rigor, and trustworthiness of the study's findings on climate change adaptation among smallholder farmers in Kalomo District.

4. Results

This chapter presents the results of the study based on data collected from a sample of seventy-two (72) smallholder farmers, with the findings organized to capture key dimensions of climate change adaptation. It begins by outlining the demographic characteristics of respondents such as age, gender, education level, household size, and farming experience which provide important context for interpreting adaptation behavior. The chapter then evaluates the effectiveness of current adaptation strategies, including the use of drought-tolerant and early-maturing crop varieties, crop diversification, and alternative income sources, highlighting both their strengths and limitations in building resilience. Socioeconomic determinants such as access to credit, extension services, farm size, and market opportunities are examined to understand how they shape farmers' adaptive capacity and decision-making. In addition, farmers' perceptions of climate change and its impacts are analyzed, offering insights into their awareness, attitudes, and willingness to adopt new practices. The chapter concludes by identifying the major adaptation strategies adopted by smallholder farmers and recommending sustainable practices to enhance agricultural resilience in the face of climate variability.

4.1 Demographic Distribution of Respondents

A total of 72 small-scale farmers participated in the study. The demographic characteristics of respondents are summarized in the figures below, showing gender, age groups, education levels, and farm sizes.

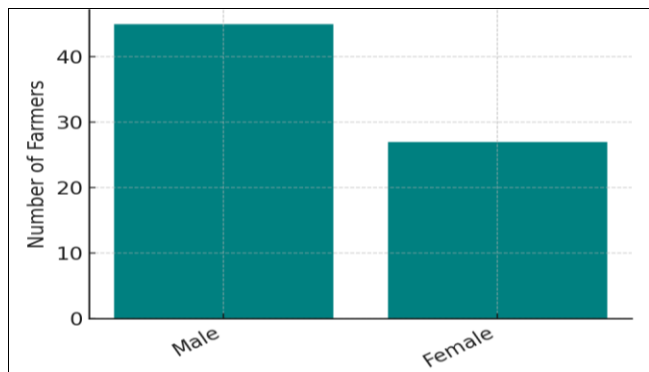


Fig 1: Distribution of the respondents by Gender

The study participants were composed of 45 males (62.5%) and 27 females (37.5%) shown in figure 1. This indicates that men dominate small-scale farming in the study area. This may reflect traditional land ownership patterns and decision-making structures where men are often recognized as the primary farmers. However, the substantial proportion of women highlights their important role in agricultural production, often as contributors to food security through subsistence farming and household crop management. Gender-inclusive adaptation strategies will therefore be essential to ensure equitable benefits.

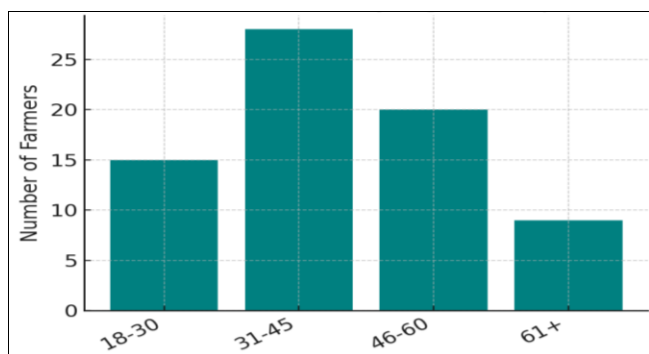


Fig 2: Distribution of respondents by Age

The majority of farmers were between 31–45 years (38.9%), followed by 46–60 years (27.8%), while younger farmers aged 18–30 years (20.8%) and older farmers above 60 years (12.5%) were fewer. This suggests that most farmers are in their economically active and productive years, which is advantageous for adaptation as they can provide labor and are more open to adopting new technologies. The lower proportion of youth may point to migration to urban areas or disinterest in farming, which raises concerns about the long-term sustainability of agricultural labor.

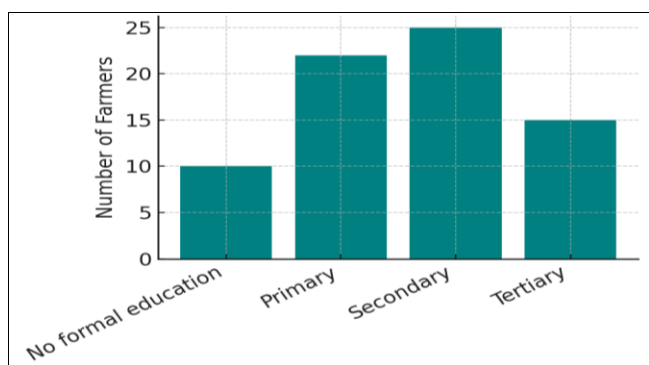


Fig 3: Distribution of Respondents by Education Level

Most respondents had attained at least some formal education: Primary (30.6%), Secondary (34.7%), and Tertiary (20.8%), while 13.9% had no formal education. Education is a critical factor in adaptation, as better-educated farmers are more likely to understand climate information, evaluate risks, and adopt Climate Smart Agriculture (CSA) practices. The findings suggest that with targeted training and extension support, adoption rates could be significantly enhanced across all education groups, though special attention should be given to illiterate farmers to ensure inclusivity.

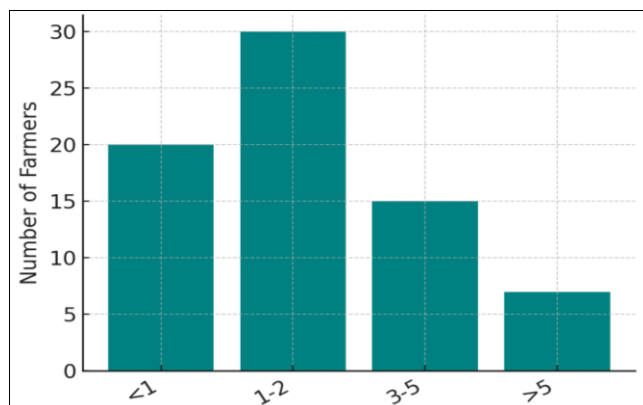


Fig 4: Distribution of Respondents by Farm Size (ha)

The majority of farmers cultivated 1–2 hectares (41.7%), while 27.8% farmed less than 1 hectare. A smaller group cultivated 3–5 hectares (20.8%), and only 9.7% had more than 5 hectares. This distribution shows that most respondents are smallholders with limited land resources, which constrains economies of scale and productivity. Farmers with very small landholdings may struggle to diversify crops or adopt labor- and resource-intensive practices like agroforestry and irrigation. This underscores the importance of promoting low-cost, land-efficient strategies such as drought-tolerant seeds, intercropping, and soil moisture conservation.

4.2 Effectiveness of the current adaptation strategies in enhancing agricultural resilience

Table 1: Effectiveness of current of current adaption strategies

Adaptation Strategy	Adoption Rate (%)
Drought-tolerant crop varieties	49
Early-maturing crops	68
Crop diversification	37
Household income diversification	20

The results in Table 1 revealed that early-maturing crops (68%) and drought-tolerant varieties (49%) were the most effective strategies in stabilizing yields and minimizing the risk of total crop failure during erratic rainfall seasons. Other practices such as crop diversification (37%) and intercropping also played a significant role in enhancing household food security by spreading production risks across multiple crops. In addition, conservation agriculture was widely perceived as effective in improving soil fertility, conserving moisture, and ensuring yield stability over time. Although less commonly practiced, household income diversification (20%) proved valuable for adopters by cushioning against agricultural income losses, particularly

during drought years. The patterns of effectiveness indicate that strategies with visible short-term benefits, such as early-maturing crops and drought-tolerant varieties, had higher adoption rates, while those with long-term but labor-intensive benefits, such as agroforestry and conservation tillage, were adopted less frequently due to the delayed realization of benefits. Notably, farmers who combined multiple strategies achieved higher levels of resilience compared to those who depended on a single approach.

Early-Maturing and Drought-Tolerant Varieties

The adoption of early-maturing and drought-tolerant crop varieties has proven highly effective in stabilizing crop yields under erratic rainfall and high-temperature stress. This study's results showing adoption rates of 68% for early-maturing and 49% for drought-tolerant varieties indicate that these strategies are well-accepted by smallholder farmers seeking immediate resilience benefits. According to Liu *et al.* (2024) [29], variety improvement and genetic enhancement are key pathways for agricultural adaptation. Breeding crops for drought tolerance, pest resistance, and heat resilience directly enhances yield stability and food security. Similarly, Mereu *et al.* (2018) [34] found that hybrid and stress-resistant varieties significantly reduced production losses under fluctuating rainfall in semi-arid India, illustrating cross-regional effectiveness. Locally, Phiri *et al.* (2025) [45] and Tembo *et al.* (2025) [55] confirmed that Zambian smallholders using improved maize and sorghum varieties achieved yield increases of up to 25% and reduced risk of total crop failure. These findings affirm that seed-based adaptation is highly effective in short-term resilience due to rapid and visible benefits. However, long-term effectiveness requires consistent seed system support, farmer training, and soil fertility management to prevent yield stagnation over time (Hapeza & Kelvin Chibomba, 2025; Neubert *et al.*, 2011 [37]; Pattanaik *et al.*, 2025a) [18, 37, 42].

Conservation Agriculture (CA)

Conservation Agriculture incorporating minimum tillage, crop rotation, and residue retention has demonstrated substantial resilience benefits in Zambia. Empirical evidence from this study and Phiri *et al.* (2025) [45] shows that CA increased maize yields by 24–39% while improving soil moisture and reducing erosion. Muyabe *et al.* (2025) [36] found that CA is particularly effective during drought years when rainfall deficits are severe. Globally, Karri & Nalluri (2024) [24] observed that no-till systems and soil carbon recarbonization under climate-smart agriculture significantly enhanced soil structure, nutrient cycling, and water-holding capacity. Similarly, El Chami *et al.* (2022) [14] emphasized CA's high cost-effectiveness, ranking it among the top practices for climate-resilient farming in the Middle East and North Africa. However, CA's widespread effectiveness in Zambia is constrained by labor intensity, equipment costs, and knowledge gaps. Farmers without access to extension services or mechanization often revert to conventional plowing. Hence, CA remains a medium-term effective strategy, with success depending on sustained institutional support and farmer incentives.

Agroforestry and Ecosystem-Based Adaptation

Agroforestry is one of the most effective long-term resilience strategies due to its contribution to ecosystem

restoration, soil enrichment, and microclimate regulation. In Zambia, farmers integrating leguminous trees such as *Faidherbia albida* and *Gliricidia sepium* reported improved soil fertility and reduced fertilizer dependency. Muyabe *et al.* (2025) [36] and Chisengele & Nyanga (2025) [11] confirmed that agroforestry improves both ecological and livelihood resilience, providing diversified income through fuelwood and fruit sales. At the global level, Antwi-Agyei & Stringer (2021) [4] identify tree-based systems as vital components of climate-smart agriculture, enhancing carbon sequestration and soil organic matter. Liu *et al.* (2024) [29] similarly note that integrating perennial vegetation into croplands improves soil water retention, biodiversity, and nutrient cycling, creating self-sustaining resilience systems. Despite its proven long-term effectiveness, adoption is limited by land tenure insecurity and delayed economic returns. Hence, agroforestry effectiveness increases where governments provide seedlings, technical guidance, and land tenure reforms to support tree planting (Hussein, 2024; Rosenzweig & Tubiello, 2007) [20, 47].

Crop and Income Diversification: Multi-Dimensional Risk Reduction

Crop diversification (37%) and household income diversification (20%) emerged as complementary adaptation pathways. They reduce climate and market risks by spreading production and income sources. Neubert *et al.* (2011) [37] found that diversified farming systems in Southern Zambia reduced the impact of drought on household food availability by over 30%. In Ethiopia, Karri and Nalluri (2023) reported that diversification combined with efficient water and nutrient management improved overall resilience and resource-use efficiency. Meena & Rahaman (2025) [33] further observed that livelihood diversification through value addition, small-scale enterprises, and livestock integration increases adaptive capacity and reduces vulnerability to income shocks. In Zambia, however, effectiveness remains moderate due to poor market access, limited agro-processing infrastructure, and financial exclusion. For diversification to achieve full potential, there is a need for rural enterprise support, market linkages, and climate-informed value chain development.

Soil and Water Management

Soil fertility and water management practices remain the foundation of resilience, as they sustain productivity across climate extremes. In this study, farmers practicing organic manure application, mulching, and contour bunding experienced higher yields and improved water retention. Kumar *et al.* (2019) [25] emphasize that soil protection and improvement are indispensable for maintaining soil structure, water retention capacity, and fertility, while Guja & Bedeke (2025) [16] underscore that water management through efficient irrigation systems, reservoirs, and drainage is crucial to address uneven rainfall. Al Mamun *et al.* (2024) [2] further illustrated that integrated soil-water management systems in India led to yield increases of up to 40%, even under water-stressed conditions. The similarity of these findings across regions indicates that soil and water management offer high effectiveness in both short- and long-term resilience if adequately scaled.

4.3 Socioeconomic factors determinants of farmer's adaptation to climate change impact

Table 2: Socioeconomic Determinants of Adaptation

Determinant	Influence on Adoption
Household Income	High
Education Level	High
Farm Size	Moderate
Access to Credit	High
Gender	Moderate

The results of this study reveal that farmers' adoption of climate change adaptation strategies is determined by a combination of socioeconomic, demographic, and institutional factors. The key determinants identified include household income, education level, farm size, access to credit, and gender. Each of these variables plays a distinct yet interconnected role in shaping how farmers perceive risks, access resources, and implement adaptation measures. The findings are consistent with regional and global literature, confirming that adoption decisions are context-specific and influenced by both internal household characteristics and external enabling environments.

Household Income

Household income demonstrated a high and positive influence on the adoption of climate-smart and adaptive farming practices. Farmers with higher incomes were found to adopt strategies such as conservation agriculture, agroforestry, irrigation, and improved crop varieties more readily than those with lower incomes. This finding mirrors the results of Kuntashula *et al.* (2015) [27], who established that wealthier Zambian farmers were 10.6% more likely to adopt crop rotation, 9.5% more likely to practice minimum tillage, and 7.1% more likely to use fertilizer trees compared to their poorer counterparts (Kuntashula *et al.*, 2015) [27]. Similarly, Petros *et al.* (2025) [44] found that income levels and livestock ownership were significant predictors of climate-smart agriculture (CSA) adoption in Nyimba District, leading to a 20.2% increase in total crop yields among adopters compared to non-adopters. Higher household income enhances adaptive capacity by enabling farmers to invest in new technologies, purchase drought-tolerant seeds, and hire labor for labor-intensive practices such as conservation tillage and agroforestry (Zamasiya *et al.*, 2017) [60]. In contrast, low-income farmers tend to rely on traditional practices and risk-averse behavior, adopting only low-cost or short-term measures. This income-based disparity reflects a common pattern in sub-Saharan Africa, where liquidity constraints and poverty limit innovation adoption (Adeagbo *et al.*, 2021; Atube *et al.*, 2021) [1, 6]. It therefore underscores the importance of economic empowerment and livelihood diversification in strengthening farmers' resilience to climate shocks.

Education Level

Education level was also found to exert a strong positive influence on adoption behavior. Educated farmers were more likely to recognize long-term climate risks, comprehend extension advice, and evaluate the costs and benefits of adaptation options. This finding is consistent with the results of Gebru *et al.* (2020) [15], who reported that in Ethiopia, education and membership in cooperatives significantly increased the adoption of soil and water

conservation, improved seed varieties, and irrigation practices. Similarly, Sichoongwe & Jinxia Wang, (2023) [51] found that education and awareness were key enablers of adaptation to climate extremes among smallholder farmers in Southern Zambia. Education enhances farmers' access to information, their ability to interpret seasonal forecasts, and their confidence to experiment with new techniques. In Zambia, Petros *et al.* (2025) [44] also found that education level significantly affected CSA adoption, implying that literacy empowers farmers to engage effectively with agricultural extension and climate information services. Furthermore, Zamasiya *et al.* (2017) [60] noted that education improves behavioral intention and positive attitudes toward adaptation, especially when supported by extension programs. The implication is that education acts as a "gateway variable": it enhances both awareness and capability. Therefore, increasing farmers' education whether formal or through adult training and participatory extension should be a policy priority in Zambia and similar contexts.

Farm Size

Farm size showed a moderate influence on adaptation adoption. Larger farms generally provide greater opportunities for diversification, experimentation, and risk management. In Nyimba District, Petros *et al.* (2025) [44] reported that farmland size was one of the critical variables influencing adoption of CSA practices alongside household income and fertilizer use. In Uganda, Atube *et al.* (2021) [6] found that land size significantly influenced adoption of crop diversification and planting of different crop varieties. However, the relationship between land size and adoption is not always linear. Smallholder farmers, particularly those operating on less than two hectares, may adopt intensification strategies such as early-maturing crops, mulching, or conservation tillage, which optimize productivity on limited land (Adeagbo *et al.*, 2021; Tesfaye *et al.*, 2016) [1, 57]. Conversely, very large landholders might adopt fewer intensive measures if they prioritize extensive land use. This diversity indicates that land availability interacts with labor, capital, and technology access to determine specific adaptation choices. Farm size also reflects wealth and social status, which often correlate with access to credit, mechanization, and extension services. Therefore, programs promoting adaptation should recognize that both small- and medium-scale farmers require differentiated support mechanisms for example, subsidies and micro-irrigation for smallholders, and conservation training and mechanization incentives for larger farms.

Access to Credit

Access to credit emerged as a critical enabling factor influencing adoption across nearly all reviewed studies. Farmers with credit access were more likely to implement high-investment strategies such as irrigation, agroforestry, or fertilizer use. Credit mitigates liquidity constraints and allows farmers to cope with climate variability by investing in adaptive technologies and diversification. The findings of Atube *et al.* (2021) [6] showed that credit access, combined with farm income, strongly predicted adoption of drought-resistant varieties, tree planting, and fertilizer use in Uganda. Likewise, Adeagbo *et al.* (2021) [1] in Nigeria found that access to credit and extension visits significantly increased both the probability and intensity of adaptation among smallholder maize farmers. In Zambia, Nhuong *et al.* (2025)

[40] observed that resource-endowed households, who often have better access to credit, exhibited higher adoption rates of fertilizer trees and conservation farming. Access to financial capital thus represents one of the most powerful levers for scaling climate-smart technologies. However, most smallholders in Zambia remain excluded from formal credit systems due to lack of collateral, high interest rates, and limited financial literacy (Kuntashula *et al.*, 2015; Petros *et al.*, 2025; Sichoongwe & Jinxia Wang, 2023) [27, 44, 51]. To address this, policy interventions could strengthen microfinance institutions, farmer cooperatives, and village savings and loan associations as viable channels for rural financial inclusion. Moreover, integrating credit with agricultural extension for example, through climate insurance or input loans could amplify the impact on adaptive behavior.

Gender

Gender differences exerted a moderate but context-dependent influence on adoption decisions. Male farmers were generally more likely to adopt climate-smart practices due to greater access to land, credit, and extension services, while female farmers often faced systemic barriers. Petros *et al.* (2025) [44] found gender to be among the key demographic factors affecting CSA adoption in Nyimba District. Similarly, Gebru *et al.* (2020) [15] in Ethiopia observed that gender, along with limited access to credit and information, constrained women's adoption of soil and water conservation and irrigation practices. Nonetheless, Zamasiya *et al.* (2017) [60] emphasized that gender gaps are not purely biological but institutional rooted in land tenure systems, cultural norms, and labor burdens that restrict women's participation in adaptation decisions. Evidence from Dang *et al.* (2019) [12] also supports the argument that when women gain equal access to resources, their adoption levels often equal or exceed those of men. Thus, gender mainstreaming should be integral to climate-smart agriculture programs. Women-focused extension services, capacity building, and access to group credit schemes can significantly bridge the adaptation gap. In Zambia's context, empowering women farmers through cooperatives and decentralized training could improve community-level resilience and sustainability.

Table 3: Farmers' Perceptions of Adaptation Strategies

Strategy	Perception
Conservation Agriculture	Positive
Early-maturing Crops	Positive
Agroforestry	Mixed (Labor-intensive)
Conservation Tillage	Mixed (Slow benefits)

4.4 Farmer's perception to climate change adaptation strategies

Farmers' perception of climate change adaptation strategies reflects their understanding, experience, and evaluation of the practicality and benefits of different interventions. The study results indicate that most farmers have positive perceptions of Conservation Agriculture and Early-Maturing Crops, while their views on Agroforestry and Conservation Tillage were mixed. This pattern suggests that farmers value strategies offering visible short-term benefits and manageable labor requirements, whereas those requiring sustained effort or delayed returns are perceived with caution. These findings are consistent with those of Asrat &

Simane (2018) [5] in Ethiopia, Mafongoya P (2015) [30] in Zimbabwe, and Habibu *et al.* (2017) [17] in Southern Zambia, who all found that perception is a precursor to adoption, but its strength depends on the balance between effort, cost, and time to benefit.

Perception of Conservation Agriculture

The majority of farmers in this study expressed a strongly positive perception of Conservation Agriculture (CA), recognizing it as one of the most practical and effective climate adaptation strategies available to smallholders. Farmers emphasized that CA helped them conserve soil moisture, improve soil fertility, and maintain stable yields even under erratic rainfall patterns. Their appreciation was grounded in personal observation and experience those who had practiced CA over multiple seasons noted visibly reduced surface runoff, enhanced soil tilth, and improved drought tolerance compared to fields managed under conventional plowing systems. Many reported that CA plots retained more moisture during dry spells, allowing crops to survive mild droughts that devastated conventionally tilled fields. These findings are consistent with the empirical evidence reported by Phiri *et al.* (2025) [45] and Muyabe *et al.* (2025) [36], who demonstrated that CA practices such as minimum tillage, residue retention, and crop rotation increased maize yields by 24–39% in Zambia's semi-arid agro-ecological regions, particularly in Southern and Central Provinces. The authors attributed these yield gains to enhanced infiltration, soil carbon accumulation, and reduced evapotranspiration losses. Likewise, Mafongoya P (2015) [30] in Zimbabwe found that smallholder farmers viewed CA as a "climate-smart" agricultural practice, describing it as both an ecologically friendly and economically efficient approach that reduced their vulnerability to drought while lowering dependence on external inputs such as fertilizers and fuel.

Furthermore, the positive perception among farmers reflects an increasing awareness of the long-term environmental benefits of CA, which aligns with regional and global climate-smart agriculture objectives. As Karri & Nalluri (2024) [24] and Liu *et al.* (2024) [29] argue, farmers' acceptance of CA signifies growing recognition of the link between soil health and climate resilience an important shift from short-term yield orientation toward sustainability thinking. Farmers in this study frequently mentioned that CA "keeps the land alive" and "protects the soil for future generations," indicating that local awareness extends beyond immediate productivity concerns to encompass intergenerational stewardship. However, despite this positive outlook, the study also revealed several practical constraints that temper full-scale adoption. A significant number of farmers identified CA as labor-intensive during initial land preparation, especially when using hand hoes for minimum tillage and weed control. Similar challenges were reported by Asrat & Simane (2018) [5], who found that even when farmers in Ethiopia perceived CA as beneficial, they were deterred by resource limitations, lack of equipment, and insufficient technical support. The management of crop residues essential for soil cover was another area of concern. Many farmers noted that residues are often used as livestock feed, leaving insufficient mulch for CA fields. These challenges demonstrate that perception alone, though positive, does not automatically translate into consistent practice unless complemented by appropriate technology

and institutional support. Additionally, gender and socioeconomic differences influenced perceptions. Male-headed and relatively wealthier households were more likely to perceive CA as a practical and profitable approach due to easier access to tools, labor, and extension training. Conversely, women farmers and those with limited capital reported difficulties implementing residue management and weed control, highlighting the need for inclusive extension models that consider labor-saving innovations and gender dynamics. Sani & Chalchisa (2016) [48] underscored that farmers' trust in local institutions and access to credible technical advice significantly shape their perception of CA's reliability and feasibility.

The temporal dimension of perception is also important. While the majority recognized CA's long-term benefits, a few farmers expressed impatience with the slow visible improvements in soil structure and yield stability, especially during the first one or two seasons. As Phiri *et al.* (2025) [45] and Singh (2020) [53] observed, CA outcomes often compound gradually over time, requiring sustained commitment before benefits fully materialize. This temporal lag may explain why initial enthusiasm sometimes wanes in the absence of immediate yield improvements or continuous support. Nevertheless, the overall sentiment remains overwhelmingly favorable. Farmers' narratives portrayed CA as a "reliable and science-backed strategy" that aligns with their lived realities of climate stress. Its visible outcomes healthier soils, reduced erosion, and steady yields have reinforced their belief in CA as a cornerstone of climate-resilient farming. The widespread approval captured in this study, corroborated by Mafongoya P (2015) [30] and Muyabe *et al.* (2025) [36], confirms that CA is not only perceived as a technical innovation but also as a symbol of adaptive self-reliance in the face of climate uncertainty. Importantly, this positive perception provides a strong foundation for policy and programmatic scaling. To sustain and expand adoption, interventions must focus on addressing the perceived barriers through mechanization support, residue management training, and continuous extension follow-up. Integrating CA into climate-smart village models and farmer field schools can reinforce experiential learning, which farmers in this study described as "seeing to believe." Such participatory approaches can transform perception into sustained behavioral change.

Perception of Early-Maturing Crops

Farmers in this study demonstrated a strongly positive perception of early-maturing crop varieties, recognizing them as among the most practical, reliable, and low-risk adaptation strategies in the face of increased rainfall variability. Participants emphasized that the use of early-maturing maize, sorghum, and groundnut varieties allowed them to harvest before the end of the shortened rainy season, thereby reducing the likelihood of total crop failure during mid-season dry spells. They regarded these varieties as a "timely shield" against the unpredictability of climate change particularly erratic rainfall onset and early termination of the wet season. Many respondents explained that conventional long-season varieties often fail to reach maturity under current climatic conditions, leading to significant yield losses, while early-maturing crops "fit the new climate reality." This perception reflects a form of experiential adaptation, where farmers continuously refine their crop choices based on observed climate trends.

Farmers also appreciated that early-maturing varieties provide an opportunity for sequential planting allowing them to plant vegetables or legumes after harvesting the early crops, which enhances household food security and income diversification. The strong positive perception observed in this study corroborates the findings of Phiri *et al.* (2025) [45] and Tembo *et al.* (2025) [55], who documented that Zambian smallholders using early-maturing maize and legume varieties experienced yield stability improvements of 20–25% under shortened rainy seasons. These studies attribute such success to the varieties' short phenological cycles and enhanced drought tolerance, which allow farmers to cope with both late rainfall onset and early cessation. Similarly, Dhaka *et al.* (2010) [13] in India and Asrat & Simane (2018) [5] in Ethiopia reported that early-maturing and drought-tolerant seeds were the most trusted and widely adopted adaptation measures because they provided visible benefits within a single agricultural season, unlike soil-management or tree-based strategies that require years of investment. These findings highlight that farmers' positive perception is closely linked to immediacy of benefit. In contrast to labor-intensive conservation or agroforestry practices, early-maturing crops provide rapid, measurable, and low-cost results, reinforcing the notion that perception strength increases with the speed and visibility of outcomes. Farmers described these varieties as "climate-smart seeds" because they directly translate awareness of climate risks into practical, results-oriented actions.

Accessibility has also played a key role in shaping these positive perceptions. Farmers reported that early-maturing seed varieties are often made available through government input-support programs, NGOs, and research institutions such as the Zambia Agricultural Research Institute (ZARI). Such programs have reduced barriers to adoption, allowing even resource-poor households to experiment with new seed types. This resonates with the observations of Nyambe (2024) [41], who found that awareness campaigns, field demonstrations, and seed-fair exhibitions significantly increased farmers' confidence and trust in early-maturing varieties in several districts of Zambia. Demonstration plots, in particular, serve as experiential learning platforms, where farmers can witness yield differences firsthand an approach that strengthens both awareness and positive perception. Farmers' perception was also influenced by risk aversion and livelihood stability. Many respondents explained that they preferred early-maturing crops because they minimize exposure to climate risks and ensure at least some level of harvest even in poor rainfall years. In line with this, Mertz *et al.* (2009) [35] and Zeleke *et al.* (2023) [61] both observed that risk-averse farmers are more likely to favor short-cycle and stress-tolerant crops because they provide security against climatic uncertainty. This adaptive preference is particularly relevant in Zambia's Agro-ecological regions I and II, where annual rainfall has become increasingly erratic. The perception that early-maturing crops "guarantee something" even in drought-affected seasons indicates that farmers prioritize resilience and reliability over maximum yield potential.

Furthermore, gender and household dynamics appear to influence this perception. Women farmers, who often manage smaller plots for household food production, expressed particularly strong approval for early-maturing groundnut and cowpea varieties because they enable quicker household food supply and reduced labor demand. This

observation is consistent with Phiri *et al.* (2025) [45], who noted that female farmers in Zambia favored early-maturing legumes for both nutritional and economic reasons, enhancing household resilience through diversified diets and income sources. While perceptions were overwhelmingly positive, a few concerns were raised regarding seed affordability and long-term sustainability. Some farmers reported challenges in accessing certified seed after donor projects ended, leading them to recycle seeds that gradually lost vigor. Kahsay *et al.* (2019) [22] and Mafongoya P (2015) [30] warned that the benefits of early-maturing varieties may decline if supply chains and extension systems are not institutionalized to ensure continuous access and training. Nevertheless, these concerns did not significantly diminish farmers' enthusiasm for the technology; rather, they highlight the need for sustained institutional support to preserve the positive momentum of adoption. Overall, the strong positive perception of early-maturing crops reflects farmers' rational assessment of cost-effectiveness, reliability, and climate compatibility. The varieties offer an adaptive match between farmers' limited resources and the pressing need to manage weather variability. They embody a form of "no-regret adaptation" low-cost, widely acceptable, and immediately beneficial. As Asrat & Simane (2018) [5] and Nyambe (2024) [41] argue, such perceptions are pivotal for driving the diffusion of climate-smart innovations, as they link awareness of climate change directly with adaptive action.

Perception of Agroforestry (Mixed – Labor-Intensive)

Farmers' perception of agroforestry in this study was mixed, revealing both strong appreciation for its long-term ecological and livelihood benefits and frustration over its labor demands and delayed economic returns. Most farmers acknowledged that integrating trees with crops contributes to soil fertility improvement, microclimate regulation, erosion control, and livelihood diversification through fruit, timber, and fodder. Many respondents described agroforestry as "a good practice for the future" or "a way of protecting the land for our children," indicating awareness of its sustainability potential. However, a substantial number also regarded it as labor-intensive, requiring careful management, and yielding slow, long-term benefits that may not align with their short-term livelihood needs. This duality of perception seeing agroforestry as valuable yet burdensome is consistent with research across Africa. In Southern Zambia, Habibu *et al.* (2017) [17] reported that smallholder farmers valued *Faidherbia albida* and *Gliricidia sepium* for their ability to fix nitrogen, improve soil quality, and sustain yields, especially in degraded fields. Yet, adoption was limited by land tenure insecurity, competition between crops and trees, and delayed economic returns from timber or fruit harvests. Farmers often feared that planting trees might later create conflicts over land ownership or use, particularly in customary tenure systems where land rights are informally inherited. This insecurity discouraged long-term investments such as tree planting. Similarly, Kahsay *et al.* (2019) [22] found that although Ethiopian farmers perceived agroforestry as ecologically beneficial, its widespread adoption was constrained by limited technical support, lack of quality seedlings, and insufficient extension guidance on species selection and spacing. These structural limitations mirror the Zambian context, where inadequate extension coverage and weak

nursery systems limit farmers' ability to sustain agroforestry beyond pilot projects. From an environmental perception perspective, farmers recognized that trees act as "natural fertilizers" and "protectors of the soil." Many described observable benefits such as leaf litter improving soil fertility and trees retaining moisture during dry spells. Yet, they also expressed concern that trees compete with crops for sunlight and water if not properly spaced. This ambivalence valuing ecological gains but worrying about agronomic trade-offs captures the practical challenges smallholders face when balancing environmental stewardship with food production. In terms of labor and time, farmers consistently mentioned that agroforestry requires "patience and extra effort." Tree establishment involves digging pits, watering seedlings, pruning, and protection from livestock, tasks that many found time-consuming given existing labor shortages. These sentiments echo Muyabe *et al.* (2025) [36], who noted that even when farmers in Eastern Zambia understand the benefits of agroforestry, the delayed financial returns and initial labor costs discourage large-scale adoption. The economic rationality behind these perceptions is clear: in resource-constrained households where daily survival depends on annual harvests, long-gestation investments like trees are often viewed as secondary priorities. Social factors also shape perception. Amadou *et al.* (2022) [3] emphasized that trust in extension officers, peer influence, and collective participation play decisive roles in farmers' acceptance of long-term practices like agroforestry. Farmers who saw neighbors succeed with *Faidherbia albida* or fruit trees were more likely to describe the practice as "worth the wait." Conversely, in areas where projects were short-lived or lacked follow-up support, farmers viewed agroforestry as "another donor activity that ends." This underscores the importance of continuity and community-based learning in shaping lasting positive perceptions. At a broader conceptual level, Karri & Nalluri (2024) [24] highlight that agroforestry embodies ecosystem-based adaptation a nature-based solution that strengthens soil health, biodiversity, and carbon sequestration while supporting livelihoods. The farmers' mixed perceptions therefore reveal not a rejection of agroforestry's principles but a pragmatic response to implementation constraints. They see it as valuable for resilience and ecological regeneration, but not immediately profitable or feasible without external support. A few farmers in this study noted that agroforestry's benefits are "for the next generation," reflecting intergenerational awareness and cultural stewardship values. However, short-term economic pressures, such as food insecurity and cash needs, often override these long-term motives. This echoes Asrat & Simane (2018) [5], who concluded that farmers' willingness to adopt long-term strategies like agroforestry depends heavily on institutional incentives such as access to credit, seedlings, and market linkages for tree products. Despite the constraints, the underlying perception remains cautiously optimistic. Farmers view agroforestry as a sound practice that aligns with sustainable land management goals and climate resilience but one that requires stronger institutional, technical, and financial support. They suggested that government and NGOs could enhance its appeal through seedling subsidies, farmer training on tree-crop integration, and community-based nurseries to ease seedling access. Demonstration plots showing short-term benefits such as using fast-growing nitrogen-fixing species like *Gliricidia sepium* or *Sesbania sesban* could help

reshape perceptions from “long-term only” to “progressively beneficial.”

Perception of Conservation Tillage

Farmers’ perception of conservation tillage in this study was moderately positive yet cautious, reflecting both recognition of its environmental benefits and concern over its slow visible results. Respondents acknowledged that reduced tillage helps minimize soil erosion, retain soil moisture, and maintain soil organic matter, particularly in drought-prone areas. Farmers noted that soils under conservation tillage remained “softer and cooler” during hot seasons, which helped crops withstand dry spells. However, they also pointed out that the tangible benefits especially yield improvements were not immediate, often taking several seasons to manifest. Many farmers expressed frustration that “the land takes time to respond,” leading some early adopters to revert to conventional plowing after observing limited short-term gains. These sentiments indicate that while farmers conceptually appreciate conservation tillage, delayed outcomes weaken sustained commitment, particularly among those facing urgent livelihood needs.

These findings align closely with previous research across Africa and Asia. Singh (2020) [53] observed similar perceptions among Indian farmers, who initially faced challenges such as increased weed pressure, uneven germination, and low early-season yields during the first years of conservation tillage adoption. Likewise, Mafongoya P (2015) [30] reported that smallholder farmers in Zimbabwe acknowledged conservation tillage as an effective soil management practice but hesitated to continue due to labor intensity in weed control and lack of immediate yield improvement. In Ethiopia, Tesfaye *et al.* (2016) [57] found that the psychological barrier of slow benefits significantly constrained adoption, as farmers tend to favor practices that deliver visible, short-term results over those requiring cumulative investment and delayed returns. This aligns with behavioral adaptation theory, which posits that perceived temporal distance between action and benefit directly affects willingness to sustain new agricultural practices. In short, farmers’ patience and risk tolerance shape their perception: when benefits are intangible or postponed, enthusiasm tends to decline. In this study, conservation tillage was perceived as technically sound but time- and knowledge-demanding, especially for resource-poor farmers lacking access to machinery or herbicides. Farmers with greater access to extension advice, mechanization, and inputs held more favorable views, suggesting that perception is strongly influenced by information access and resource endowment. Wealthier or better-trained farmers understood that conservation tillage requires consistent residue retention and weed management to yield long-term benefits, whereas those with limited support viewed it as unproductive and laborious. Maulu *et al.* (2024) [32] further emphasized that when farmers are supported with training and proper tools, they begin to appreciate conservation tillage as an investment in soil health rather than an immediate yield enhancer. The overall mixed perception observed in this study thus reflects a balance between environmental awareness and economic pragmatism: farmers value soil conservation and sustainability, but their adoption decisions remain constrained by the need for quick, tangible returns in resource-scarce settings. Addressing these perceptions through continuous extension support, demonstration plots,

and short-term incentives can help bridge the gap between awareness and consistent practice, ultimately strengthening conservation tillage adoption as part of Zambia’s climate-smart agriculture framework.

4.5 Recommended sustainable practices to improve adaptation strategies

Table 4: Sustainable Recommendations

Sustainable Recommendation	Description	Frequency (n=72)	% of Respondents
Strengthen Water Management	Promote affordable irrigation kits, rainwater harvesting, and efficient water-use technologies.	30	41.7%
Enhance Institutional Support	Increase extension officers, establish demonstration plots, and improve access to climate information.	25	34.7%
Improve Access to Finance	Provide microcredit, savings groups, and subsidized inputs.	22	30.6%
Promote Inclusive Capacity Building	Design gender-responsive and youth-focused training programs.	18	25.0%
Strengthen Market Linkages	Develop value chains, storage facilities, and reliable market systems.	20	27.8%

The results in Table 4 indicate that the most emphasized recommendation was water management (41.7%), reflecting farmers’ major challenge of coping with rainfall variability and unreliable water sources. This highlights the urgent need for affordable irrigation technologies, rainwater harvesting, and efficient water-use practices. Institutional support (34.7%) and access to finance (30.6%) were also ranked highly, underscoring the importance of enabling environments where farmers have access to extension services, demonstration plots, timely climate information, and affordable credit facilities to adopt and scale adaptation practices. Although market linkages (27.8%) and inclusive capacity building (25%) were mentioned less frequently, they remain critical for long-term sustainability, as they ensure that increased production translates into improved household incomes and that marginalized groups, such as women and youth, are fully included in adaptation efforts. Overall, the results suggest that while farmers recognize the potential of adaptation strategies such as Conservation Agriculture and early-maturing crops, their sustainability depends on supportive systems notably water access, institutional guidance, and capital availability. These findings align with Muyabe *et al.* (2025) [36], who noted that climate adaptation in Zambia remains constrained not by knowledge gaps, but by limited institutional coordination and resource mobilization.

Strengthen Water Management

Water management emerged as the most critical recommendation, with 41.7% of respondents emphasizing the need for affordable irrigation, rainwater harvesting, and

efficient water-use technologies. Farmers' prioritization of this measure reflects Zambia's growing exposure to rainfall variability and drought events, which have increasingly disrupted rainfed agriculture. Respondents identified access to small-scale irrigation kits (e.g., treadle pumps, drip systems) and community water harvesting structures as key to improving productivity and ensuring resilience. This finding is strongly supported by Phiri *et al.* (2025) [45] and Pathak *et al.* (2015), who demonstrated that integrated soil and water management significantly enhances crop yields and resilience under semi-arid conditions. Similarly, Asrat & Simane (2018) [5] and Chisanga *et al.* (2017) noted that water scarcity is a major determinant of adaptive capacity in both Ethiopia and Zambia, and that farmers often perceive irrigation as the most visible solution to climate stress. However, adoption remains limited due to the high initial cost of irrigation equipment, lack of training, and insufficient infrastructure. Studies such as Kamruzzaman *et al.* (2023) [23] recommend promoting low-cost technologies like rooftop rainwater harvesting, contour bunds, and community micro-dams to improve smallholder participation. Furthermore, Charlton & Danny (2025) [10] and Tembo, Bernard, Sihubwa Sydney, masilokwa ignitius (2020) advocate for integrating water-efficient practices within Conservation Agriculture, linking soil moisture conservation and irrigation scheduling to maximize resource use efficiency. Thus, water management is not merely a technical intervention but a foundation for all other adaptation efforts. Ensuring access to affordable irrigation and water harvesting systems can significantly reduce farmers' vulnerability to drought, stabilize food supply, and enhance overall agricultural resilience.

Enhance Institutional Support

A substantial proportion (34.7%) of respondents emphasized the need to enhance institutional support, including increasing the number of extension officers, establishing demonstration plots, and improving access to climate and agronomic information. Farmers highlighted that while they are aware of adaptation strategies, practical implementation is often hindered by inconsistent extension visits and inadequate training. This gap between knowledge and practice mirrors findings by Shiferaw *et al.* (2009) [49], who observed that access to institutional support particularly agricultural extension was one of the strongest determinants of both perception and adoption of adaptation strategies in Ethiopia. In Zambia, Makondo *et al.* (2014) [31] and Ngoma, Pelletier, *et al.* (2021) [39] also documented that farmers' confidence in new technologies (such as early-maturing crops and agroforestry) increased significantly when extension officers provided continuous technical guidance and demonstrations. Similarly, Pattanaik *et al.* (2025b) [43] emphasized that trust and communication between farmers and institutions determine how effectively adaptation messages are received and acted upon. Without consistent institutional presence, farmers are less likely to sustain new practices, regardless of their initial perception of climate risks. This study also found that farmers value local demonstration plots where they can directly observe adaptation results before implementation. Such participatory learning aligns with Bogale & Bekele (2023) [8], who showed that experiential knowledge sharing fosters stronger behavioral change than theoretical training alone. Accordingly, strengthening institutional support should

involve community-based extension models, ICT-enabled information dissemination, and multi-stakeholder collaboration involving research centers, NGOs, and government agencies. A well-coordinated institutional network can enhance farmer confidence, streamline adaptation financing, and accelerate technology diffusion across districts.

Improve Access to Finance

Financial barriers remain a major limitation to effective adaptation. About 30.6% of respondents recommended improving access to microcredit, savings groups, and subsidized inputs to enable smallholders to adopt climate-resilient technologies. Farmers explained that lack of capital prevents them from purchasing improved seeds, irrigation equipment, and conservation implements reinforcing dependence on low-input systems that are vulnerable to climate shocks. This finding echo Yang *et al.* (2020) [59], who identified income and credit access as among the most significant determinants of adaptation decisions. Similarly, Haro-Monteagudo *et al.* (2023) [19] and Zulfikri *et al.* (2024) [62] observed that farmers with greater access to loans and financial institutions were more likely to invest in climate-smart technologies such as conservation agriculture and drought-tolerant crops. In Zambia, Simatele *et al.* (2012) [52] found that microfinance programs and cooperative savings schemes improve adoption rates by reducing liquidity constraints and building resilience through diversified income sources. However, conventional banking systems often exclude smallholders due to lack of collateral and perceived risk. To address this, Binesh *et al.* (2019) [7] and Kumar *et al.* (2019b) [26] recommend climate-sensitive microfinance models that combine credit with training and insurance, thereby reducing default risks and strengthening adaptive capacity. Integrating microcredit into community cooperatives and village savings groups also enhances inclusivity, particularly for women and youth, who are disproportionately excluded from formal finance. Expanding such financial innovations is therefore essential to scale up adaptation adoption across Zambia's rural areas.

Promote Inclusive Capacity Building

A quarter of respondents (25%) emphasized inclusive capacity building as a key pillar for sustainable adaptation. Farmers highlighted that training and awareness programs should be gender-responsive and youth-focused, reflecting the unequal distribution of resources and decision-making power in rural communities. This finding aligns with Lee *et al.* (2014) [28] and Nyambe (2024) [41], who observed that women farmers often possess valuable indigenous knowledge on soil and water management but are underrepresented in extension programs and training sessions. Similarly, Shrestha *et al.* (2018) [50] argue that inclusivity in capacity building fosters trust, ownership, and intergenerational learning, which are crucial for long-term resilience. Incorporating indigenous knowledge into formal training can also enhance local relevance and farmer participation. Stadtbäumer *et al.* (2022) [54] demonstrated that integrating traditional forecasting methods such as reading wind patterns and flora behavior alongside scientific data improved community engagement in Southern Zambia. Moreover, Bunn *et al.* (2019) [9] suggested that when women and youth are directly involved in adaptation planning, there is greater social acceptance and diffusion of innovations.

Therefore, sustainable adaptation requires human-centered capacity building, where farmers transition from passive recipients of knowledge to active co-creators of climate solutions. Strengthening leadership among women and youth in farmer organizations, along with participatory training, can help institutionalize resilience thinking at the community level.

Strengthen Market Linkages

Finally, 27.8% of farmers emphasized the importance of strengthening market linkages through reliable value chains, storage facilities, and improved access to markets. Respondents explained that even when they adopt adaptation strategies and increase production, poor market access and price volatility often erode potential benefits. This constraint discourages sustained investment in improved seeds, fertilizers, and irrigation technologies. This perception aligns with Jain (2007) [21], who found that linking smallholders to structured markets not only enhances income but also incentivizes adoption of climate-smart practices. Similarly, Ngoma *et al.* (2021) [38] and Umar (2021) [58] noted that climate adaptation can only be sustainable if it integrates post-harvest management and value chain development, ensuring that farmers receive fair returns. Rijal *et al.* (2022) [46] also argued that policy frameworks must go beyond production to support market-based resilience, especially in remote areas. Investing in rural aggregation centers, storage infrastructure, and farmer cooperatives can reduce post-harvest losses and strengthen negotiation power. Additionally, digital platforms that link producers to buyers complemented by transport subsidies can improve profitability and motivation to adopt adaptation technologies. A resilient agricultural system, therefore, depends as much on market stability as on climatic adaptation.

5. Conclusion

The study assessed smallholder farmers' perceptions, determinants, and adaptation strategies to climate change impacts, focusing on their effectiveness and sustainability. Based on the findings, it is evident that smallholder farmers possess a high level of awareness of climate change and its associated risks, as reflected in their proactive adoption of multiple adaptation strategies. The results demonstrate that early-maturing and drought-tolerant crop varieties, alongside conservation agriculture, are perceived as the most effective and reliable strategies for managing rainfall variability and ensuring yield stability. These strategies have proven successful in reducing crop failure, improving soil fertility, and conserving soil moisture under erratic rainfall patterns. The findings further revealed that farmers' perceptions toward adaptation practices vary depending on perceived benefits and labor demands. While conservation agriculture and early-maturing crops were viewed positively due to their quick and visible results, practices such as agroforestry and conservation tillage received mixed perceptions because they require long-term investment and delayed benefits. This highlights that adaptation behavior is influenced not only by knowledge but also by the cost-benefit dynamics and temporal expectations of the farmers. The study also established that the adoption of adaptation strategies is determined by several socioeconomic and institutional factors, including household income, access to credit, education, farm size, and gender. Wealthier and

better-educated farmers with access to extension services were more likely to adopt climate-smart technologies, while poorer farmers relied on low-cost and short-term coping mechanisms. Gender disparities persisted, with women farmers facing limited access to productive resources, though they demonstrated strong willingness to participate in adaptation initiatives when supported through inclusive programs. Furthermore, the study revealed that water scarcity, weak institutional support, and inadequate access to finance remain the most significant barriers to sustainable adaptation. Consequently, most farmers recommended strengthening water management systems, increasing institutional support through extension services and demonstration plots, improving access to microcredit, and enhancing inclusive training and market linkages. These recommendations underscore the interdependence of technical, financial, and institutional interventions in building agricultural resilience.

5.1 Study Limitations

While this study provides valuable insights into smallholder farmers' perceptions, determinants, and adaptation strategies to climate change in Zambia, several limitations should be acknowledged to guide interpretation and future research. Firstly, the sample size of 72 respondents, though adequate for qualitative and descriptive analysis, limits the statistical generalization of findings to all smallholder farmers in the country. The study focused on selected areas that may not fully capture variations across Zambia's Agro-ecological zones, cultural settings, or market environments. Future studies should therefore include larger and regionally diverse samples to improve external validity and policy applicability. Secondly, the study relied primarily on self-reported data from farmers through interviews and questionnaires. While this method effectively captured perceptions and lived experiences, it may have been influenced by recall bias or social desirability bias, where respondents provided answers, they considered favorable to researchers or institutions. Triangulation with longitudinal or observational data could enhance the reliability of such findings. Thirdly, the study assessed the effectiveness of adaptation strategies based on farmers' subjective perceptions rather than long-term empirical yield or economic data. Although perceptions are crucial for understanding behavioral choices, they do not always reflect actual biophysical or economic outcomes. Future research should therefore integrate quantitative impact assessment such as yield monitoring, soil quality analysis, and cost-benefit modeling to validate perceived effectiveness. Fourthly, limited access to secondary climatic and socioeconomic datasets constrained the ability to analyze long-term climate trends or cross-verify farmers' perceptions with meteorological records. Collaboration with national agencies like the Zambia Meteorological Department and the Ministry of Agriculture would strengthen future assessments through data integration. Despite these limitations, the findings remain highly relevant and contribute significantly to understanding the context-specific drivers and barriers of climate adaptation among smallholder farmers in Zambia. They provide a strong empirical foundation for designing targeted, inclusive, and evidence-based interventions aimed at enhancing agricultural resilience under changing climatic conditions.

5.2 Future Research Directions

The study recommends further research to assess the long-term impacts of adopted adaptation strategies on soil health, household income, and ecosystem services. Future studies should also explore gendered adaptation pathways, the cost-effectiveness of integrated climate-smart interventions, and the role of digital tools in climate risk communication. Such research will provide empirical insights for scaling context-specific and inclusive adaptation solutions.

6. References

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