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Assessing the Effects of Rainfall Variability on Household Food Security: A Case Study of Small-Scale Farmers in Mungule Village - Chibombo District

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Abstract
This study examines the implications of rainfall variability for household food security in Mungule Village, Chibombo District, with particular emphasis on smallholder farmers whose livelihoods are predominantly dependent on rain-fed agricultural systems. In Zambia, agricultural productivity and crop yields are strongly influenced by the spatial and temporal distribution of rainfall, making farming communities especially vulnerable to climatic fluctuations. Within this context, the paper analyses long-term rainfall variability and its relationship with agricultural production in Chibombo District of Zambia's Central Province. The analysis is based on two sources of precipitation data: observed rainfall records from the Zambia Meteorological Department (ZMD) and satellite-derived gridded data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), covering the period from 1981 to 2021. Agricultural production data spanning 1999 to 2018 were also utilized. Non-parametric statistical techniques were applied to detect trends in precipitation, while the Standardized Precipitation Index (SPI), Seasonality Index,

and Precipitation Ratio were employed to evaluate changes in rainfall characteristics over the study period. In addition, the influence of El Niño events on rainfall distribution and seasonal onset in the study area was assessed. Correlation analysis between annual rainfall totals and rice production revealed a moderate positive relationship (r = 0.40), suggesting that interannual rainfall variability exerts a measurable influence on crop yields. The results indicate a statistically significant increasing trend in rainfall during the study period, although agricultural production remains highly sensitive to rainfall variability. The findings underscore the reliance of certain areas on rainfall for paddy cultivation and emphasize the importance of localized rainfall monitoring to support sustainable agricultural planning. The study provides valuable insights for farmers and policymakers by identifying rainfall-sensitive zones and encouraging the adoption of drought-resilient cropping strategies. Future research should integrate socio-economic and soil-related factors to improve assessments of agro-climatic vulnerability in rain-fed farming systems.

1. Introduction
This study examined the impacts of climate change–induced rainfall variability on small-scale agricultural practices in Chibombo District, with particular emphasis on Mungule Village. Agriculture remains highly sensitive to climatic variability, and small-scale farmers who rely heavily on rain-fed systems are particularly vulnerable to erratic weather conditions. In both global and local contexts, climate change poses a serious threat to food security, rural livelihoods, and sustainable development.

The study situated the local experiences of farmers in Mungule within the broader discourse on climate change, highlighting how global environmental shifts translate into concrete challenges at the community level. These challenges include reduced crop yields, prolonged dry spells, and increased livelihood insecurity. Despite the existence of national policies aimed at promoting climate resilience, many smallholder farmers lack access to adequate institutional support, early warning systems, and climate-smart agricultural technologies.

By examining the adaptation strategies employed by farmers and evaluating the effectiveness of existing support mechanisms, this research aimed to contribute to the development of context-specific, evidence-based interventions. Ultimately, the study

was sought to inform more responsive policies that address the practical realities of small-scale farmers navigating the risks posed by a changing climate.

1.1 Background
Rainfall variability poses a significant threat to agriculture and food security globally, with small-scale, rain-fed farmers in Sub-Saharan Africa particularly vulnerable. In Zambia, where agriculture remains the primary source of livelihood for the majority of rural households, shifting climatic conditions especially rainfall variability and rising temperatures have increasingly disrupted farming systems, leading to reduced crop yields, prolonged dry spells, and heightened food insecurity. In Mungule Village, Chibombo District, these challenges are acute, with average temperatures having risen by 1.3°C and annual rainfall declining by 1.9 mm since 1960, contributing to recurrent droughts, floods, post-harvest losses of approximately 30%, and acute food insecurity affecting 76% of households. Smallholder farmers' capacity to cope with climate-induced hazards is constrained by high poverty levels, low literacy, labor migration, limited access to irrigation, modern technologies, financial services, and institutional support. While national policy frameworks such as Zambia's National Climate Change Policy (2016) and National Adaptation Plan (2020) aim to enhance climate resilience, implementation at the local level remains fragmented, and existing studies have largely focused on national-level agriculture or crop production, often neglecting comprehensive assessments of food security and household-level adaptation strategies. This study, therefore, seeks to examine the impacts of rainfall variability on small-scale farming in Mungule Village, assess the challenges faced by farmers, and evaluate their adaptation strategies, with the aim of informing context-specific, evidence-based interventions and policy responses that enhance climate resilience and food security in rural Zambia.

1.2 Statement of the Problem
Rainfall variability constitutes a significant constraint to agricultural productivity and household food security in Mungule Village, located in Chibombo District. Increasing climatic variability has exposed the area to recurrent droughts and floods, which have contributed to declining crop yields and persistent food insecurity. Since 2002, the mean annual temperature has risen by approximately 1.8°C, while average annual rainfall has declined by about 1.7 mm, trends that have adversely affected agricultural performance and livelihood sustainability in the village. Post-harvest losses are estimated at nearly 30 percent, and levels of acute food insecurity are reported to affect about 70 percent of households, underscoring the severity of the problem.

Enhancing household capacity to cope with climate-induced rainfall variability remains a critical objective for mitigating the negative impacts of climate change on agriculture and food security. However, adaptive capacity at the household level remains limited due to widespread poverty, low literacy levels, and increased labor migration from rural areas to urban centers. These structural constraints significantly reduce the ability of small-scale farmers to respond effectively to climate-related shocks.

Although a growing body of literature has examined the impacts of climatic variability on food security in Zambia, most studies have focused primarily on agricultural production at the national scale. For instance, Jain (2007) applied the Ricardian model to assess the economic effects of rising temperatures and declining seasonal rainfall on farming activities, with emphasis on crop production rather than comprehensive food security outcomes. Similarly, Jemma *et al*. (2010) analyzed the influence of climate variability on agricultural output without providing a detailed assessment of food security dimensions. Vermenlon *et al*. (2010) offered a qualitative evaluation of rainfall variability across economic sectors but did not adequately address household food security or coping mechanisms strategies effectively.

1.3 General Objective
To assessing the effects of rainfall variability on household food security in Mungule Village of Chibombo District. To examine the effects of Specific Objectives of the Study include the following:hanging rainfall patterns on the agricultural productivity and livelihoods of small-scale farmers in Mungule Village, Chibombo District, to analyze the adaptation strategies employed by small-scale farmers in response to rainfall variability and other climate-related challenges and To assess the effectiveness of institutional and policy support available to small-scale farmers in enhancing climate resilience and adaptation capacity.

1.4 Theoretical Framework
This study is grounded in the Sustainable Livelihoods Framework (SLF), originally developed by the United Kingdom Department for International Development (DFID) and subsequently refined to address contemporary challenges, including climate change, environmental degradation, and institutional capacity constraints. The SLF offers a comprehensive analytical framework for examining how small-scale farmers construct and sustain their livelihoods amid interacting climatic, economic, and policy pressures.

The framework defines a sustainable livelihood as one that can cope with and recover from shocks, maintain or enhance its assets, and ensure future well-being without undermining natural resources. It comprises five interrelated components: the vulnerability context, livelihood assets, transforming structures and processes, livelihood strategies, and livelihood outcomes. Together, these elements explain how farmers respond to climate variability and institutional constraints.

In Chibombo District, the vulnerability context is shaped by increasing rainfall variability including erratic rainfall, droughts, and extreme weather which directly threatens agricultural productivity. The livelihood assets (natural, human, financial, social, and physical capital) determine how effectively farmers adapt. For instance, access to financial and social capital can enable investments in irrigation or access to early warning systems.

Transforming structures and processes, including policies, institutions, and governance mechanisms, play a critical role in shaping access to and utilization of livelihood assets. While Zambia's National Climate Change Policy (2016) and the National Adaptation Plan (2020) are designed to enhance climate resilience, limitations in local-level implementation and weak institutional support constrain effective adaptation outcomes. As a result, small-scale farmers employ a range of autonomous adaptation strategies, such as crop diversification, conservation

agriculture practices, and adjustments to planting calendars, to reduce climate-related risks and maintain livelihood sustainability.

In this study, the Seasonality Index (SI), as proposed by Walsh and Lawler, is employed to quantify inter-annual rainfall distribution patterns. The dataset used for this analysis was obtained from the India Meteorological Department (IMD). The index is particularly useful for assessing relative rainfall seasonality in regions characterized by two or more precipitation peaks within a year. The Seasonality Index is defined as the absolute deviation between mean monthly precipitation and the long-term monthly average, normalized by the mean annual precipitation, thereby providing a standardized measure of rainfall concentration and seasonal variability.

The resulting livelihood outcomes particularly household food security depend on how successfully these strategies and institutional mechanisms interact with climatic conditions. Thus, the SLF provides a conceptual basis for examining the relationship between rainfall variability (independent variable) and household food security (dependent variable), while considering the mediating role of institutional support and adaptation strategies. Overall, the SLF offers a dynamic and multidimensional analytical framework that captures the interplay between climate variability, assets, policies, and strategies shaping smallholder farmers' resilience and food security in Chibombo District. The figure below shows the diagrammatic relationship between the independent and dependent variables of the study.
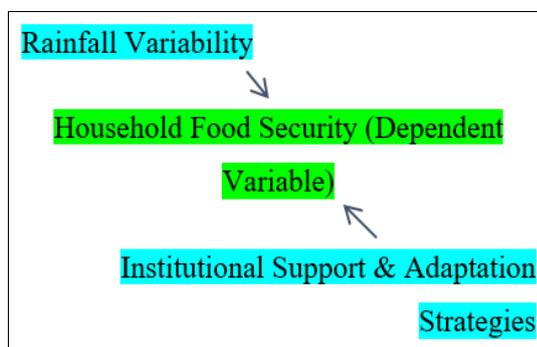
Source: Researcher

Fig 1.1: Shows a conceptual framework for measuring the impact of rainfall variability on family food security. A case study on small-scale farmers in Mungule village, Chibombo district.

1.5 Literature Review
Rainfall variability has emerged as a key global problem due to its extensive impacts on agriculture and food security across varied locations. Over the past two decades, it has been recognized not only as a physical phenomenon affecting climate systems but also as a socio-political and cultural challenge requiring coordinated governance (Hulme & Turnpenny, 2004). The increasing frequency and intensity of extreme weather events, such as droughts and floods, is projected to exacerbate food insecurity worldwide (Eugene, 2013). Agriculture, a climate-sensitive sector, is particularly vulnerable, with disruptions having cascading effects on livelihoods and household food security (Mudenda *et al*., 2009). Food security encompasses availability, access, utilization, and stability, all of which are threatened by climatic variability (Edame, 2013). Historical events, including the 1995 drought and 2000 floods in the United

Kingdom, illustrate the tangible impacts of climate extremes on agricultural productivity and household food security, highlighting the need for responsive policies (Hulme & Turnpenny, 2004).

In the context of Asia, a study by Hussain and Thapa (2012) [14] assessed the perceptions of smallholder farmers regarding climate change and its impact on agriculture. The research, conducted in Nepal, utilized household surveys and focus group discussions to gather data. Findings indicated that farmers observed changes in rainfall patterns and increased incidence of pests and diseases, which they attributed to climate change. The study underscored the importance of incorporating indigenous knowledge into climate adaptation strategies.

In Latin America, Eakin *et al*. (2014) [13] investigated the adaptive capacity of smallholder coffee farmers in Mexico. The study employed mixed methods, including surveys and participatory workshops, to assess farmers' responses to climate variability. Results showed that while some farmers adopted diversification strategies, others lacked the resources to implement effective adaptations. The authors concluded that institutional support plays a crucial role in enhancing the adaptive capacity of small-scale farmers.

The impacts of climate change are especially pronounced for smallholder farmers in vulnerable regions. Global undernourishment rates reflect this disparity: Southern Asia reports 24% undernourishment, while fragile states face 31.4% compared to 14.5% in non-fragile countries, largely due to low agricultural productivity and climate-induced food insecurity (FAO, 2012). Regional variability is evident; the US Midwest experienced high minimum temperatures during the 2010–2012 rainy seasons, affecting crop yields, while the US Southwest is projected to face more severe climate impacts (Peters *et al*., 1971; Hamlin, 2012; Kurukulasuriya & Mendelsohn, 2006). In the Asia-Pacific region, warming trends and extreme weather events—including droughts, floods, and cyclones—have disrupted rice and wheat production in India, Nepal, Bangladesh, and Pakistan, contributing to under nutrition among children under five (Edame *et al*., 2011; Lal *et al*., 2011).

Empirical studies indicate that rising temperatures, altered precipitation, and extreme weather events have already reduced crop yields, particularly in tropical regions (Wheeler & von Braun, 2013; Knox *et al*., 2016; Morton, 2007). Smallholder farmers are disproportionately affected due to limited access to resources, technology, and institutional support, which exacerbates vulnerability and poverty (Nkomwa *et al*., 2014; Bryan *et al*., 2013) [17, 12]. Regional studies further highlight context-specific impacts: in Latin America, resource-constrained coffee farmers in Mexico rely on institutional support for adaptation (Eakin *et al*., 2014) [13], while in Sub-Saharan Africa, smallholders face declining yields and economic hardship due to climate variability (Nkomwa *et al*., 2014) [17]. In Zambia, agriculture supports approximately 85% of the population, with small-scale rain-fed farming dominating rural livelihoods (Mikkel *et al*., 2013; MTENR, 2011). Climate projections indicate rising temperatures (1.2–3.4°C by 2060), shifts in rainfall patterns, and increased frequency of droughts, floods, and heatwaves, posing severe risks to agricultural production and household food security (Nehemia *et al*., 2009). Combined with high rural poverty (80%), these climatic stresses threaten livelihoods and national development goals. Land-use changes, deforestation, and mining further

exacerbate greenhouse gas emissions and local climate impacts (IPCC, 2007). Overall, the literature underscores the need for context-specific adaptation strategies that enhance the resilience of smallholder farmers. These include financial services, extension support, agro ecological approaches, social networks, and integration of indigenous knowledge (Altieri & Nicholls, 2017 [11]; Prokopy *et al*., 2015; Hussain & Thapa, 2012 [14]; Rickards & Howden, 2012). Climate adaptation is crucial for mitigating the long-term impacts of climate change on smallholder agriculture. Farmers employ climate-smart agriculture (CSA) practices such as soil management, tree planting, agroforestry, intercropping, and the balanced use of organic and inorganic inputs to improve productivity and resilience. These practices enhance soil fertility, crop health, and yields (Kuwornu *et al*., 2018).

Household and farmer characteristics, including age, education, landholding size, and social cohesion, significantly influence the choice and effectiveness of adaptation strategies. Older and less-educated farmers often rely on traditional methods, while younger, more educated farmers adopt innovative techniques that are profitable and easier to implement (Obayelu *et al*., 2019; Tazeze *et al*., 2018; Belay *et al*., 2017; Adger *et al*., 2018). Farmers' perceptions of climate change and related risks also shape their adaptation choices, as awareness is a prerequisite for adopting coping strategies (Moyo *et al*., 2012; Kihupi *et al*., 2015; Adger *et al*., 2005).

Climate change and variability through altered temperatures, water availability, and extreme weather events pose significant uncertainties for agriculture, particularly in semi-arid regions like Kazungula district. The area has historically experienced droughts, floods, and extreme temperatures, which threaten crop growth and food security (Hulme *et al*., 2005; FAO, 2009; Eriksen, 2005; Glantz, 1994). For example, maize requires 450–600 mm of rainfall per season and optimal temperatures around 20°C, with yields declining above 32°C. Observed rainfall and temperature trends indicate that the climate system in Kazungula has changed beyond natural variability (Eriksen, 2005; Bolin, 2007).Socio-economic and institutional factors further affect adaptation. Farmers with larger landholdings can implement more strategies and generate higher incomes, while social cohesion and shared experiences improve collective adaptive capacity (Belay *et al*., 2017; Turasih & Kolopaking, 2016; Adger *et al*., 2018). Successful adaptation also requires external support, including drought-resistant crop varieties, weather forecasts, financial services, mixed farming strategies, and improved rural infrastructure (Osbahr *et al*., 2010; Below *et al*., 2010).

Globally, smallholder farmers employ diverse adaptation strategies, but research gaps remain, particularly in developing countries. A bibliometric analysis by Okolie *et al*. (2024) of 1,635 publications (2010–2022) revealed that most studies originate from developed countries, highlighting the need for localized research and collaboration to address context-specific challenges and solutions. Adaptation is also vital for food security beyond crops. For example, rising temperatures and water scarcity threaten freshwater fish stocks, such as tilapia (Tilapia mariae), which prefer 25–33°C and have critical thermal maxima of 37°C, potentially impacting rural diets and livelihoods (WWF, 2006). Overall, effective climate adaptation for smallholder farmers combines local knowledge, socio-economic considerations, and institutional support to enhance resilience and sustain agricultural productivity. In 2017, Zambia released a draft National Climate Change Adaptation (NCCA) strategy, which is yet to be endorsed by Cabinet. Although Zambia has progressive climate policies, implementation faces challenges including policy alignment, coordination, public-private engagement, data gaps, and limited municipal capacity. South Africa, despite its commitment to climate legislation, continues to face developmental challenges such as poverty, limited access to services, and high unemployment. The National Development Plan (NDP) emphasizes agriculture as a means to reduce poverty and advocates transitioning to a low-carbon economy. The plan recognizes South Africa's vulnerability to climate impacts, particularly for marginalized groups, but social vulnerability, dispersed development, and inadequate infrastructure have limited the NDP's effectiveness in addressing climate change (National Planning Commission, 2012; 2018). At the provincial level, the Provincial Growth and Development Strategy (PGDS) highlights environmental risks from extreme weather events and unsustainable land-use practices. It emphasizes enhancing ecosystem resilience, promoting green technologies, and implementing adaptation measures (PGDS, 2016). Soil degradation, water scarcity, and unsustainable land practices threaten agricultural productivity. Strategies to address these include soil restoration (nutrient amendments, composts, reduced tillage), water-harvesting techniques (Zai pits, retention ditches, ponds, rainwater harvesting), and efficient irrigation systems, which also support carbon storage in soils (Ibrahim, 2012; Kenya Rainwater Association, 2010).

Agroforestry, combining trees with crops or livestock, provides ecological, social, and economic benefits such as enhanced soil fertility, food security, and income (FAO, 2012). However, agricultural expansion must balance food production with long-term sustainability to avoid resource depletion (von Braun & Díaz-Bonilla, 2008). Climate-smart agriculture (CSA) has gained prominence, though past initiatives have often failed due to land tenure issues, lack of infrastructure, finance, and gender inequality (Delgado, 1995; Lahiff, 2001; Macleod *et al*., 2008). Secure access to land, water, and livestock, combined with financial resources, is essential for successful CSA investment (FAO & CARE, 2010). Education, knowledge sharing, and awareness-raising including through farmer facilitators, media, and extension services are critical for CSA adoption. Indigenous Technical Knowledge (ITK) plays an important role in building understanding of sustainable agricultural practices (Chambers & Gillespie, 2015; IIED, 2011; FAO, 2010).

Non-governmental organizations have been key in promoting CSA in sub-Saharan Africa. In Zambia, conservation farming was introduced in the late 1980s through the Conservation Farming Unit (CFU) and has since been scaled up with support from the Ministry of Agriculture, the EU, and the World Bank. Programs such as the Conservation Agriculture Scaling Up Project (CASU), the Zambia Integrated Landscape Project (ZIFILP), and the Sustainable Intensification of Smallholder Farming Systems in Zambia Project (SIFAZ) promote CSA practices, sustainable mechanization, and commercialization of crops (Westengen *et al*., 2018). Zambia's Climate-Smart Agriculture Investment Plan (CSAIP, 2018), in partnership

with the World Bank, supports climate resilience and productivity by promoting conservation agriculture, agroforestry, drought-tolerant crops, efficient irrigation, and sustainable land management practices. These initiatives aim to increase farmers' resilience to climate-related risks while improving yields and income. If you want, I can merge this with your earlier section on Southern Africa's climate change context into a fully integrated literature review that flows seamlessly from global perspectives to national policies, challenges, and CSA interventions. This would give you a ready-to-use draft for a thesis chapter or journal paper.

In the United States, a study by Prokopy *et al*. (2015) explored the role of social networks in climate adaptation among farmers. The research employed social network analysis to examine how information flows influence adaptation decisions. Results suggested that farmers with extensive networks were more likely to adopt adaptive practices. The authors emphasized the importance of fostering collaborative networks to facilitate knowledge sharing and adaptation. Furthermore, a study by Niles *et al*. (2016) investigated the barriers to climate adaptation among farmers in New Zealand. Utilizing surveys and interviews, the research identified financial constraints, lack of information, and policy uncertainty as major barriers. The authors recommended the development of clear policies and provision of financial incentives to encourage adaptation among farmers.

These studies collectively highlight the complex and region-specific challenges that climate change poses to small-scale farmers globally. They underscore the necessity for tailored adaptation strategies that consider local contexts, resource availability, and institutional support to enhance the resilience of smallholder agriculture in the face of a changing climate. Climate change has emerged as a formidable challenge to smallholder farmers across Africa, significantly impacting agricultural productivity and livelihoods. Recent studies provide comprehensive insights into the multifaceted challenges these farmers face due to climate variability and change.

This study consulted a wide range of scholarly articles and books to develop a conceptual framework within which the research was undertaken. The review focused on assessing the impact of rainfall variability on smallholder farmers in the study area and on illustrating how these farmers confront the challenges posed by climatic variability and its implications for crop yield. One of the principal objectives of this study was to determine the extent of climate variability specifically temperature and rainfall in the study area over the past decade (2014-2024). The research also reviewed related national and international studies to establish the relevance and value of the current investigation. It was observed that the aspect of *experience* how smallholders perceive, interpret, and respond to climate variability has not been extensively examined in existing literature. Accordingly, this study seeks to address this gap and to contribute new insights that may inform future research and policy development. The conceptual framework of this study therefore integrates two interrelated dimensions: First, the patterns and impacts of climatic variability on crop yields and rural livelihoods; and second, the policies and strategies implemented by governmental and institutional actors to mitigate these impacts, including how such measures are perceived and enacted at the

community level. From the review of literature studies on climate smart, there have been various practices such as conservation agriculture; water management, agroforestry that exists. However, adoption of many CSA practices has been very slow, particularly in food insecure and vulnerable regions in sub-Saharan Africa and Southeast Asia especially among smallholders' farmers. There are several potential explanations for failure to adopt such activities which in the above literature they have not been addressed (Giller *et al*., 2019). Due to dynamic and the uncertain nature of climate change impacts, capacity development approach that is comprehensive and which stimulates socio-institutional learning processes and at the same time utilizes the innovation potential of agricultural systems is required to transition towards climate-smart agriculture. Bridging the current information and knowledge gap for more inclusive and effective decision-making within CSA is a key challenge. Successful adaptation to climate change by small producers is not merely a question of developing new adaptation technologies but depends on ensuring access and use of them. When reported-shocks are "memories associated, biases in reporting shocks can be both downward and upward, depending on the direction of the error-variable connection" (Beegle *et al*., 2012). Regarding social perception, it generally occurs in reporting natural disaster shocks by rural households in low-income countries (Nguyen & Nguyen, 2020). Households generally report natural disaster shock, based on reward attached to the survey participation (Parvathi & Nguyen, 2018). In survey process, researchers discovered a link between gender, education level, age, and residence location with the incidence of health shock reporting inaccuracies (Okura *et al*., 2004). According to Christiaensen (2007) health shocks reported during survey are more frequently by individuals with better salaries, less serious illnesses, to take time off. For instance, households with low incomes are tempted to report fewer health concerns Gertler *et al*., 2002), and the desire to receive assistance (Groot, 2000), this could bring in the issue of over-reporting shocks during surveys (Baker, 2004). In addition, measurement error during the survey process could occur when surveyors undertake surveys in different conditions (Bound' *et al*., 2001).

In general, researchers on self-reported shocks discovered that the likelihood of over-reporting a shock is connected to the type of shock reported (diseases in health shock), the time of occurrence, the severity of the shock, the features of the respondent, and the justification that motivates the participants. However, biases in self-reported shocks can be attenuated, especially when they are used as explanatory variables (Baker, 2004). In this study, self-reported weather shock is not related to any respondent's motivation, such as remuneration or reward for reporting shock or the household's coping ability, as is the case in self-reported health shocks (Quisumbing & Maluccio, 2003) Mudenda *et al*. (2009), notes that climate change is likely to impact on agriculture and food security across the globe. Any impacts on agriculture will have multiple effects on agriculture dependent livelihoods and household food security.

The ideal of food security has developed over the last three decades and first appeared in the 1970s during discussion about the international school food crisis at a time of global food shortage. The main focus of these talks was primarily on food availability and price price stability of essential food items to some degree. At the 1970 world food summit, food

security defined as having food availability at all times. In 1986, the World Bank advanced the definition of food security by distinguishing between chronic food insecurity associated with problems of continuing structural poverty and transitory food insecurity which was a product of natural disasters and economic collapse (FAO, 1912). This definition was further broadened to include access of all people at all times to enough food for an active and healthy life. By 1990, the World Food Summit adopted a still more complex definition, which contained that "food security, at the individual, household, national, regional and global levels is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 2012).

Food security is achieved when every individual has reliable physical, social and economic access to enough safe, nutritious food that satisfies their dietary needs and food preferences, enabling them to lead an active and healthy life making it vital for agriculture. Despite regional disparities, this seasonal rainfall governs groundwater recharge, reservoir levels, and irrigation scheduling. Recent decades have shown mixed trends: while 55% of Indian tehsils witnessed an increase in monsoonal rainfall between 2012 and 2022, others, particularly in eastern states like Bihar, West Bengal, and Uttar Pradesh, have seen a significant decline. Increases in short-duration, high-intensity rainfall events, along with prolonged dry spells, are becoming more common, posing risks such as floods, droughts, and reduced agricultural productivity.

Agriculture in India remains heavily reliant on rainfall, especially for Kharif crops like rice. Pulses, and oil-seeds. According to the NSSO, over 56% of the workforce is engaged in agriculture, which contributes around 16% to the national GDP. Variability in monsoonal rainfall influences not only agricultural output but also rural livelihoods, food prices, and overall economic stability. Delayed or insufficient monsoon rainfall can postpone planting operations, depress crop yields, and reduce farm incomes, whereas excessive rainfall often results in flooding and extensive crop damage. Bankura District, situated in the western part of West Bengal, is largely characterized by rain-fed agriculture, with approximately 60-70 percent of cultivated land fully dependent on monsoonal precipitation. Major grain-fed crops in the district include paddy (particularly Aman rice), maize, groundnut, and pulses, while crops such as wheat, mustard, and vegetables cultivated during the Rabi season rely on supplementary irrigation. The southwest monsoon serves as the principal source of rainfall in the region; however, its increasing unreliability in recent years has contributed to crop stress and declining agricultural productivity. Focusing on such a region enables the generation of practical insights that can inform climate-resilient planning in comparable agro-climatic settings.

In this context, the present study seeks to analyse the trends and variability of monsoon rainfall over Chibombo District and to examine the relationship between southwest monsoon rainfall and rice production in the area. By integrating long-term monsoon rainfall data with rice production patterns, the study provides a comprehensive assessment of how changing precipitation regimes affect one of the region's most important staple crops. The findings are expected to contribute valuable knowledge for improving water resource

management, optimizing cropping decisions, and formulating adaptive strategies aimed at promoting climate-resilient agricultural development in Chibombo District.

2. Research Methodology
2.1 Research Design/Methods/Approach
The study adopted a descriptive research design to examine the effects of rainfall variability on household food security among small-scale farmers in Mungule Village, Chibombo District. A concurrent triangulation mixed-methods approach was utilized, combining quantitative and qualitative techniques to generate a comprehensive and robust understanding of the research phenomenon. Quantitative data were collected through surveys and analyzed using linear regression analysis and mean estimation to determine the relationship between rainfall variability and household food security indicators. Qualitative data were obtained through field research and interviews to capture farmers' experiences and perceptions regarding rainfall patterns and their impact on food security. The combination of both methods enabled triangulation, ensuring a deeper and more reliable interpretation of the findings.

Population refers to the universe of units from which a sample is selected. According to Babbie (1992), a study population is "the aggregation of elements from which the sample elements are actually selected." This study focused on Chibombo District, specifically in Mungule Village, which has a total population of 8,972 individuals, including 4,109 farmers, as reported in the 2022 Population and Housing Census. Mungule Village covers an area of approximately 10,187 square kilometers. According to the 2010 Census on Smallholder Farmers, the camp recorded a population of 3,845 individuals, of whom 867 were smallholder farmers. Although the 2022 Ward Statistical Report on Smallholder Farmers is yet to be published, an increase in the number of farmers is anticipated. Therefore, the target population for this study comprised all 4,109 farmers residing in Mungule Village, Chibombo District. For this study, the researcher utilized Purposive sampling to sample key farmers in Mungle village under Chibombo district.

A Sample size denotes the number of elements drawn from a target population to form a representative sample, indicating the quantity of sampling units to be surveyed or interviewed (Kothari, 1990). The study population comprised 4,109 farmers residing in Mungule Village, Chibombo District, as reported in the 2022 Population and Housing Census. From this population, a sample of 50 farmers was selected to participate in the study.

The sample size of 50 was determined using purposive sampling, which involves selecting participants who possess specific characteristics or knowledge relevant to the study objectives (Patton, 1990). This approach was considered appropriate, as the study aimed to gather in-depth insights rather than produce statistically generalizable results. The sample size was also influenced by resource availability, time constraints, and the need to achieve data saturation during analysis. The 50 participants were purposively selected to represent diverse farming experiences, gender, and socioeconomic backgrounds among farmers in Mungule Village. The researcher utilized thematic analysis as it looks at patterns of meaning in a data set. Thematic analysis takes bodies of data and groups them according to similarities in

other words, themes. These themes helped the research make sense of the content and derive meaning from it. Quantitative data will be presented using simple descriptive statistic methods including tables, percentages, pie charts, and linear regression analysis. Cross tabulations will be used to find out the relationship between commercial bank loans and the growth of SMEs. The data collected was computerized, sorted, edited, classified and coded. The resultant data was entered using statistical package STATA for analysis. This generated frequency tables for demographic and descriptive data. The relationship between the study variables was established using regression analysis. The study ensured that informed consent was acquired from the participants before engaging with them. This was done by asking the participants if they were willing to take part in the study after having explained to them what the study was about. Anonymity of the participants was also ensured by excluding their identity on the responses of the interview as well as when reporting the findings. To add on, the study did not inflicted any kind of harm on the participants as they were interviewed within their contexts.

3. Results/Findings
The study distributed a total of 68 questionaires. Of these 68 questionnaires, 50 were completed and returned, resulting in a response rate of 73.5%, which is considered adequate for rigorous analysis. In terms of gender composition, 66% of respondents (n = 33) were female, while 34% (n = 17) were male. This distribution highlights the greater involvement of female smallholder farmers, underscoring their significant contribution to agricultural production within the study area.
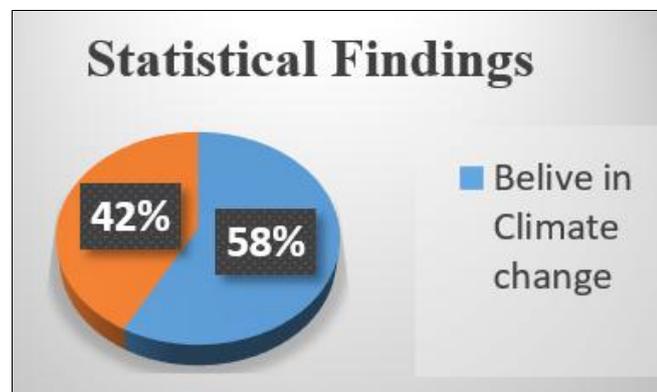
Source: Primary Data

Fig 1: Evidence of Climate Variability and Change

According to the researcher's findings on the aspect of Evidence of Climate Variability and Change, 58% of households perceive that the local climate has changed over the past 30 years.
Meteorological data confirms a 2°C increase in temperature and a 26.5% decline in rainfall between 1963 and 2010. There has been a rise temperatures and erratic rainfall patterns which clearly indicates climate variability, increasing stress on agricultural systems that depend on predictable weather.

Table 1: Presentation of results based on the adaptation strategies employed by small-scale farmers in response to climate change.

|	Frequency	%	Valid %	Cumulative %
Most important	26	52.0	52.0	52.0
Second important	22	44.0	44.0	96.0
Third important	2	4.0	4.0	100.0
Total	50	100.0	100.0	

Source: Primary Data

According to our findings on the aspect of Increased Frequency of Extreme Weather Events. It showed that farmers face dual climate threats both droughts and floods, which damage crops, reduce yields, and threaten food security.
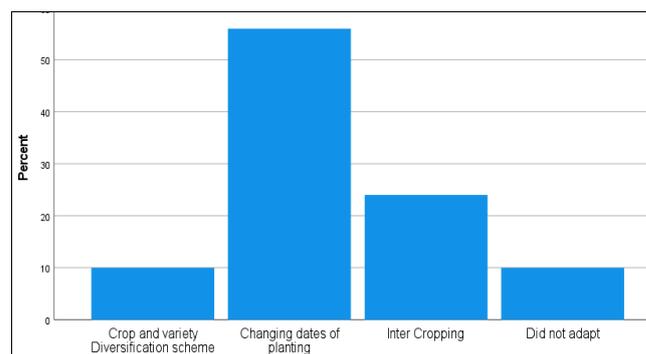
Source: Field Data, 2025

Fig 2: Adaptation Measures to Rainfall Change

The figure indicate the adaptation measures to rainfall by the participants. 56% (28) changing date of plant is the most important adaptation measure of rainfall, 24% (12) inter-cropping is also best adaptation measure of rainfall for them, 10% (5) adopt crop and variety diversification scheme while 10% (5) respondent's says they don't adapt any strategies.
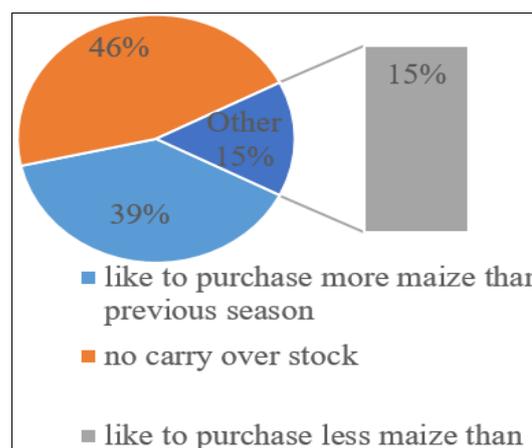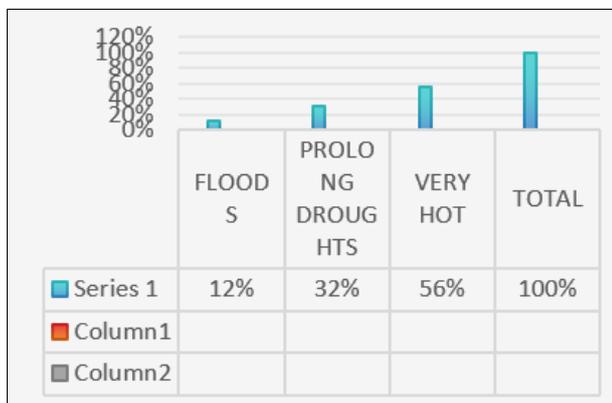

Source: Field Data, 2025

Fig 3: Impacts of Climate Change on Food Stability

The findings presented in Fig 3 indicate that 39 percent of households were likely to purchase more maize than in previous seasons due to reduced carryover stocks and low

crop yields. A majority of households (46 percent) reported having no carryover stocks, contributing to food instability. Conversely, approximately 15 percent of households were able to purchase less food, as they maintained relatively stable food reserves. However, most households faced difficulties in acquiring additional food stocks because their primary source of income from crop production was low. Overall, food instability is largely attributed to reduced agricultural production resulting from insufficient and erratic rainfall.

Source: Field Data, 2025

Fig 4: Weather Changes last 10 years

The figure indicates the weather changes over last 10 years of the participants. 56% (28) have been mostly affected by the very hot season, 32% (16) have been secondly affected by the prolonged drought while 12 %(6) have at least affected by floods.
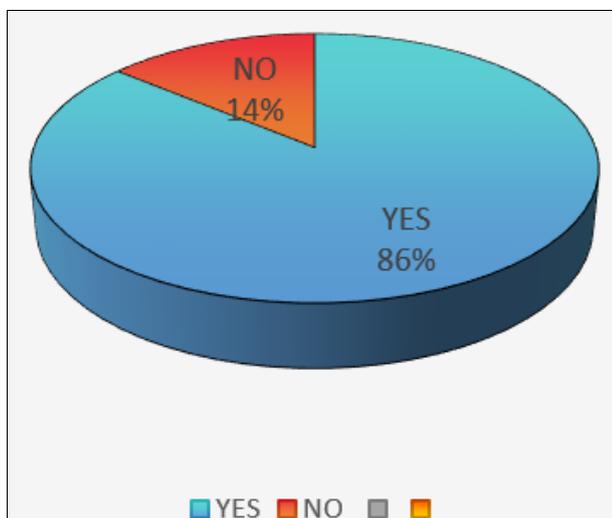
Source: Field Data, 2025

**Fig 5:** Knowledge and Awareness on Climate Smart Agricultural Practices

Finding in Figure shows that 86% (197) of the respondents are aware and have some basic knowledge on CSA practices. However, 14% (31) of the respondents noted that they lack awareness and no knowledge on climate smart agricultural practices. This implies that adoption of Climate

Smart Agriculture may be a challenge thus the need to institutionalize structures that will be enable information reaching as many farmers as possible.

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Source: Primary Data

**Fig 6:** Institutions/Organization's that are working with you to provide Climate Change support

As shown in Figure, 100% (50) of the respondents says no any single institutions or organization provide them support regarding the climate change.
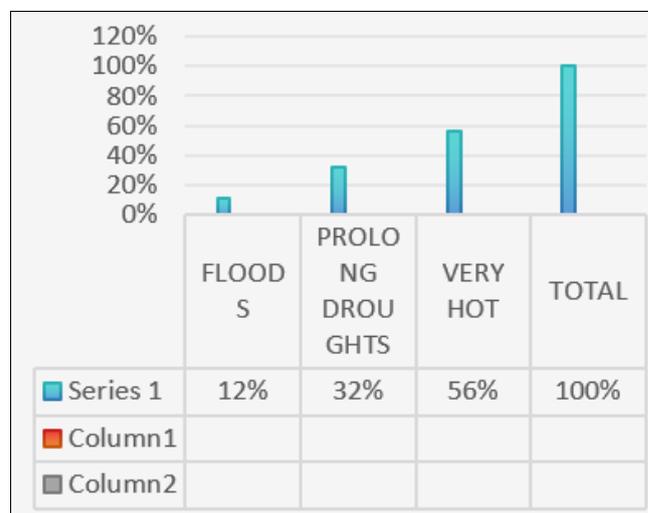
Source: Field Data, 2025

**Fig 7:** Weather Changes last 10 years

The figure indicates the weather changes over last 10 years of the participants. 56% (28) have been mostly affected by the very hot season, 32% (16) have been secondly affected by the prolonged drought while 12 %(6) have at least affected by floods.
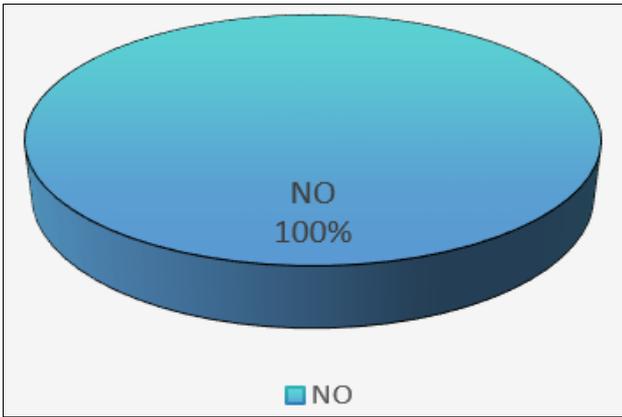
**Fig 8:** Information you get from extension about climate change support interventions makes a difference in your crop production

Findings in figure indicate that, 100% of the respondents have strong responded none of any climatic support invention was provided.
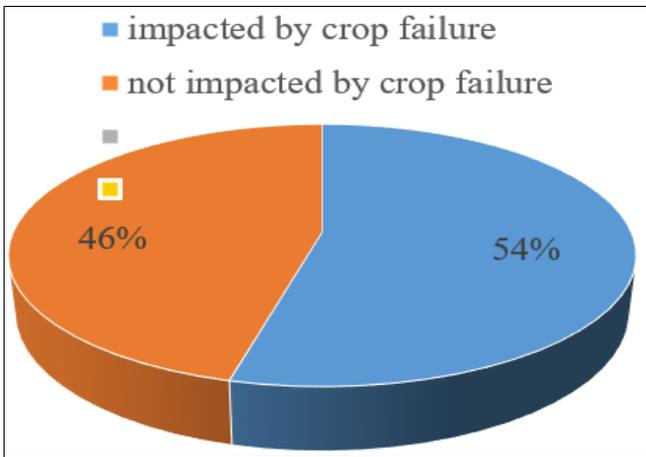
Fig 9: Climatic Impact on Community

The figure illustrates the climatic impacts on the participant community, showing that 54% (27) were primarily affected by crop failure, while 46% (23) experienced secondary impacts in the form of food insecurity.

	Severe impact	Moderate Impact	Low Impact
Floods	22%	15%	8%
Drought	15%	15%	12%
Series 3			
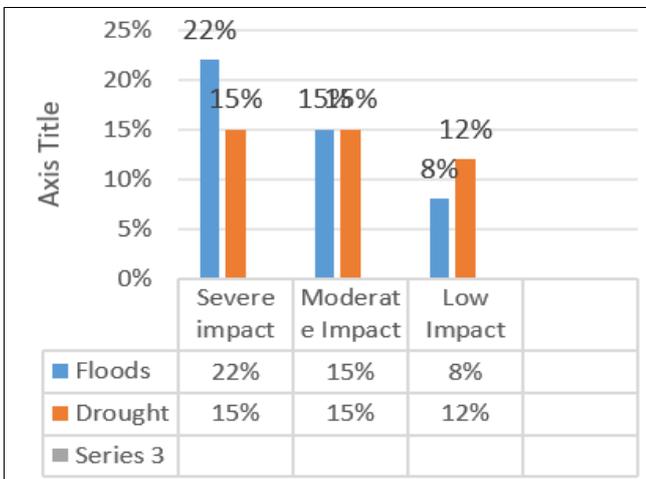
Fig 10: Shows Severity of Climate Change and Climate Variability Impacts

The research findings indicated that floods had the most severe impact on households, affecting 22 percent, followed by droughts, which impacted 17 percent. Additionally, 15 percent of households reported experiencing moderate effects from both floods and droughts. These results clearly show that the major climate induced hazards that were impacting agricultural production and household food security were floods and droughts.
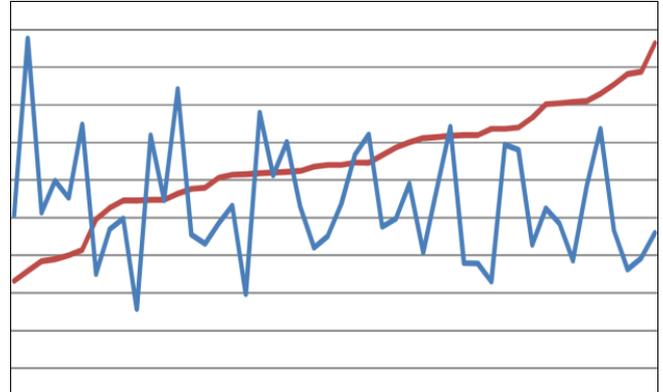
Fig 11: Rainfall Long-term Trend Analysis

According to climate data from the Zambia Meteorological Station, temperature in Mungule villag from 2010-2020,chbombo district, has risen by 2 degree Celsius from 1963-2010,while rainfall has fluctuated widely over the same period and dropped 26.5%due to alternating floods and droughts. Between 1963-2010 the area received 373.6mm to 593.9mm of rain-below the long-term average of 600mm,causing frequent dry spell and drought.at times rainfall exceeded 800mm(804-1415.5mm),leading to floods and flash floods. Studies (MTENR, 2007) shows region experiences severe droughts, water shortage along the caprivi strip making it the most vulnerable region to climatic change and variability.
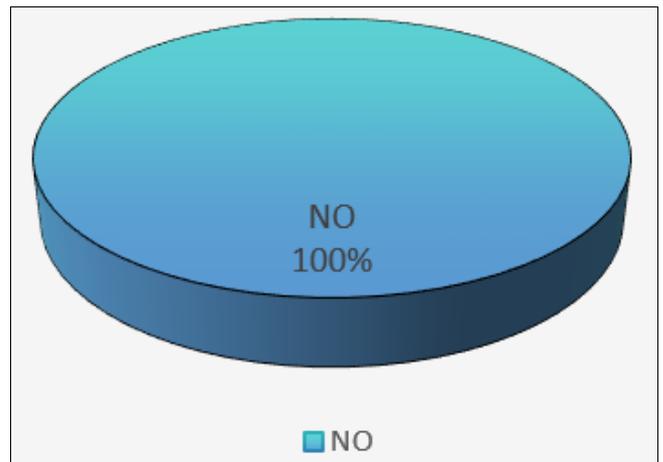
Fig 12: Adjustment in farming practice

Findings in figure indicate that, 100% of the respondents have strong responded none of any adjustment in farming practices. Through insurance and subsidies, the Zambian government protects farmers that own 2 hectares or less land from unpredictable events due to climate change which endanger their farming systems. This support enables the

farmers to minimize agriculture risks and avoid crop failure (Republic of Indonesia, 2013).

4. Discussion of Results
This section presents the findings from the descriptive and factor analyses conducted to investigate the adaptation strategies employed by smallholder farmers in response to climate change. The descriptive analysis provided a summary of the data, focusing on measures of central tendency and dispersion. The findings revealed that adaptation strategies had the highest mean score (2.52), indicating that most farmers adopted coping mechanisms to address climatic challenges, while the unstable Zambian climate, with the lowest mean score (1.512), contributed to low agricultural productivity.

Smallholder farmers in Mungule village face recurring droughts, pest outbreaks, and declining crop quality. In response, they practice agroforestry, soil and manure management, and inter-cropping to enhance productivity and environmental sustainability. However, limited financial resources restrict the extent of these practices. Unpredictable rainfall and insufficient access to climate information further complicate planting decisions. Establishing village information boards linked to BMKG data and improving technological dissemination are proposed to mitigate these challenges.

Water scarcity during dry seasons remains a major constraint, suggesting the need for inter-village water piping systems. Tree selection for agroforestry should consider transpiration rates; teak is suitable for Mungule's conditions, while paraserianthes is less appropriate. Low participation in crop insurance (AUTP) results from unaffordable premiums and limited awareness, highlighting the need for better education and more accessible insurance schemes. Delays in fertilizer subsidies and limited capital further hinder productivity.

Enhancing extension officers' capacity, promoting organic farming and supporting value-added processing such as chili-based products can strengthen smallholder resilience. Government facilitation through market protection, product standardization and financial assistance is essential to improve income stability and promote sustainable agricultural development.

5. Conclusion
The study examined the impacts of rainfall variability on agricultural production and household food security in Mungule Village, Chibombo District. An analysis of long-term meteorological records from 1963 to 2010 indicated an approximate 2°C increase in temperature alongside a 26.5 percent decline in rainfall, trends that are consistent with projections reported by the Intergovernmental Panel on Climate Change (IPCC). Socio-demographic characteristics, particularly age and gender, were found to influence the adoption of Climate-Smart Agriculture (CSA) practices, with the majority of adopters falling within the economically active age group of 34–41 years and both men and women participating in farm-level decision-making processes. Economic determinants, including landholding size, household income, and land tenure security, significantly affected CSA uptake, as higher income levels and land ownership enhanced farmers' willingness to invest in sustainable agricultural practices. Institutional factors, especially access to extension services and training

initiatives facilitated by non-governmental organizations, were critical in promoting awareness and implementation of CSA practices such as soil fertility management, improved crop and livestock varieties, agroforestry, and water harvesting techniques. Although smallholder farmers have initiated the adoption of CSA measures, the findings highlight the need to scale up and diversify these practices, alongside enhanced policy support through subsidies and agricultural insurance schemes, to improve resilience to climate change and strengthen household food security.

Maize farmers in Mungule Village exhibit limited willingness to participate in the Agricultural Insurance and Underwriting Programme (AUTP) for maize production. Although the insurance premiums are partially subsidized by the government, many farmers still consider them unaffordable. Moreover, the perceived benefits of AUTP are viewed as insufficient relative to the financial commitment required to pay monthly premiums. Given the relatively small landholdings of most farmers, compensation payouts are minimal, reducing the attractiveness of the scheme (Farmer Interview 1; Stakeholder Interviews 2, 6, 7, and 8). These findings suggest a need for clearer communication regarding the benefits of AUTP to enhance farmers' understanding and participation, as well as a reassessment of premium structures to improve affordability.

Additionally, a number of interviewed farmers cultivate chili, a high-value crop that is particularly susceptible to diseases during the rainy season. Farmers demonstrate a preference for inorganic pesticides due to their rapid effectiveness, which minimizes immediate crop losses, while organic alternatives are perceived as less efficient. Given the economic importance of chili, the introduction of crop insurance tailored to chili production could offer significant benefits by reducing farmers' exposure to production risks and ensuring access to capital for subsequent planting seasons.

Furthermore, challenges in the allocation and distribution of subsidized fertilizers persist, largely due to administrative inefficiencies that cause delays in delivery (Stakeholder Interview 4). Unsubsidized fertilizers are priced at nearly twice the subsidized rate, rendering them inaccessible to most smallholder farmers. Consequently, delayed or inadequate fertilizer application during the rainy season negatively affects crop performance and yields (Farmer Interviews 1 and 20).

Reduced product quality further constrains farmers' profitability, as illustrated by poor chili growth under suboptimal soil moisture conditions. Promoting small-scale agro-processing enterprises, such as home-based chili processing, could enhance value addition, increase farm incomes, and generate local employment. In this regard, stronger involvement of local government is essential to facilitate market access, support value chain development, and implement policies and subsidies aimed at food quality assurance and product standardization.

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