

ASSESSING THE IMPACT OF CLIMATE VARIABILITY ON HOUSEHOLD FOOD SECURITY AMONG SMALLHOLDER FARMERS IN MULANJE

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ABSTRACT

Climate variability is a major threat to food security among smallholder farmers in Mulanje District, where agriculture largely depends on rainfall. This study assessed the impact of climate variability on household food security, evaluated the effectiveness of adaptation strategies, and identified challenges affecting adaptation among smallholder farmers. A mixed-methods approach was used, involving household surveys of 100 farmers and analysis of rainfall data from 2016–2025. Data were analyzed using descriptive statistics, chi-square tests, ANOVA, correlation analysis and rainfall trend analysis in R.

The findings revealed high exposure to climate shocks, including erratic rainfall, droughts, floods, and rising temperatures. About 86% of households experienced moderate or severe food insecurity. Irrigation and education were found to significantly improve food security, while most households relied on reactive coping strategies such as reducing meals and casual labor. Major adaptation challenges included lack of money, limited access to farming inputs, inadequate extension support, and poor market access.

The study concludes that limited adaptive capacity worsens the impacts of climate variability on food security. It recommends improving irrigation access, strengthening agricultural extension services, and increasing support for climate-smart farming practices to enhance resilience among smallholder farmers.

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ACRONYMS/ABBREVIATIONS

ANOVA	Analysis of Variance
CSA	Climate-Smart Agriculture
DADO	District Agricultural Development Office
FAO	Food and Agriculture Organization
FISP	Farm Input Subsidy Program
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
NGO	Non-Governmental Organization
RCT	Randomized Controlled Trial
SLF	Sustainable Livelihoods Framework
SSA	Sub-Saharan Africa
VSLA	Village Savings and Loan Association
WFP	World Food Programme

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1. INTRODUCTION

1.1. Background

Climate variability is one of the principal challenges to global food security, with pervasive consequences for agricultural productivity, livelihoods, and economic stability. The impacts of climate variability—such as irregular rainfall patterns, temperature fluctuations, prolonged droughts, and extreme weather events—have manifested in low crop production, increased food prices, and elevated vulnerability among smallholder farmers (Lobell et al., 2008). The global food system is coming under pressure as climate-related shocks disrupt agricultural production, threatening the livelihoods of billions of people, the majority of whom live in developing countries where agriculture remains the backbone of the economy(Vermeulen et al., 2012).

Sub-Saharan Africa is one of the most affected regions due to its high reliance on rain-fed agriculture, which subject's farmers to high vulnerability to altering climatic conditions (Thornton et al., 2014). Unpredictable rainfall patterns, increased temperatures, and extreme weather events such as droughts and floods have led to low agricultural yields, food shortages, and malnutrition(Müller et al., 2011). Malawi, just like most countries in the region, has experienced unpredictable climatic conditions over the past few decades, leading to increased food insecurity among its rural populations (Joshua et al., 2016).

Agriculture provides the primary source of livelihood for over 80% of Malawi's population, and maize is the staple crop (Bhatti et al., 2021). However, the increased frequency of droughts, floods, and shifting rainfall patterns has severely impacted smallholder farmers, who rely on traditional farming methods with limited exposure to modern climate adaptation strategies (Twinomugisha & Mushy, 2021). The 2015–2016 El Niño-induced drought, for example, led to a 30% drop in maize production, plunging millions of Malawians into food insecurity (Boliko, 2019).

Mulanje District in southern Malawi is very vulnerable to climate variability due to its high dependence on rain-fed agriculture, high population density, and poor access to irrigation facilities (Sevillano Gutierrez, 2021). Farmers in Mulanje are exposed to increasingly unpredictable rainfall, frequent dry spells, and periodic floods that reduce crop production and undermine food security (Bezner Kerr et al., 2019). Smallholder farmers have no option but to adopt coping strategies such as crop diversification, conservation agriculture, and reliance on food aid during extreme climate events(Mango et al., 2018).

Despite several government and NGO interventions aimed at building resilience among farmers, financial constraints, weak agricultural policies, and limited access to climate information are some of the factors that hamper effective adaptation (Kamanga, 2021). This study, therefore, seeks to examine the impact of climate variability on food security among smallholder farmers in Mulanje, Malawi, with the aim of identifying feasible adaptation strategies to mitigate these challenges.

1.2. Problem Statement

Malawi's food security is increasingly exposed to climate variability, which destabilizes agricultural production, reduces household incomes, and limits access to adequate food supplies. Smallholder farmers in Mulanje District, who practice rain-fed agriculture, are most vulnerable to erratic rainfall patterns, prolonged droughts, and extreme weather events. These climatic changes have led to poor crop yields, food shortages, and increased dependency on external food aid (Joshua et al., 2016).

While adaptation strategies such as diversification of crops, irrigation, and agroforestry have been promoted, their adoption is low due to financial, infrastructural, and knowledge constraints (Mango et al., 2018). There is scarce empirical data on the exact impact of climate variability on food security in Mulanje and how smallholder farmers are adapting to such impacts. Therefore, this study seeks to fill this gap by evaluating the effectiveness of adaptation strategies adopted by smallholder farmers in Mulanje District and identifying the challenges that influence their adoption and success in improving food security.

1.3. Objectives

1.3.1. Main Objective

To examine the impact of climate variability on food security among smallholder farmers in Mulanje, Malawi.

1.3.2. Specific Objectives of the Study

i. To assess the impact of climate variability on household food security among smallholder farmers in Mulanje District.
ii. To evaluate the effectiveness of adaptation strategies adopted by smallholder farmers in improving household food security.
iii. To identify the challenges smallholder farmers, face when adopting climate adaptation strategies.

1.4. Research Questions

1. How does climate variability affect household food security among smallholder farmers in Mulanje District?
2. What adaptation strategies are adopted by smallholder farmers in response to climate variability?
3. How effective are these adaptation strategies in improving household food security?
4. What challenges do farmers face when adopting climate adaptation strategies?
5. Through what policy interventions can smallholder farmers be supported to build resilience to climate variability?

1.5. Significance of the Study

This study contributes to understanding the relationship between climate variability, agricultural adaptation, and food security among smallholder farmers in Malawi. By generating localized empirical evidence from Mulanje District, the research provides valuable insights into the effectiveness of adaptation strategies used by rural households to cope with climatic shocks.

The findings will assist policymakers, development organizations, and agricultural extension services in designing more targeted and context-specific interventions aimed at improving food security and climate resilience among smallholder farmers. Furthermore, the study contributes to the broader academic literature on climate change adaptation and rural livelihoods in Sub-Saharan Africa.

CHAPTER TWO: LITERATURE REVIEW

This chapter reviews existing literature relevant to climate variability, food security, and smallholder farmer adaptation. It begins with a global overview of climate impacts on agriculture, followed by a discussion of the four dimensions of food security. The review then narrows its focus to Sub-Saharan Africa and Malawi, examining key policies, programs, and on-the-ground challenges. Finally, the chapter presents the theoretical frameworks guiding this study and identifies specific knowledge gaps that the research aims to address.

2.1. Climate Variability and Its Global Impacts

Variability in climate is both a symptom and a result of fluctuations over time. Changes in temperature and precipitation levels also bring frequent changes in extreme weather such as droughts, floods and cyclones. According to IPCC (Intergovernmental Panel on Climate Change) report published in 2021, these variabilities directly affect productivity for agriculture and food chains. Studies show that precipitation patterns and anomalies of temperature lead to crop failures and lesser harvests and greatly increase vulnerability among farming communities (Holleman et al., 2020).

Globally, regions dependent on rain-fed agriculture are particularly at risk, as shifts in rainfall patterns and increased evapotranspiration reduce soil moisture and hinder crop growth(FAO, 2018). In Asia and Latin America, prolonged droughts have not only triggered crop failures but also contributed to rising food prices and social unrest (Holleman et al., 2020). Moreover, climate-induced migration is increasingly becoming a global phenomenon, affecting both rural and urban populations, especially in low-income and conflict-prone regions(Bhattacharya, 2023).

These cascading impacts illustrate that climate variability is not only a local or regional challenge but a significant global concern with implications for food security, economic stability, and human health worldwide.

2.1.1. Impacts on Agricultural Productivity

For agriculture, climate variability is where it causes most suffering and has a far-reaching effect for food security on a global scale. Research by (Verón et al., 2015) shows that temperature and precipitation changes negatively impact yields. Countries for instance suffer especially badly in areas of the tropics and parts of zones of the subtropics. Major staples such as maize, wheat and rice which literally feed billions stand out as especially at risk (Mbow et al., 2019) negatively affected harvest declines can easily lead to shortage of food, steep price hikes and rapid import dependence.

2.1.2. Socio-Economic Consequences

Economic and social impacts of climate variability are deeper. Societies living far from urban centers and with limited financial resources suffer quite a lot. Studies show erratic weather causes income loss and high poverty levels, even higher malnutrition rates (Schmidhuber & Tubiello, 2007). The combination of such events intensifies future resilience of households and their benefit with dire implications on the longer term.

2.2. Food Security: Concepts and Dimensions

According to the Food and Agriculture Organization (Kidane et al., 2006) food security is an overall state, where everybody can count on reliable supplies of food through production, circulation and trade. Four key elements determine this condition —Availability, Access, Utilization and Stability. Climate instability deeply impacts each of these elements. Through fluctuations in crop yields, stunting agricultural livestock productivity and rising post-harvest losses (Vermeulen et al., 2012) unstable climate conditions solidify the vulnerability of small family farmers. They depend on agriculture that relies full on rainfall and therefore suffer most from erratic rains and unusually long dry periods that all too often scuff their yield.

2.2.1. Availability

Food availability means having food supplies through production, distribution and exchange. Such dimension is impacted by variability of climate by decreasing crop production reducing productivity among livestock and triggering increased spoilage losses after harvest (Vermeulen et al., 2012). Farmers who rely on basically rain fed agriculture are especially disadvantaged by erratic rain and extended spells of dry weather which have a huge impact on crop output.

2.2.2. Access

Access depends on household income, food prices, and heightened market dynamics. Research suggests crop failure resulting from climate destabilization frequently raises food prices and makes essential foods unaffordable for the less well off. High price volatility proves a major issue particularly during lean times when food reserves are trivial and imports are key (Hossain et al., 2015). For example, in Malawi price variation is a major difficult especially aligning to lean periods when reserves are low. The staple food, maize, has undergone substantial price volatility in the past few years. Between August 2022 and August 2023 alone, retail maize prices skyrocketed by 146%, soaring from K320 up to K690 per kilogram. This dramatic increase was largely the result of speculative trading; severe crop damage caused by Cyclone Freddy; and a drought that affected the Northern Region, which normally supplies the country with its staple during the lean period (Times, 2023). The Festival of Malawi's maize price 2023 featured 104% higher prices than in the same period in 2022. At the start of this year, maize prices rose 24% from January to February, hitting K633/kg. The price spike was attributed to "profound shortages" in the national reserve and poor harvests.

2.2.3. Utilization

Utilization is concerned with how food is distributed and metabolized within the human body. This element is compromised by broad variety of foods promotion, food safety and nutritional education. Climate variability reduces variety of foods and impacts utilization and nutritional deficiencies especially on those particularly vulnerable such as children and pregnant women (Pinstrup-Andersen, 2009).

2.2.4. Stability

Stability policy aims to ensure supply of availability, access and utilization remain constant over time. Climate irregularities threaten stability by intensifying the frequency and severity of extreme weather events and thereby creating fluctuations in food supply and household incomes (Onyeaka et al., 2024). Recurring droughts and flooding in Malawi result in recurrent food crises thus requiring emergency interventions and external food aid. In Malawi, for instance, drought conditions induced by El Niño in early 2024 caused maize harvests to plummet nearly 23% below the five-year average. The shortfall had a devastating effect on national food availability and approximately 9 million Malawians—roughly 40% of us—faced acute food insecurity. Despite the government and various humanitarian organizations attempting to stem the tide of hunger and desperation, El Niño was doing us no favors (WFP, 2024a). In the north, flooding and landslides were doing the Elderlies no favors either. They had displaced over 14,000 people and destroyed homes, croplands, and lives (WFP, 2024a). Similar trends are seen across Southern Africa. The 2023–2024 El Niño event caused widespread harvest failures in Zimbabwe, Zambia, and Mozambique, where more than 70% of the population relies on rain-fed agriculture. The compounded impacts of drought and flooding resulted in soaring food prices and heightened dependence on external food assistance (WFP, 2024b).

2.3. Climate Variability and Food Security in Sub-Saharan Africa

Small farmers in Sub-Saharan Africa (SSA) suffer the most from climate instability because they rely heavily on rain fed agriculture and limited access to adaptation resources (Thornton et al., 2014). Studies suggest that prolonged droughts and irregular rainfall in tandem with rising temperatures have all but degrading yields, shortage of food and malnutrition (Lobell et al., 2008). Proposed adaptive strategies for mitigation such as improved irrigation and development of drought resistant crops and warning systems.

2.3.1. Adaptation Strategies

Adaptation strategies are critical in lessening the impacts of climate variability. Studies point to the high importance of smart agriculture approaches that mix conserving soil and vegetation like conservation farming along with agroforestry; using crop varieties that are more resistant to climate shocks (Sutherland et al., 2011). Large investments in irrigation infrastructure and improved weather forecasting also ranks high as we improve the resilience of small farmers that live in Sub-Saharan Africa (Ariom et al., 2022).

2.4. Climate Variability and Food Security in Malawi

Malawi is highly vulnerable to variability in climate; frequent droughts and floods disrupt agricultural production. Research by Zulu (n.d.) reports significant food insecurity for resource users in Mulanje due to erratic climate. Studies also show that maize – a staple crop – suffers most from drought and irregular rainfall episodically resulting in many shortages of food (Simtowe et al., 2019). Policies like smart agriculture and government programs creating food assistance have already been introduced, but challenges remain. Need is there to assess lasting effectiveness.

2.4.1. Policy and Institutional Responses

Government in Malawi, backed by other international entities has introduced policy interventions aimed at improving security, enhancement of resilience. Programs like Farm Input Subsidy Program (FISP) and smart agriculture initiatives have presented mixed results (Dorward et al., n.d.).

2.4.2. Farm Input Subsidy Program (FISP)

This is one of Malawi's most well-known agricultural programs, providing subsidized seeds and fertilizer to increase smallholder output. When it was first introduced in 2005–06, it was said to have increased maize yields and improved national food security. But over time, FISP has yielded inconsistent outcomes. Even while it helped some households, particularly in the beginning, enduring problems like inadequate beneficiary targeting, ineffective logistics, corruption, and an excessive dependence on chemical fertilizers have caused worries. These issues have weakened long-term sustainability by contributing to soil degradation. Furthermore, as the most vulnerable farmers are frequently left out of the program's advantages, equity concerns have surfaced. Therefore, although though FISP is still a part of Malawi's food policy, concerns regarding its long-term sustainability and efficacy in promoting inclusive agricultural expansion still exist.

2.4.3. Smart Agriculture Initiatives

Smart Agriculture in Malawi are designed to build resilience to climate variability by promoting climate-smart agricultural (CSA) practices such as conservation agriculture, agroforestry, improved seed varieties, and irrigation systems. These strategies seek to improve adaptation, raise productivity in a sustainable manner, and, when practical, lower greenhouse gas emissions. The overall effects of such methods have been mixed, despite mounting evidence that they can increase yields, stabilize food production, and lessen susceptibility to climate shocks like floods and droughts. Low adoption rates have been a significant problem, mostly because of restricted access to resources including loans, extension services, agricultural inputs, and information. Furthermore, a lot of smallholder farmers are unable to invest in these techniques due to financial limitations or a lack of technical expertise. Because of this, smart agriculture projects in Malawi's rural communities have not yet realized their full potential, despite their promise.

2.4.4. Local Implementation in Mulanje District

While the Farm Input Subsidy Program (FISP) was originally created to increase agricultural productivity, its implementation in such places as Mulanje district has faced numerous problems. The issue of reduced beneficiary coverage is prevalent, with some of the studies had identified the problem as targeting inefficiencies that were caused by the poorly defined selection criteria, thus the intended beneficiaries were not reached by the program (Lunduka et al., 2013). Moreover, the late distribution of agricultural inputs resulted in farmers sowing uncertified or improved varieties of seeds which, in combination with climate disruptions, has seriously affected the harvests (Lunduka et al., 2013). At the same time, a number of local farmers still could not access the inputs because of various reasons such as corruption and mismanagement—diversion and leakage of inputs (Lunduka et al., 2013).

In the meantime, Mulanje is still far from becoming a model of Climate-Smart Agriculture (CSA). The progress is narrow even though local people receive education through many channels; a few surveys demonstrate that the sown conservation agriculture plots in Malawi are very insufficient (Marambanyika, 2022). The major problems are related to a shortage of awareness, access to finance, and land security as well. Furthermore, the conflicting information given by various agricultural extension outlets has left farmers with no clarity on the best practices to adopt due to the overall frequency change (Marambanyika, 2022). The venturing of these obstacles in the distributed way reveals that national models are working but still, they are not effective at the local level except where more place-based interventions are necessary.

2.5. Theoretical Frameworks and Models

A number of key theoretical frameworks help explain the relationship of variability in climate and food security: Sustainable Livelihoods Framework (Chambers & Conway, 1992) offers insights into how households manage climate stress through diverse livelihood strategies; Vulnerability and Resilience Framework (Adger, 2006) studies adaptive capacity and socioeconomic factors influencing resilience towards climate shocks. Models guide understanding of food security dynamics facing such variability.

2.5.1 Sustainable Livelihoods Framework (SLF)

The Sustainable Livelihoods Framework (SLF), developed by Chambers and Conway (1992), offers a holistic approach to analyzing how households respond to climate stress through various livelihood strategies. It focuses on five key capitals—natural, physical, human, social, and financial—which collectively shape resilience and adaptability. SLF is widely applied to assess the impact of climate-smart agricultural practices, such as irrigation and soil management, on rural livelihoods. It has also been integrated with Climate-Smart Agriculture (CSA) in initiatives like Climate Smart Villages (CSV) to evaluate sustainability outcomes. Its main strengths lie in its comprehensive perspective and ability to pinpoint specific vulnerabilities within livelihood systems.

2.5.2. Vulnerability and Resilience Framework

The framework focusses on how a community's susceptibility to climatic variability is determined by exposure, sensitivity, and adaptive capacity. It draws attention to how much climatic shocks influence people and systems, how much it affects their ability to adapt and recover, and how much it affects their livelihoods. The approach, which emphasizes how socioeconomic variables like inequality and governance shape adaptive capacity, is commonly used in studies on disaster risk reduction and agricultural resilience. Its strength is in bringing social factors into the conversation about climate adaptation and providing useful information for creating policies that will increase resilience.

2.5.3. Comparison of Models

Table 1 : Comparison of models

framework	focus area	strengths	common usage in studies
Sustainable Livelihoods Framework	Household-level livelihood strategies	Comprehensive analysis of resources	Widely used in CSA studies
Vulnerability & Resilience Framework	Adaptive capacity to climate shocks	Focus on exposure, sensitivity, adaptation	Common in disaster risk reduction studies

Because of its comprehensive approach that takes into account several aspects of livelihoods, the Sustainable Livelihoods Framework (SLF) is more frequently utilized in research pertaining to food security under climatic variability. It works especially well for assessing how interventions like Climate-Smart Agriculture affect rural populations. For examining more comprehensive systemic hazards and adaptive capabilities at the regional or national level, the Vulnerability and Resilience Framework is recommended.

2.6. Knowledge Gaps and Areas for Further Research

Despite extensive research on climate variability and food security in Malawi, there remains limited localized empirical evidence evaluating the effectiveness of adaptation strategies adopted by smallholder farmers in specific districts such as Mulanje. Most existing studies focus on broader regional or national analyses and often do not examine whether these strategies translate into improved food security outcomes at the household level. This study therefore seeks to fill this gap by providing district-level evidence on the effectiveness of adaptation strategies and identifying the factors that influence their adoption and success among smallholder farmers.

CHAPTER THREE: METHODOLOGY

This chapter outlines the methodological approach used to investigate the impact of climate variability on food security among smallholder farmers in Mulanje District. It describes the study area, justifies the mixed-methods research design, and details the sampling strategy, data sources and procedures for variable and index construction. The chapter also explains the statistical techniques employed for data analysis, including descriptive statistics, chi-square tests, ANOVA and correlation analysis. It concludes with a discussion of ethical considerations and the limitations encountered during the research process.

3.1 Study Area

The study was conducted in Mulanje District, located in the Southern Region of Malawi. Mulanje lies between latitudes 15°38' and 16°05' South and longitudes 35°20' and 35°50' East. The district covers an area of approximately 2,056 square kilometers and has an estimated population of over 500,000 people, with the majority engaged in smallholder agriculture.

Mulanje District was purposively selected for this study due to its high vulnerability to climate variability. The district is characterized by:

- Rain-fed agriculture dependence: Over 90% of farmers rely on seasonal rainfall
- High population density: One of the most densely populated rural districts in Malawi
- Climate exposure: History of droughts, floods, erratic rainfall, and strong winds
- Limited irrigation infrastructure: Most farmers lack access to supplementary water sources

The district experiences a subtropical climate with annual rainfall ranging from 1,145 mm to 4,312 mm, as shown in the secondary yield data collected from Mulanje DADO records. Maize is the dominant staple crop, with yields fluctuating considerably depending on seasonal rainfall patterns.

As illustrated in Figure 1, the district is divided into several Traditional Authority areas, each with varying agro-ecological conditions.

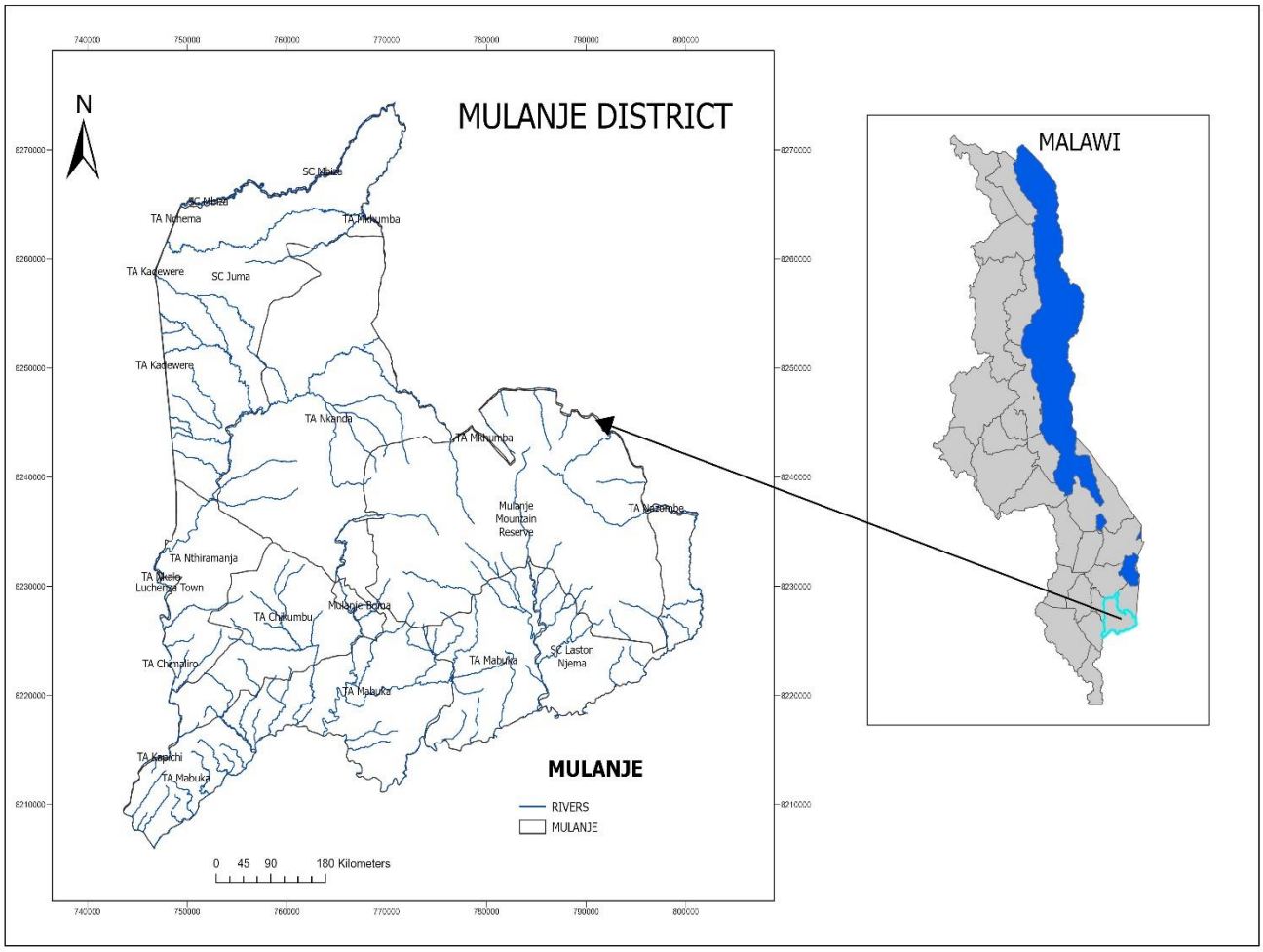


Figure 1: Map of Malawi with Mulanje magnified showing its subdivisions

3.2 Research Design

This study adopted a mixed-methods research design combining quantitative and qualitative approaches.

Table 2 : Research design

Component	Purpose
Cross-sectional household survey	Collect primary data on food security, adaptation practices, and challenges
Secondary data analysis	Analyze 10 years of rainfall records (2016 - 2025)
Statistical hypothesis testing	Test associations between variables

The mixed-methods approach allowed for triangulation of findings and provided both breadth (through survey data) and depth (through statistical testing) of analysis.

3.3 Sampling Strategy

3.3.1 Target Population

The target population comprised of smallholder farming households in Mulanje District who practice rain-fed agriculture and have resided in the district for at least five years.

3.3.2 Sample Size and Sampling Technique

A sample of 150 households was selected using a multi-stage stratified random sampling technique:

Step 1: Purposive selection of Mulanje District (high climate vulnerability)

Step 2: Stratification by traditional authority areas to ensure geographic representation

Step 3: Random selection of villages within each stratum

Step 4: Systematic random sampling of households within selected villages

The achieved sample of 100 households (67% response rate) resulted from non-response (30 households), incomplete questionnaires (15 households) and logistical constraints (5 households). A post-hoc power analysis (G*Power, $\alpha=0.05$, effect size $f=0.30$) confirmed 80% power for detecting medium effects, consistent with comparable studies in the region ((Bezner Kerr et al., 2019; Mango et al., 2018)). The reduction thus does not compromise the validity of the findings.

3.4 Data Sources

3.4.1 Primary Data

Table 3: Primary Data

Variable Category	Specific Variables
Demographics	Sex, age group, education level, household size
Livelihood assets	Land holdings (hectares), livestock ownership, main livelihood sources
Climate exposure	Perceived changes in rainfall, temperature, droughts, floods, strong winds
Adaptation strategies	Irrigation practice, cropping adjustments, farming practices
Coping strategies	Meal reduction, casual labor, borrowing, food aid, sleeping hungry
Food security	Months of food shortage per year

3.4.2. Secondary Data

Secondary data on rainfall were obtained from Mimosa Station; Rainfall data (2016-2025). The rainfall data were used to assess annual rainfall variability and climatic trends in Mulanje District. These data complemented household survey responses by providing objective evidence of climate variability within the study area.

3.5. Variable Construction and Index Development

To improve comparability among indicators measured on different scales, variables were standardized using z-scores before index construction. Equal weighting was then applied due to the absence of established empirical evidence supporting differential weighting of indicators.

3.5.1. Food Security Classification

Following the methodology in Step 10: Food Security Classification of the analysis, food security status was constructed based on months of food shortage reported by households.

The categorization procedure can be represented as follows:

$$FSi = \begin{cases} 1, \ if \ food \ shortage \leq 2 \ months \\ 2, \ if \ food \ shortage \ is \ 3-5 \ months \\ 3, \ if \ food \ shortage \ is \geq 6 \ months \end{cases}$$

Where:

- FSi = Food security status of household (i)
- 1 = Food secure
- 2 = Moderately food insecure
- 3 = Severely food insecure

The food security index served as the principal dependent variable in the study and was used in subsequent chi-square tests, ANOVA analysis and cross-tabulation procedures examining relationships between food security and household adaptation variables.

The approach was considered appropriate because food shortages represent a direct and practical indicator of household vulnerability among smallholder farming households' dependent on seasonal agricultural production.

3.5.3. Climate Variability Exposure Index

The climate index was constructed based on household-reported exposure to seven climate shocks:

- Late onset of rains
- Early end of rains
- Increased temperatures
- Droughts
- Floods
- Strong winds
- Unpredictable seasons

Each shock was coded as binary (0 = not experienced, 1 = experienced), and the climate index represented the total number of climate shocks experienced by each household. the climate index ranged from 3 to 7, with a mean of 6.05 (SD = 1.18).

The climate variability exposure index for each household was then computed as:

$$C\ Ii\ = \sum_{j=1}^{7} X_j$$

Where:

- $C\ Ii$ = Climate variability index for household (i)
- X_j = climate shock indicator

The index was later used in descriptive statistics, correlation analysis, and comparison of mean climate exposure across food security groups.

3.5.4. Coping Index

The coping index measured the number of coping strategies employed by households during food shortages, the seven coping strategies included:

1) Reduce meals per day
2) Do casual labor
3) Borrow from others
4) Buy food
5) Sleep with hunger
6) Receive food aid
7) Other strategies

Coping Index Formula

$COPi = \sum_{j=1}^{n} C_j$

Where:

$COPi$ = Coping index for household (i)

C_j = coping strategy indicator

n = total number of coping strategies

3.5.5. Adaptation Capacity Index

The adaptation index combined both farming adaptations and coping responses. the index ranged from 1 to 6, with a mean of 3 (SD = 0.99).

Adaptation Capacity Formula

$ADPi = \sum_{j=1}^{n} A_j$

Where:

- $ADPi$ = Adaptation index for household (i)
- A_j = adaptation strategy indicator
- n = total adaptation strategies

3.5.6. Objective 3: Challenges Index

For Objective 3, a challenges index was created from 12 constraint variables (Question 28 of the survey). Each challenge was binary-coded (1 = reported, 0 = not reported), and the index represented the total number of challenges per household.

Adaptation Challenges Formula

$CHi = \sum_{j=1}^{n} H_j$

Where:

- CHi = Challenges index for household(i)
- H_j= challenge indicator
- n = total reported challenges

Challenge levels were categorized as:

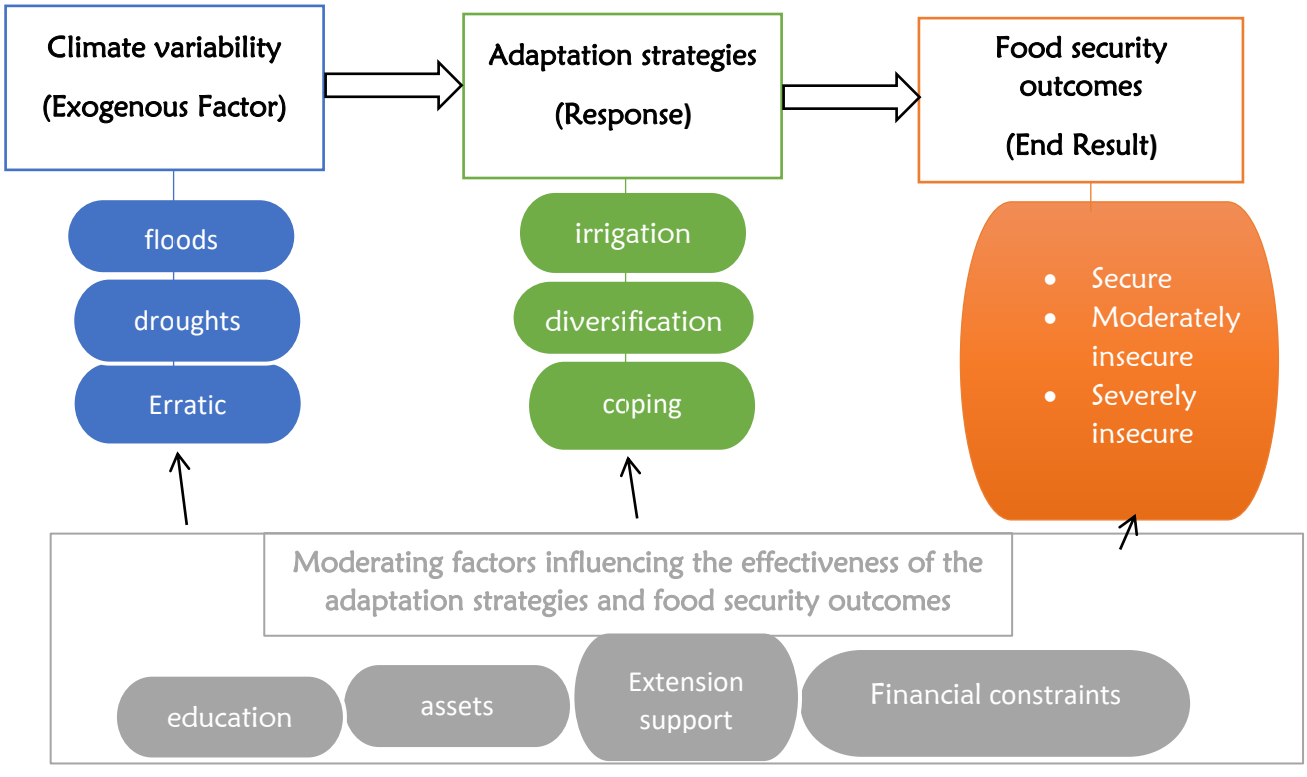
Table 4 : Challenge levels

Challenge Level	Index Range	Households	Percentage
Moderate	4-6 challenges	15	15%
High	7+ challenges	85	85%

3.6 Analytical Framework

This study was guided by the **Sustainable Livelihoods Framework (SLF)** developed by Chambers and Conway (1992). The SLF provided a holistic lens for understanding how households mobilize five capital assets (natural, physical, human, social and financial) to respond to climate variability and achieve food security outcomes.

Figure 2 : Conceptual Framework for the Study



The framework guided the statistical analyses for each objective:

Table 5 : Objective and Analysis

Objective	Analytical Approach
Objective 1	Descriptive statistics, Rainfall trend analysis, comparison of mean climate index across food security groups
Objective 2	Chi-square tests, ANOVA, comparison of adaptation means
Objective 3	Descriptive statistics, frequency analysis, ranking of challenges, Pearson correlation

3.7. Statistical Analysis Methods

3.7.1 Descriptive Statistics

Descriptive statistics (frequencies, percentages, means, standard deviations, minimum, maximum) were computed for all variables.

3.7.2. Chi-Square Tests of Association

Chi-square tests were used to examine associations between categorical variables:

Table 6: Categorical variables

Test	Purpose
Irrigation vs food security	Determine if irrigation users have better food security outcomes
Livestock vs food security	Determine if livestock ownership improves food security
Education vs food security	Determine if education level is associated with food security

The significance level was set at $\alpha = 0.05$.

3.7.3. Analysis of Variance

One-way ANOVA was used to test whether adaptation capacity differed significantly across food security groups. The ANOVA technique was selected because:

- the dependent variable (adaptation index) was continuous,
- while the grouping variable (food security status) consisted of three categorical groups:
    - food secure,
    - moderately food insecure,
    - and severely food insecure.

3.7.4. Pearson Correlation

Pearson correlation analysis was conducted to assess the relationship between climate index and coping index.

3.7.5. Ranking Analysis

For Objective 3, challenges were ranked by the percentage of households reporting each constraint,

3.7.6. Rainfall Trend Analysis

Annual rainfall totals were computed from monthly rainfall records and analyzed using descriptive statistics and trend graphs. The rainfall trends were compared with farmer perceptions of climate variability and reported agricultural impacts obtained from questionnaire data.

3.8 Data Processing and Software

All data were analyzed using R statistical software (version 4.x). The following R packages were used: readxl for importing Excel data, dplyr for data manipulation, ggplot2 for data visualization, and tidyr for data cleaning.

The data analysis process involved a systematic sequence of steps. First, data entry and cleaning were performed to ensure accuracy, which included checking for missing values, correcting inconsistent entries, and validating responses against questionnaire ranges. Variable coding and recoding transformed raw responses into analyzable formats, such as converting categorical answers (e.g., types of climate shocks) into binary indicators and grouping continuous variables (e.g., months of food shortage) into ordinal categories. Analytical indices were constructed by standardizing indicators using z-scores and applying equal weighting; these included the food security classification, climate variability exposure index, coping index, adaptation capacity index and challenges index. Descriptive statistical analysis was conducted to compute frequencies, percentages, means, standard deviations, and ranges for all variables, providing an overview of sample characteristics and distributions. Inferential statistical testing was applied using chi-square tests of association (for categorical variables), one-way ANOVA (to compare adaptation capacity across food security groups) and Pearson correlation (to examine relationships between climate stress and coping). Graphical presentation of findings was generated using ggplot2 to create bar charts, grouped bar charts, stacked bar charts and trend lines that visually support the statistical results. Finally, interpretation of results was carried out by comparing statistical outputs with the study's objectives, contextualizing findings within existing literature, and drawing conclusions anchored in the Sustainable Livelihoods Framework.

3.9 Ethical Considerations

Ethical considerations were carefully observed throughout the research process in order to protect the rights, dignity, privacy and welfare of study participants. The study adhered to accepted ethical principles governing social science and household survey research.

1. Informed consent: All participants provided verbal or written consent before participation
2. Confidentiality: Confidentiality of respondent information was maintained throughout the research process. Personal identifiers such as names and private household information were not included in the analysis or reporting of findings.
3. Voluntary participation: Farmers could decline or withdraw without penalty.
4. Minimization of Harm: The study did not involve physical experimentation or procedures likely to expose respondents to physical harm. However, because food insecurity and livelihood challenges may be sensitive topics for some households, efforts were made to conduct interviews carefully and respectfully in order to minimize emotional discomfort.

3.10 Limitations

Despite the strengths of the study design and analytical procedures, several limitations were encountered during the research process. These limitations should be considered when interpreting the findings of the study.

One major limitation relates to the cross-sectional nature of the study. Since data were collected at a single point in time, the study was limited in its ability to establish direct causal relationships between climate variability and household food security outcomes. The study therefore focused primarily on identifying associations and observable relationships among variables rather than proving causation.

Another limitation involved reliance on self-reported household information. Some respondents may not have accurately remembered past climatic events, food shortages, or adaptation activities, leading to potential recall bias. In addition, household perceptions of climate variability may differ among respondents based on personal experiences, education levels, or access to climate information.

The study also experienced non-response during household data collection. Although the initial target sample size was 150 households, only 100 households completed the survey and provided usable responses for analysis. The reduction in achieved sample size may have reduced the statistical power of some inferential analyses and affected representativeness of findings.

Another limitation concerns the adaptation index used in the study. Some overlap existed between coping strategies and adaptation measures because vulnerable households often combine immediate survival responses with longer-term livelihood adjustments. Consequently, the distinction between reactive coping behavior and proactive adaptation practices was not always entirely clear during index construction and interpretation.

The study was also geographically limited to Mulanje District. As a result, findings may not be fully generalizable to all farming communities in Malawi because climatic conditions, livelihood systems and socio-economic characteristics differ across regions.

Despite these limitations, several measures were undertaken to improve the credibility and reliability of the findings. These included triangulation of household survey data with secondary climatic records, application of appropriate statistical techniques and systematic data cleaning and analysis procedures.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Introduction

This chapter presents the results of the study organized according to the three specific objectives. Each section presents statistical findings followed by discussion in the context of existing literature and the Sustainable Livelihoods Framework.

4.2. Socio-Demographic Characteristics of Respondents

4.2.1. Household Characteristics

Table 7: Socio-Demographic Profile of Respondents

Characteristic	Category	Frequency	Percentage
Sex	Female	67	67%
	Male	33	33%
Education	High	1	1%
	Medium	33	33%
	Low	66	66%
Household Size	Mean	4.87 persons	-
	Range	2-8 persons	-

The predominance of female-headed or female-managed farming households aligns with (Bhattacharya, 2023), who noted that over 80% of Malawi's population relies on agriculture and that women play a central role in smallholder farming. The low education level mirrors findings by(Kamanga, 2021) who identified education as a key determinant of adaptive capacity. The average household size of 4.87 is similar to national rural averages reported by (Joshua et al., 2016).

4.2.2. Livelihood Sources

Table 8: Main Sources of Livelihood

Livelihood Source	Number of Households
Farming	100
Casual labor	74
Business	59
Employment	7

All 100 households engaged in farming as their primary livelihood, confirming the district's dependence on agriculture as noted by (Bezner Kerr et al., 2019) The high proportion engaged in casual labor (74%) indicates livelihood diversification as a coping mechanism. (Mango et al., 2018) similarly found that smallholder farmers in central Malawi often supplement farming with casual labor to smooth consumption during lean seasons. This strategy is consistent with the Sustainable Livelihoods Framework's emphasis on multiple asset portfolios.

4.3. Objective 1: Impact of Climate Variability on Household Food Security

4.3.1. Rainfall Trend Analysis

Figure 3 presents the annual rainfall trend in Mulanje District from 2016 to 2025. The figure shows that annual rainfall fluctuated dramatically over the ten-year period. In 2016, rainfall was approximately 1,400 mm, rising sharply to over 2,200 mm in 2017, then dropping to around 1,200 mm in 2018. Another peak occurred in 2021 at approximately 2,200 mm, followed by a steep decline to under 900 mm in 2024, before recovering slightly to about 1,300 mm in 2025. The dashed red trend line indicates a marginal upward slope over the decade, but the most striking feature is the extreme year-to-year variability, with a range of more than 1,300 mm between the wettest and driest years.

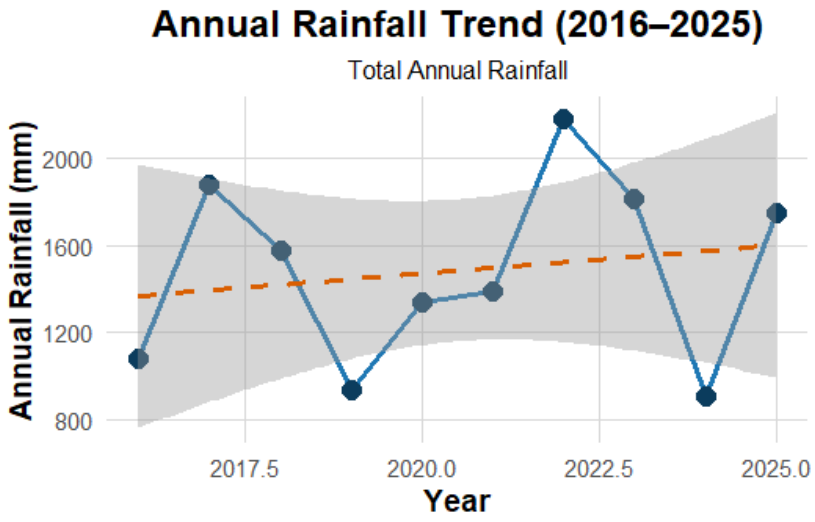


Figure 3: Annual rainfall trend in Mulanje

The rainfall trend analysis strongly validates the farmers' perceptions of severe climate variability. While the overall trend line shows a marginal increase in total annual rainfall, the extreme year-to-year volatility (from over 2,200mm in 2021 to under 900mm in 2024) explains why farmers report experiencing both devastating droughts and destructive floods within a single decade. This pattern is consistent with (Joshua et al., 2016) who documented increasing rainfall variability in semi-arid Malawi. (Thornton et al., 2014) also observed that Sub-Saharan Africa is experiencing more frequent extreme weather events, which directly undermine rain-fed agriculture.

4.3.2. Climate Variability Exposure

Table 9: Climate Index Summary

Statistic	Value
Mean	6.05
Standard Deviation	1.18
Minimum	3
Maximum	7

The mean climate index of 6.05 out of 7 indicates that households experienced an average of 6 different climate shocks, suggesting extremely high exposure to climate variability in Mulanje District. This level of multi-hazard exposure is higher than reported in some national studies(Simtowe et al., 2019). for example, Studies found that drought and irregular rainfall were the primary shocks in other parts of Malawi, but Mulanje's position near Mount Mulanje also exposes farmers to floods and strong winds, as noted by Sevillano Gutierrez (2021).

4.3.3. Food Security Distribution

Table 10: Food Security Status of Households

Food Security Status	Frequency	Percentage
Food Secure	14	14%
Moderately Insecure	61	61%
Severely Insecure	25	25%

Only 14% of households were food secure, while 86% experienced some form of food insecurity (61% moderate, 25% severe). This high prevalence of food insecurity (86%) is alarming but consistent with findings from WFP (2024a) which reported approximately 40% of Malawians facing acute food insecurity during El Niño years. The higher rate in this study (86%) may reflect the specific vulnerability of Mulanje District and the fact that "moderate insecurity" (3-5 months of shortage) captures households that are food secure part of the year but face lean season gaps.

4.3.4. Climate Variability Vs Food Security

Table 11: Mean Climate Index by Food Security Status

Food Security Status	Mean Climate Index
Food Secure	6.36
Moderately Insecure	6.16
Severely Insecure	5.60

Counter-intuitively, food-secure households reported the highest climate exposure (6.36), while severely insecure households reported the lowest (5.60). This unexpected finding requires careful interpretation. There are three possible explanations:

a. Food-secure households may be more aware of climate shocks because they monitor environmental conditions closely as part of proactive management. (Lobell et al., 2008) argued that better-resourced farmers often have greater climate awareness.
b. Severely food-insecure households may under-report climate shocks due to focusing on immediate survival needs rather than environmental perceptions, a phenomenon noted by (Müller et al., 2011) in vulnerable African communities.
c. Food-secure households may have experienced more climate shocks but possess greater adaptive capacity (irrigation, assets, education) that buffers the impacts. (Bezner Kerr et al., 2019) found similar results in Malawi, where households with diversified assets maintained food security despite higher exposure. This aligns with the Sustainable Livelihoods Framework—households with more capital assets can experience shocks without falling into food insecurity.

4.4. Objective 2: Effectiveness of Adaptation Strategies

4.4.1. Adaptation Strategies Adopted

Table 12: Coping Strategies Used by Households

Coping Strategy	Number of Households	Percentage
Reduce meals per day	92	92%
Do casual labor	71	71%
Borrow from others	69	69%
Buy food	24	24%
Sleep with hunger	24	24%
Receive food aid	20	20%

The most common "adaptation" strategies are actually reactive coping mechanisms (meal reduction, casual labor, borrowing) rather than proactive agricultural adaptations. Only 20% receive food aid, indicating limited external support. (Mango et al., 2018) similarly reported that Malawian smallholders often rely on consumption-smoothing strategies rather than long-term agricultural adaptations due to resource constraints.

4.4.3. Effectiveness Test: Adaptation vs Food Security

Table 13: Mean Adaptation Index by Food Security Status

Food Security Status	Mean Adaptation Index
Food Secure	2.93
Moderately Insecure	3.05
Severely Insecure	2.92

Table 14: ANOVA Results

Source	Df	Sum Sq.	Mean Sq.	F-value	p-value
Food security status	2	0.38	0.19	0.188	0.829
Residuals	97	97.62	1.01		

The ANOVA test is not significant ($p = 0.829$), indicating that adaptation capacity does not differ significantly across food security groups. This counter-intuitive finding that food-secure households do not have higher adaptation indices suggests that

a. The adaptation index may capture reactive coping, not proactive adaptation. Severely insecure households adopt many coping strategies (meal reduction, borrowing, casual labor) out of necessity, artificially inflating their adaptation scores. (Mango et al., 2018) warned against conflating coping with adaptation.
b. Food-secure households may use fewer but more effective strategies (e.g., irrigation, drought-tolerant seeds) rather than many desperate coping actions. (Simtowe et al., 2019) demonstrated that drought-tolerant maize varieties significantly improve yields and reduce risk, even if adopted by a minority.
c. This finding validates the framework's distinction between coping and adaptation, as noted by Thornton et al., (2014).

4.4.4. Specific Adaptation Strategy: Irrigation

Figure 4 presents a grouped bar chart comparing irrigation users and non-users across the three food security categories. The figure shows that among the 26 households using irrigation, 8 (31%) are food secure, 14 (54%) are moderately food insecure, and 4 (15%) are severely food insecure. Among the 74 non-irrigation households, only 6 (8%) are food secure, 47 (64%) are moderately food insecure and 21 (28%) are severely food insecure.

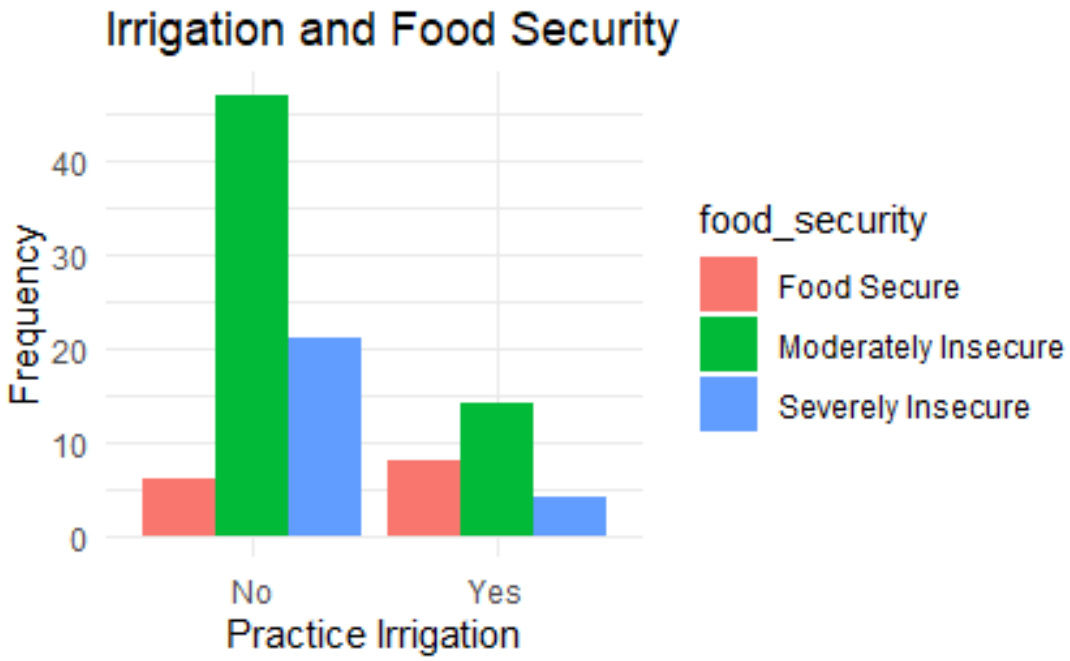


Figure 4: Irrigation vs Food Security Association

Table 15: Chi-Square Test Results

Statistic	Value
X^2	8.6515
Df	2
p-value	0.01322

The chi-square test is statistically significant (p = 0.013), indicating that irrigation practice is significantly associated with food security status. The significant association between irrigation and food security is consistent with (Ariom et al., 2022) who found that irrigation is one of the most effective climate-smart agriculture practices in Sub-Saharan Africa. (Bezner Kerr et al., 2019) also reported that access to small-scale irrigation improved dietary diversity and food security in Malawian farming communities. The low adoption rate (26%) in Mulanje highlights a major policy gap, as noted by (Twinomugisha & Mushy, 2021).

4.4.5. Specific Adaptation Strategy: Livestock

Table 16: Livestock Ownership by Food Security Status

Livestock	Food Secure	Moderately Insecure	Severely Insecure	Total
No	9	37	17	63
Yes	5	23	8	36

Table 17: Chi-Square Test Results

Statistic	Value
X^2	0.3089
Df	2
p-value	0.8569

Livestock ownership showed no significant association with food security. This may reflect the small scale of livestock keeping in the study area, where animals are often kept for savings rather than direct consumption. (Mango et al., 2018) similarly found that livestock alone does not guarantee food security unless integrated with crop production and market access.

4.4.6. Education vs Food Security

Table 18: Education Level by Food Security Status

Education	Food Secure	Moderately Insecure	Severely Insecure	Total
High	1	0	0	1
Medium	8	21	4	33
Low	5	40	21	66

Table 19: Chi-Square Test Results

Statistic	Value
X^2	14.017
Df	4
p-value	0.00724

The strong positive association between education and food security echoes (Kamanga, 2021) who identified education as a critical enabler of climate adaptation. Educated farmers are more likely to access extension services, adopt improved technologies, and diversify income sources. (Lunduka et al., 2013) also noted that education influences effective participation in input subsidy programs.

Figure 5 provides a stacked bar chart showing the composition of food security status by education level (low, medium, high). The figure reveals that among the single household with high education, 100% are food secure. Among the 33 households with medium education, 8 (24%) are food secure, 21 (64%) moderately insecure, and 4 (12%) severely insecure. Among the 66 households with low education, only 5 (8%) are food secure, while 40 (61%) are moderately insecure and 21 (32%) are severely insecure.

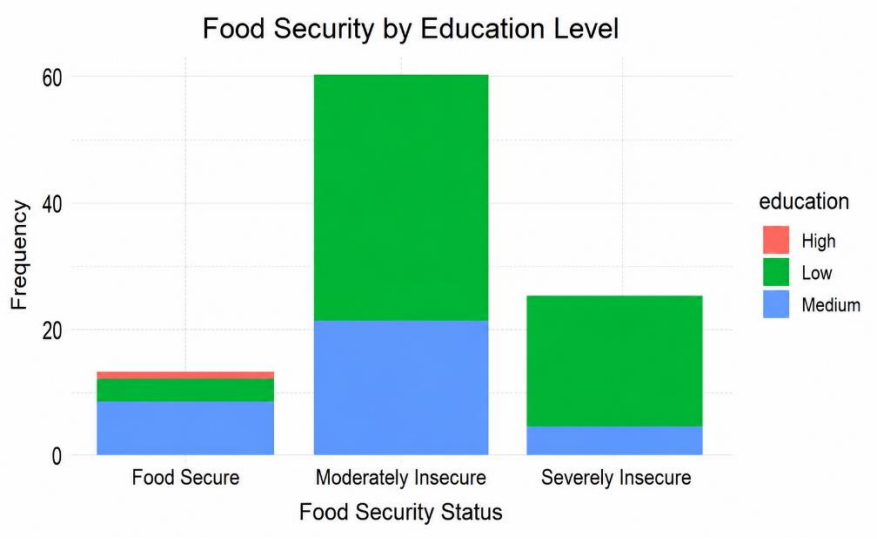


Figure 5: Education Level Distribution Across Food Security *Status*

4.4.7. Climate Stress Vs Adaptation Response

Table 20: Mean Adaptation Index by Climate Stress Level

Climate Stress Group	Mean Adaptation Index
Low (3-4.33)	2.64
Medium (4.33-5.67)	2.88
High (5.67-7)	3.08

This reactive pattern is typical in resource-limited settings. (Thornton et al., 2014) observed that smallholders often increase coping efforts only after shocks occur, rather than proactively building resilience. The weak correlation (r = 0.197, see section 4.6) indicates that other factors (assets, social networks) are more important determinants of coping capacity.

4.5. Objective 3: Challenges in Adopting Climate Adaptation Strategies

4.5.1. Overview of Adaptation Constraints

Table 21: Distribution of Challenge Levels

Challenge Level	Number of Households	Percentage
Moderate (4-6 challenges)	15	15%
High (7+ challenges)	85	85%

The finding that 85% of households face 7 or more adaptation constraints is consistent with (Mango et al., 2018) who identified multiple overlapping barriers (financial, informational, institutional) in central Malawi. (Lunduka et al., 2013) also documented systemic challenges in input subsidy programs, including targeting inefficiencies and late delivery.

4.5.2. Thematic Grouping of Challenges

Table 22: Categorization of Adaptation Constraints

Category	Challenges (Rank)	Average %	Interpretation
Financial/Material	Money (1), Equipment (2), Seeds (3)	86%	Primary barrier
Biophysical	Pests (4), Land (5), Soil (6)	80%	Secondary barrier
Institutional	Extension (7), Training (8), Market (9)	71%	Tertiary barrier
Social/Labor	Labor (10), Cultural (11)	44%	Lesser barrier
Water	Irrigation water (12)	36%	Site-specific

4.5.3. Discussion of Key Challenges

Financial Constraints (90%): The dominance of financial barriers confirms findings from (Mango et al., 2018) that lack of capital is the primary constraint to adaptation adoption. (Kamanga, 2021) similarly reported that without money for inputs, farmers cannot purchase drought-tolerant seeds, fertilizer or irrigation equipment.

Input and Equipment Access (86–83%): Even when farmers recognize the need for improved seeds and equipment, physical access is limited. This reflects weak agricultural input supply chains in rural Mulanje, as noted by (Simtowe et al., 2019).

Land Scarcity (80%): With average household size of 4.87 and small land holdings (food secure average 1.14 ha, severely insecure average 0.49 ha), limited land constrains diversification and soil management options. (Bezner Kerr et al., 2019) found similar land constraints in northern Malawi.

Extension and Training Gaps (75–73%): The finding that 75% report inadequate extension support and 73% lack technical training indicates systemic failures in agricultural extension services. (Marambanyika, 2022) reported that conservation agriculture adoption in Malawi is hindered by limited extension contact and conflicting information.

Market Access (64%): Even when farmers produce surplus, market access problems prevent them from converting production into income. (Holleman et al., 2020) noted that poor rural infrastructure exacerbates food insecurity by raising transaction costs.

Lowest Challenges (36–37%): Water scarcity for irrigation was reported by only 36%, which is surprising given rain-fed dependence. This may indicate that farmers have normalized water scarcity or do not consider irrigation a viable option given financial constraints. Cultural barriers (37%) are relatively low, suggesting community acceptance of adaptation practices, a positive finding also reported by (Ariom et al., 2022) in other African countries.

4.6. Correlation Between Climate Stress and Coping

Table 23: Pearson Correlation Between Climate Index and Coping Index

Statistic	Value
Correlation (r)	0.197
t-statistic	1.992
Df	98
p-value	0.0492
95% CI	(0.0009, 0.3790)

There is a statistically significant but weak positive correlation (r = 0.197, p = 0.049) between climate exposure and coping index. As climate stress increases, households adopt more coping strategies. However, the weak correlation (r < 0.2) indicates that climate exposure explains less than 4% of the variation in coping other factors (assets, education, social networks) are more important determinants of coping capacity. This aligns with (Thornton et al., 2014), who argued that adaptive capacity is shaped more by socio-economic conditions than by climate exposure alone.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study assessed the impact of climate variability on household food security among smallholder farmers in Mulanje District, evaluated the effectiveness of adaptation strategies, and identified the challenges farmers face when adopting these strategies. Each objective is addressed respectively.

The study found that smallholder farmers in Mulanje experience extremely high exposure to climate variability, with an average of six different climate shocks per household, including erratic rainfall, droughts, floods, rising temperatures, and strong winds. Rainfall trend analysis confirmed severe year-to-year volatility, with annual totals swinging from over 2,200 mm to under 900 mm within a decade. Despite this high exposure, only 14% of households were food secure, while 86% experienced moderate or severe food insecurity. Notably, food-secure households reported more climate shocks than severely insecure ones, indicating that the primary driver of food insecurity is not the frequency of hazards but the lack of adaptive capacity. Households with stronger asset portfolios, such as irrigation access and education, remained food secure even when facing greater climate stress.

The study revealed a critical distinction between reactive coping and proactive adaptation. The most common responses to climate variability were reactive coping strategies; reducing meals (92%), engaging in casual labor (71%) and borrowing (69%) which are symptoms of distress rather than effective adaptation. Overall adaptation capacity did not differ significantly across food security groups ($p = 0.829$), suggesting that simply counting strategies without assessing their nature is misleading. However, specific proactive strategies proved effective: irrigation users were four times more likely to be food secure ($p = 0.013$), and education showed a strong positive association with food security ($p = 0.007$), with zero high-education households falling into food insecurity. Livestock ownership, in contrast, showed no significant association.

The study identified systemic, multi-layered barriers to adaptation. The vast majority (85%) of households faced seven or more adaptation constraints. Financial constraints were the most dominant challenge (90% of households), followed by limited access to equipment (86%), seeds (83%), pests (83%), land scarcity (80%), poor soil fertility (77%), inadequate extension support (75%), and lack of technical training (73%). These findings indicate that adaptation adoption is hindered not by single factors but by overlapping financial, biophysical and institutional barriers. The weak but significant positive correlation between climate stress and coping ($r = 0.197$, $p = 0.049$) further confirms that other factors like assets, education and social networks are more important determinants of coping capacity than climate exposure alone.

5.2. Recommendations

Based on the findings, the following recommendations are made to improve food security and climate resilience among smallholder farmers in Mulanje District.

Financial constraints must be addressed as the primary barrier to adaptation. The study recommends expanding agricultural input subsidy programs, particularly the FISP, to reach more farmers in Mulanje with improved seeds and fertilizers. Additionally, establishing VSLAs specifically for agricultural inputs and introducing micro-credit schemes for irrigation equipment (such as treadle pumps and drip kits) would enable farmers to invest in effective adaptation strategies.

Irrigation access should be scaled up significantly, given that irrigation users are four times more likely to be food secure. The study recommends promoting low-cost treadle pumps for small-scale irrigation along perennial rivers, developing community-based irrigation schemes, and providing matching grants or subsidies for irrigation equipment purchase. These interventions would reduce dependence on erratic rainfall and stabilize crop production.

Agricultural extension and training services must be strengthened, as 75% of households reported inadequate extension support and 73% lacked technical training. The study recommends recruiting and training more frontline extension officers for Mulanje, establishing demonstration plots for drought-tolerant seeds and conservation agriculture and developing farmer to farmer training programs using lead farmers to disseminate knowledge more efficiently.

Access to drought-tolerant seeds should be improved, as 83% of households faced seed access constraints. The study recommends establishing community-based seed banks managed by farmer cooperatives, subsidizing drought-tolerant maize varieties through FISP, and promoting crop diversification beyond maize (including cassava, millet, and sorghum) to spread risk.

Biophysical constraints such as poor soil fertility (77%) and pest problems (83%) should be addressed through soil fertility management practices (compost, manure, cover crops), integrated pest management (IPM) training and advocacy for land tenure security to incentivize long-term soil conservation investments.

Market access must be improved, as 64% of households reported market problems. The study recommends constructing and rehabilitating rural feeder roads connecting Mulanje to major markets, establishing farmer cooperatives for collective marketing to increase bargaining power and providing market information via mobile phones (digital extension) to reduce information asymmetries.

The study recommends that future interventions shift from simply counting coping strategies to deliberately promoting proactive adaptation. Policies should prioritize enabling conditions—financial capital, irrigation infrastructure, education and extension support—rather than relying on reactive coping measures that indicate distress. These recommendations, if implemented in a coordinated manner, would significantly enhance the resilience of smallholder farmers in Mulanje District to climate variability and improve household food security

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7.APPENDICES

Appendix A: Household Questionnaire

Section A: Demographic Information

1. Sex of respondent

    - Male
    - Female

2. Age group

    - Below 20 years
    - 21 – 30 years
    - 31 – 40 years
    - 41 – 50 years
    - Above 50 years

3. Highest education level attained

    - No formal education
    - Primary education
    - Secondary education
    - Tertiary education

4. Household size

    _____members

5. Main occupation

    - Farming
    - Business
    - Casual labor
    - Formal employment
    - Other (specify) _____

Section B: Climate Variability and Farming

6. How many hectares of land do you cultivate each year?

   _____

7. Which climate-related changes have you observed?

   - Delayed rainfall onset
   - Early cessation of rainfall
   - Droughts
   - Floods
   - Increased temperatures
   - Strong winds
   - Other (specify) _____

8. How often do climate shocks affect your farming activities?

   - Every year
   - Sometimes
   - Rarely
   - Never

9. Which crops are mainly affected by climate variability?

   - Maize
   - Beans
   - Cassava
   - Sweet potatoes
   - Other (specify) _____

10. What effects has climate variability had on your farming activities?

    - Reduced crop yields
    - Crop failure
    - Pest and disease outbreaks
    - Soil erosion
    - Loss of income
    - Other (specify) _____

Section C: Food Security

11. Does your household experience food shortages?

    - Yes
    - No

12. How many months in a year does your household experience food shortages?

    - None
    - 1 – 3 months
    - 4 – 6 months
    - More than 7 months

13. What do you do when there is food shortage in your household?

    - Buy food
    - Borrow from others
    - Reduce meals per day
    - Do casual labor
    - Receive food aid
    - Sleep hungry
    - Other (specify) _____

14. How far is the nearest food market from your home? _____ km
15. What is your main source of drinking water?

    - River
    - Borehole
    - Tap water
    - Other (specify) _____

16. Do you treat your drinking water?

    - Always
    - Sometimes
    - Never

Section D: Adaptation Strategies

17. What strategies do you use to cope with climate variability?

    - Crop diversification
    - Irrigation
    - Conservation agriculture
    - Use of improved seed varieties
    - Livestock keeping
    - Other (specify) _____

18. Which adaptation strategy has been most effective for your household?

    _____

19. What are the main reasons some adaptation strategies are not adopted in your household?

    - Too costly
    - Lack of skills
    - Inputs not available
    - Too much labor required
    - Not suitable for land or soil conditions
    - Uncertainty about effectiveness
    - Other (specify) _____

20. Have you received any training or support related to climate change adaptation?

    - Yes
    - No

21. Are there any community groups or NGOs helping with climate or food security issues in your area?

    - Yes
    - No

22. What suggestions do you have for improving food security in your community?

    _____

    _____