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Assessing the Impact of Climate Variability on Smallholder Farmers' Household Income and Agricultural Investment Decisions in Eastern Province, Zambia

George Chalwe[1]*, Dr. Adrian Phiri[1]

[1]*Mulungushi University, Zambia*

* Corresponding Author

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Abstract

Climate variability poses significant challenges to agricultural production and rural livelihoods, particularly among smallholder farmers who depend largely on rain-fed agriculture. This study examined the impact of climate variability on agricultural investment decisions and household income among smallholder farmers in Eastern Province, Zambia. The study adopted a quantitative cross-sectional research design guided by the positivist research paradigm. Primary data were collected from 345 smallholder farming households selected from seven districts using structured questionnaires. Descriptive statistics and simple linear regression analysis were employed to analyse the data. The findings revealed widespread perceptions of increasing climate variability, with 99.1% of respondents reporting changes in rainfall patterns over the past decade. Conservation farming, improved seed varieties, and drought-resistant crops were identified as the principal adaptation strategies adopted by farmers. However, regression analysis showed that climate variability was not a statistically significant predictor of agricultural investment decisions ($\beta = -0.015$, $p = 0.421$) and explained only a negligible proportion of the variation in investment decisions ($R^2 = 0.002$). Similarly, the relationship between climate variability and household income was found to be very weak ($R^2 = 0.001$, $p = 0.574$), indicating that household income is influenced by a wider range of socioeconomic and institutional factors beyond climate variability alone. The study concludes that although climate variability remains a major concern for smallholder farmers, it does not independently determine agricultural investment decisions or household income in Eastern Province. The study recommends strengthening access to climate information, extension services, affordable agricultural credit, irrigation development, and improved seed varieties to enhance the resilience and productivity of smallholder farming households.

1. Introduction

1.1 Background of the Study

Climate variability represents one of the most pressing global challenges of the 21st century, with serious implications for food security, economic growth, and sustainable livelihoods (IPCC, 2021). Developing countries are disproportionately affected due to their reliance on natural resources and limited capacity to adapt to climatic shocks. Africa is among the most vulnerable regions to climate variability due to its heavy dependence on climate-sensitive sectors such as agriculture. Rising temperatures, erratic rainfall patterns, prolonged droughts, and frequent flooding have significantly affected agricultural productivity and rural livelihoods (Legg, 2021). In Sub-Saharan Africa, where farming systems are largely rain-fed, these climatic changes introduce uncertainty into agricultural production.

Zambia is among the Southern African countries severely affected by climate variability and change. Rising temperatures, delayed onset of rainfall, shortened growing seasons, and increased frequency of extreme weather events including droughts, heatwaves, and floods have negatively impacted agricultural productivity (World Bank, 2023; MGEE, 2024). Zambia ranks 15th in the list of countries most vulnerable to climate change, and temperatures in Southern Africa are projected to increase by 0.6–1.4°C by 2030 and by 1.5–3.5°C during 2040–2069 (Wheeler, 2011; Lobell et al., 2008, cited in Arslan et al., 2015).

Agriculture remains the backbone of Zambia's economy, employing more than 70% of the population and contributing approximately 20% to GDP (Chilambwe, 2021). However, the sector is highly vulnerable because it is predominantly rain-fed and characterized by low adaptive capacity, limited irrigation infrastructure, and restricted access to climate-resilient technologies (Boros et al., 2025). Approximately 64% of the total population lives in rural areas that primarily depend on rain-fed subsistence agriculture (Chapoto et al., 2011, cited in Arslan et al., 2015).

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Eastern Province is a key agricultural region in Zambia, ranked as the second top producer of maize, soybean, and sunflower. The province accounts for approximately 12% of the national population and covers an area of about 51,476 km² (CSO, 2022). Agriculture is the primary economic activity in Eastern Province, with over 80% of rural households engaged in smallholder farming. Under normal climatic conditions, the province receives approximately 800–1,000mm of rainfall annually (ZMD, 2021). The main crops grown include maize, groundnuts, cotton, tobacco, soya beans, and sunflower (Bwalya and Mwanza, 2025). Despite its agricultural potential, Eastern Province has increasingly experienced climate-related challenges including dry spells, late onset of rains, and invasive crop pests (Day et al., 2021). The 2022 Crop Forecast Survey indicated that maize yields averaged 1.78 tons per hectare during the 2021/2022 season, far below the potential yield of 5–10 tons per hectare (CSO, 2022).

1.2 Statement of the Research Problem

Despite the importance of agriculture to Zambia's economic development, climate variability continues to undermine agricultural productivity and rural livelihoods. According to ZMD (2023), average temperatures in Zambia have increased by approximately 1.3°C since the 1960s. During the 2018/2019 agricultural season, Zambia experienced below-normal rainfall, and the 2023/2024 season recorded one of the most severe droughts in recent history, affecting over 84 out of 116 districts (Gamoyo et al., 2024; UNDP, 2025).

In Eastern Province, where agriculture is predominantly rain-fed, climatic fluctuations create substantial uncertainty for smallholder farmers. These changes significantly influence farmers' decisions regarding agricultural investments such as fertilizers, improved seed varieties, irrigation equipment, and crop diversification strategies. Eastern Province is highly exposed to drought, and climate change is expected to intensify both the frequency and severity of drought impacts (MCII, 2025).

While considerable research has examined the impact of climate change on crop yields, limited empirical attention has been given to how climate variability affects smallholder farmers' agricultural investment decisions and the resulting implications for rural household income. Over the past three decades, Eastern Province has experienced recurrent climate-related shocks including droughts, floods, and dry spells (Rawlins and Kalaba, 2020). Without clear empirical evidence on how climate variability influences farmers' investment behaviour and income outcomes, policymakers may design climate adaptation strategies that fail to adequately address the real constraints faced by smallholder farmers.

1.3 Aims/Objectives/Research Questions/Hypotheses

Aim: To assess the impact of climate variability on smallholder farmers' agricultural investment decisions and household income in Eastern Province, Zambia.

Objectives

- To analyse trends and patterns of climate variability in Eastern Province.
- To examine how climate variability influences smallholder farmers' agricultural investment decisions.
- To evaluate the effect of climate variability on household income levels.
- To determine the relationship between agricultural investment decisions and household income under climate variability conditions.

Research Questions

- What are the trends and patterns of climate variability in Eastern Province?
- How does climate variability influence smallholder farmers' agricultural investment decisions?
- What is the impact of climate variability on household income?
- How do agricultural investment decisions mediate the relationship between climate variability and household income?

Hypotheses

H_0: Climate variability has no significant effect on smallholder farmers' agricultural investment decisions.

$H\alpha$: Climate variability significantly affects smallholder farmers' agricultural investment decisions.

1.4 Rationale

This study is important because it helps explain how climate variability affects not just crop production, but also the decisions smallholder farmers make about investing in agriculture and how those decisions influence household income. By linking climate variability, investment behaviour, and income outcomes, the study fills an important research gap in Eastern Province, where limited localized evidence currently exists. The findings will provide useful information to policymakers to design better climate adaptation strategies and strengthen climate-smart agriculture programmes. Adaptation investments consistently reduce drought damages and protect people (MCII, 2025).

1.5 Scope of the Study

The study was conducted in Eastern Province, focusing on seven districts: Chipata, Katete, Vubwi, Mambwe, Lumezi, Kasenengwa, and Chadiza. The study focused on smallholder farming households cultivating less than five hectares. The research examined climate variability trends over the past decade (2015-2025). Eastern Province typically experiences seasonal rainfall of between 800 and 1000 mm and a crop-growing period of 100–140 days (Bwalya and Mwanza, 2025).

1.6 Conceptual Framework

The conceptual framework is based on the assumption that climate variability (independent variable) influences agricultural investment decisions (mediating variable), which in turn affects household income (dependent variable). The framework was developed based on Binswanger's (1980) theoretical work on risk behaviour and agricultural investment decisions.

Climate variability (rainfall patterns, temperature, droughts, floods) affects farming conditions, which influences agricultural investment decisions (fertilizer use, improved seeds, irrigation, crop diversification). Both climate variability and investment decisions impact household income. Agricultural investment decisions act as a mediator, meaning climate variability affects income both directly and indirectly through investment choices. This framework aligns with the understanding that diversification is an adaptation response, as climatic shocks have a significant effect on livelihood diversification (Arslan et al., 2017).

2 Literature Review

2.1 Conceptualizing Climate Variability and Agricultural Decision-Making

Climate variability refers to short to medium-term fluctuations in climatic parameters such as rainfall, temperature, and extreme weather events (IPCC, 2021). In agrarian economies, particularly in Sub-Saharan Africa, such variability directly influences agricultural productivity, investment behaviour, and household welfare (Lobell et al., 2011). Smallholder farmers, who often depend on rain-fed systems and possess limited adaptive capacity, are disproportionately affected (Adjei and Amaning, 2021). Agricultural investment decisions are shaped by risk expectations and climatic uncertainty (Mendelsohn et al., 2006). When rainfall becomes unpredictable, farmers may reduce investment to minimize losses or adopt adaptive technologies to buffer against risks (Dercon, 2008).

2.2 Global Evidence on Climate Variability and Agricultural Investments

Empirical studies demonstrate that climate variability significantly affects production and investment decisions. Lobell et al. (2008) estimated that climate change would reduce agricultural productivity by 15-20% in Africa by 2050. Schlenker and Lobell (2010) showed that extreme heat exposure significantly reduces maize productivity in Africa. Dercon (2008) observed that climatic shocks reduced household consumption and discouraged long-term agricultural investments. Arslan et al. (2015) found that conservation agriculture improved resilience and productivity. Di Falco et al. (2011) demonstrated that climate adaptation strategies significantly increased farm productivity. However, Bryan et al. (2009) highlighted that access to climate information, education, and credit significantly influences farmers' adaptation responses.

2.3 Climate Variability and Household Income Relationship

Climate variability affects household income and poverty dynamics. Harvey et al. (2014) found that climate shocks exacerbate income instability and food insecurity. Carter et al. (2007) argued that repeated climatic shocks can trap households in poverty. In Tanzania, Kato et al. (2013) observed that rainfall variability significantly reduced agricultural income. Birthal et al. (2014) showed that diversification and irrigation investments enhance income resilience. The World Bank (2020) emphasizes that climate variability threatens rural livelihoods in Zambia (Mulenga and Kabisa, 2021).

2.4 Evidence from Zambia

Zambia's agriculture sector is highly climate-sensitive (Mulenga and Kabisa, 2021). Arslan et al. (2015) found that climate-smart practices positively influenced productivity and income stability. Ngoma et al. (2021) concluded that CSA practices improved technical efficiency and resilience. Chilambwe (2021) reported that climate change impacts on crops in Eastern Province will vary across districts. Sitko and Jayne (2014) observed that land constraints and climate risk exposure influence investment decisions. Mulenga et al. (2017) found that farmers exposed to recurrent drought were more likely to invest in drought-tolerant crops.

Recent studies in Eastern Province found that all respondents (100%) were aware of CSA, and 96% viewed CSA as important (Nanyangwe and Tembo, 2024). Conservation agriculture mother trials in Chipata, Lundazi, and Sinda districts tested crop yield and economic benefits (CIMMYT et al., 2019). The SCRALA project has trained 129,414 farmers in conservation agriculture (UNDP, 2024).

2.5 Climate Variability, Risk, and Investment Behaviour

Risk-averse farmers may underinvest in productive technologies under climate uncertainty (Binswanger, 1980). Yesuf and Bluffstone (2009) found that climatic variability increases risk aversion and discourages investments. Rosenzweig and Binswanger (1993) established that in risky environments, farmers allocate resources to less risky crops. Access to climate information and financial services moderates risk effects (Mudenda et al., 2024; Fosu-Mensah et al., 2012).

3 Methodology

Research Paradigm and Approach

The study was guided by the positivist research paradigm, emphasizing objective measurement, empirical observation, and statistical analysis. The study adopted a quantitative approach.

Research Design

The study adopted a cross-sectional survey design, collecting data from respondents at a single point in time (Nanyangwe and Tembo, 2024; Bwalya and Mwanza, 2025).

Study Area

The study was conducted in seven districts of Eastern Province: Chipata, Katete, Vubwi, Mambwe, Lumezi, Kasenengwa, and Chadiza. The province covers approximately 51,476 km² and has a population of about 2.3 million people. The province lies mainly within Agro-Ecological Region II, receiving an average annual rainfall of 800–1,000 mm (Bwalya and Mwanza, 2025).

Population and Sampling

The target population was 284,117 smallholder farming households (Enterprise Zambia Challenge Fund, 2025). A multistage sampling technique was employed. First, seven districts were purposively sampled. Second, stratified sampling was used. Third, simple random sampling was applied. Sample size was determined using the Cochran formula (n = 384) and proportionally allocated across districts. Data were collected from 345 respondents (90% response rate).

Data Collection Methods

Primary data were collected through structured questionnaires on household characteristics, farm size, crop production, agricultural investments, access to credit and extension services, and income sources. Secondary data included rainfall and temperature records from ZMD (2015-2024) and agricultural statistics from CSO (2015-2025).

Data Analysis

Data were cleaned and organized using STATA. Descriptive statistics summarized climate trends, investments, and income. Simple linear regression analysis examined how climate variability influences investment decisions and household income. All results were tested at 5% significance level. Regression assumptions were tested and satisfied (Mudenda et al., 2024; Nanyangwe and Tembo, 2024).

Validity and Reliability

Content validity index (CVI = 0.933) exceeded 0.70, indicating validity (Creswell, 2014). Test-retest reliability correlation coefficient (r = 0.85) indicated acceptable reliability (Kothari, 2004).

Ethical Considerations

Informed consent was obtained, privacy and confidentiality were protected, and ethical clearance was obtained from Mulungushi University.

4 Research Results

4.1 Demographic Characteristics of Respondents

Table 1: Distribution of Respondents by District

District	Frequency	Percentage (%)
Chipata	58	16.8
Kasenengwa	51	14.8
Mambwe	51	14.8
Chadiza	50	14.5
Vubwi	48	13.9
Lumezi	47	13.6
Katete	40	11.6
Total	345	100

Source: Field Data (2026)

The respondents were fairly distributed across the seven districts. Chipata had the largest proportion (16.8%), while Katete had the smallest (11.6%). The broad geographical distribution implies that the findings are representative of smallholder farmers across Eastern Province and capture varying climatic experiences. The relatively small differences in representation enhance the generalizability of the findings.

Table 2: Gender of Household Heads

Gender	Frequency	Percentage (%)
Male	219	63.5
Female	126	36.5
Total	345	100

Source: Field Data (2026)

Male-headed households constituted 63.5%, while female-headed households accounted for 36.5%. The predominance of male-headed households indicates that agricultural activities in Eastern Province are largely undertaken by men, reflecting traditional gender roles. However, the considerable proportion of female-headed households (36.5%) demonstrates that women play a significant role in agricultural production and household livelihood sustenance. This finding is consistent with studies showing that women farmers in Sub-Saharan Africa are often disadvantaged due to gender gaps in access to resources (Bwalya and Mwanza, 2025).

Table 3: Age Distribution of Household Heads

Age Category	Frequency	Percentage (%)
18-35 years	20	5.8
36-50 years	195	56.5
Above 50 years	130	37.7
Total	345	100

Source: Field Data (2026)

The majority of respondents (56.5%) were aged between 36 and 50 years, while 37.7% were above 50 years. The concentration within the economically active age group suggests that farming activities are mainly carried out by mature individuals with considerable farming experience. The relatively low participation of younger people (5.8%) may indicate increasing migration to urban areas or declining interest in agriculture among youth, which could have implications for the future sustainability of agricultural production and adoption of innovative adaptation strategies.

Table 4: Educational Attainment

Education Level	Frequency	Percentage (%)
Secondary	144	41.7
Primary	104	30.1
Tertiary	90	26.1
No formal education	7	2.0
Total	345	100

Source: Field Data (2026)

Most respondents had attained secondary education (41.7%), followed by primary education (30.1%), while 26.1% had tertiary education. Only 2.0% had no formal education. The relatively high literacy levels imply that most farmers possess basic literacy and numeracy skills, which are essential for understanding agricultural information and adopting improved farming technologies. Education enhances farmers' ability to interpret weather information, access extension services, and make informed investment decisions, contributing positively to resilience against climate variability.

Table 5: Main Occupation

Occupation	Frequency	Percentage (%)
Farming	337	97.7
Business	8	2.3
Total	345	100

Source: Field Data (2026)

Almost all respondents (97.7%) depended on farming as their primary occupation. This overwhelming dependence on agriculture demonstrates the central role farming plays in sustaining rural livelihoods in Eastern Province. Since nearly all respondents rely on farming for their survival, fluctuations in climatic conditions have direct consequences on household food security, income, and overall well-being. This high dependence increases household vulnerability to climatic shocks because alternative sources of income are limited.

4.2 Farm Characteristics

Table 6: Main Crops Grown

Crop	Frequency	Percentage (%)
Maize	317	91.9
Tobacco	22	6.4
Groundnuts	4	1.2
Cotton	2	0.6
Total	345	100

Source: Field Data (2026)

Interpretation: Maize was the dominant crop grown by 91.9% of households. The dominance of maize cultivation indicates that smallholder farmers in Eastern Province depend heavily on a single staple crop. While maize remains an important source of food and income, overreliance on one crop exposes households to significant risks associated with erratic rainfall and drought. This finding is consistent with the observation that maize dominates projected crop losses due to its large cultivation area and sensitivity to rainfall variability (MCII, 2025).

Table 7: Livestock Ownership

Livestock Type	Frequency	Percentage (%)
Cattle	126	36.5
Goats	89	25.8
Poultry	2	0.6
None	128	37.1
Total	345	100

Source: Field Data (2026)

Interpretation: About 37.1% of respondents did not own livestock, while cattle ownership accounted for 36.5%, and goats accounted for 25.8%. The relatively low livestock ownership, with more than one-third of households owning no livestock, suggests that many households depend almost exclusively on crop production. Livestock ownership provides an important buffer during periods of crop failure, as animals can be sold to generate income. Households without livestock may therefore be more vulnerable to the adverse effects of climate variability.

4.3 Trends and Patterns of Climate Variability

Table 8: Changes in Rainfall Patterns

Response	Frequency	Percentage (%)
Yes	342	99.1
No	3	0.9
Total	345	100

Source: Field Data (2026)

Nearly all respondents (99.1%) reported experiencing changes in rainfall patterns over the past ten years. This near-universal acknowledgment provides strong evidence that climate variability is a widespread phenomenon in Eastern Province. Farmers have become increasingly aware of changes in the timing, duration, and intensity of rainfall, which affect planting schedules, crop growth, and overall agricultural productivity. This finding aligns with research showing that individuals can accurately perceive climate variation at fine spatial scales (Bwalya and Mwanza, 2025).

Table 9: Type of Rainfall Changes Experienced

Type of Change	Frequency	Percentage (%)
Dry spells	264	76.5
Late onset of rains	42	12.2
Flooding	39	11.3
Total	345	100

Source: Field Data (2026)

Interpretation: Dry spells constituted the most common climatic challenge, affecting 76.5% of respondents. The predominance of dry spells indicates that inadequate and uneven rainfall distribution has become a serious concern. Dry spells occurring during critical stages of crop development often result in moisture stress, poor crop growth, and reduced yields. This pattern highlights the increasing vulnerability of rain-fed agriculture to moisture shortages and confirms that Eastern Province is highly exposed to drought (MCII, 2025).

Table 10: Extent Climate Variability Affected Production

Rating	Frequency	Percentage (%)
2	3	0.9
3	176	51.0
4	133	38.6
5	0	0.0
None	33	9.6
Total	345	100

Source: Field Data (2026)

Over 48% of respondents rated the effect as high (ratings 4 and 5), while 51% rated it moderate (rating 3). The mean score of 3.30 (on a 5-point scale) indicates that, on average, respondents perceived a moderate to high impact on production. The fact that a substantial proportion of farmers rated the impact as high implies that changing climatic conditions have become an important source of production risk, contributing to declining yields and increased uncertainty regarding agricultural output.

Table 11: Rainfall Reliability

Response	Frequency	Percentage (%)
Moderately reliable	199	57.7
Not reliable	146	42.3
Total	345	100

Source: Field Data (2026)

About 42.3% considered rainfall unreliable, while 57.7% described it as moderately reliable. The perception of rainfall as only moderately reliable or unreliable reflects growing uncertainty surrounding weather conditions. Unpredictable rainfall patterns make it difficult for farmers to determine appropriate timing for planting and other farming operations, increasing the risk of crop failure and discouraging investment in agricultural production. Declining rainfall reliability represents a major manifestation of climate variability affecting smallholder farmers.

4.4 Agricultural Investment Decisions

Table 12: Use of Fertilizer

Response	Frequency	Percentage (%)
Yes	296	85.8
No	49	14.2
Total	345	100

Source: Field Data (2026)

Interpretation: Most respondents (85.8%) used fertilizer. The widespread use of fertilizer demonstrates the importance farmers attach to maintaining soil fertility and improving crop yields. The increased use of fertilizer may represent an attempt to compensate for declining soil productivity and the adverse effects of climate variability. The 14.2% who did not use fertilizer likely faced financial constraints or lacked access to input markets.

Table 13: Changes in Fertilizer Usage

Response	Frequency	Percentage (%)
Increased	276	80.0
No	69	20.0
Total	345	100

Source: Field Data (2026)

The majority (80.0%) reported increasing fertilizer application over time. This suggests that farmers are investing more in soil fertility management as a response to declining yields and changing climatic conditions. However, increased fertilizer use also implies higher production costs, which may strain household finances, particularly when yields are reduced due to climate variability.

Table 14: Use of Improved Seeds

Response	Frequency	Percentage (%)
Yes	295	85.5
No	50	14.5
Total	345	100

Source: Field Data (2026)

The majority of farmers (85.5%) used improved seed varieties. The high adoption of improved seed varieties indicates that farmers are making efforts to enhance productivity and adapt to changing climatic conditions. Improved seeds are generally more resilient to drought and diseases, increasing the likelihood of obtaining better yields even under unfavorable weather conditions. This suggests that farmers recognize the importance of technological innovations in mitigating climate-related risks.

Table 15: Investment in Irrigation

Response	Frequency	Percentage (%)
No	335	97.1
Yes	10	2.9
Total	345	100

Source: Field Data (2026)

Only 2.9% of respondents had invested in irrigation. The extremely low level of investment in irrigation indicates a heavy dependence on rain-fed agriculture. This dependence exposes households to rainfall fluctuations and increases their vulnerability to climate variability. Limited investment may be attributed to inadequate financial resources, lack of infrastructure, and limited access to credit facilities. This low irrigation adoption is notable given that small-scale irrigation performs better than drought-tolerant crops alone (Matchaya et al., 2025).

Table 16: Influence of Climate Variability on Investment Decisions

Response	Frequency	Percentage (%)
Yes	333	96.5
No	12	3.5
Total	345	100

Source: Field Data (2026)

Almost all respondents (96.5%) reported that climate variability influenced their investment decisions. This finding highlights the extent to which climatic uncertainty shapes farming behaviour. Unpredictable weather conditions increase production risks and reduce farmers' confidence in committing resources to agricultural activities. As a result, many farmers adopt cautious investment strategies aimed at minimizing losses, consistent with theoretical expectations that risk-averse farmers underinvest under climate uncertainty (Binswanger, 1980; Yesuf and Bluffstone, 2009).

Table 17: How Climate Variability Influenced Investments

Effect	Frequency	Percentage (%)
Reduced investment	323	93.6
Changed crop type	22	6.4
Total	345	100

Source: Field Data (2026)

Most farmers (93.6%) reduced investments because of uncertainty associated with rainfall variability and crop failure. Faced with unpredictable rainfall and recurrent droughts, farmers become reluctant to invest heavily in inputs and technologies. A smaller proportion (6.4%) responded by changing crop types, indicating an effort to adapt to changing conditions rather than reducing investment altogether. These findings suggest that climate variability influences both the quantity and nature of agricultural investments.

4.5 Regression Analysis: Effect of Climate Variability on Agricultural Investment Decisions

Table 18: Regression Model Summary

Regression Statistics	Value
Multiple R	0.043
R Square (R^2)	0.002
Adjusted R Square	-0.001
Standard Error of Estimate	0.234
Observations	345

Source: Field Data (2026)

The regression analysis revealed a very weak relationship between climate variability and investment decisions, with a Multiple R value of 0.043. The coefficient of determination ($R^2 = 0.002$) indicates that climate variability explains only 0.2% of the variation in investment decisions. This suggests that climate variability has almost no explanatory power regarding investment decisions among the respondents. The adjusted R^2 value of -0.001 further confirms that the model has no predictive power.

Table 19: ANOVA Results

Source of Variation	df	Sum of Squares	Mean Square	F-value	Significance
Regression	1	0.036	0.036	0.650	0.421
Residual	343	18.805	0.055		
Total	344	18.841			

Source: Field Data (2026)

Interpretation: The ANOVA results show that the overall regression model was not statistically significant (F = 0.650, p = 0.421). Since the p-value is greater than the 0.05 significance level, the model does not provide sufficient evidence that climate variability significantly influences investment decisions. This means that the regression model cannot be used to predict investment decisions based on climate variability.

Table 20: Regression Coefficients

Variable	Coefficients	Standard Error	t-statistic	p-value	Lower 95% CI	Upper 95% CI
Intercept	1.112	0.068	16.366	0.000	0.978	1.245
Extent climate variability affected production	-0.015	0.019	-0.806	0.421	-0.052	0.022

Source: Field Data (2026)

The regression coefficient for the extent to which climate variability affected production was $\beta = -0.015$ ($p = 0.421$). The negative coefficient suggests that an increase in climate variability is associated with a slight decrease in investment decisions, but this relationship is not statistically significant. Since the p-value (0.421) exceeds 0.05, and the 95% confidence interval (-0.052 to 0.022) contains zero, the null hypothesis is accepted. Climate variability was not a significant predictor of investment decisions in the study area.

4.6 Adaptation Strategies

Table 21: Adaptation Strategies Adopted

Adaptation Strategy	Frequency	Percentage (%)
Conservation farming	307	88.9
Drought-resistant crops	22	6.4
Crop diversification	16	4.6
Total	345	100

Source: Field Data (2026)

Conservation farming was the most widely adopted strategy (88.9%), followed by drought-resistant crops (6.4%) and crop diversification (4.6%). The predominance of conservation farming demonstrates that farmers are increasingly adopting climate-smart agricultural practices to cope with changing conditions. Conservation farming helps conserve soil moisture, improve soil fertility, and enhance crop resilience to drought. The high adoption rate is consistent with findings that conservation agriculture provides a viable option for climate change adaptation (Terhoeven-Urselmans et al., 2025) and reflects farmers' awareness that diversification is an effective adaptation response (Arslan et al., 2017).

4.7 Household Income

Table 22: Estimated Annual Farm Income

Income Category (ZMW)	Frequency	Percentage (%)
10,000–20,000	277	80.3
5,000–10,000	42	12.2
Above 20,000	18	5.2
Below 5,000	8	2.3
Total	345	100

Source: Field Data (2026)

Interpretation: The majority of households (80.3%) earned between K10,000 and K20,000 annually. Crop farming was the main source of income for all households. The concentration of annual income within relatively low-income brackets suggests that many households have limited financial capacity to withstand climatic shocks. Any decline in agricultural productivity resulting from climate variability directly affects household income and welfare.

Table 23: Reasons for Income Increase

Reason	Frequency	Percentage (%)
Use of hybrid/improved seed	330	95.5
Crop diversification	15	4.3
Total	345	100

Source: Field Data (2026)

Interpretation: The majority of respondents (95.5%) attributed income increases to the adoption of hybrid and improved seed varieties, while a smaller proportion (4.3%) associated it with crop diversification. These findings suggest that technological innovations and diversification strategies have played an important role in enhancing agricultural productivity and sustaining household livelihoods, despite the challenges posed by climate variability.

Table 24: Extent Climate Variability Affected Income

Rating	Frequency	Percentage (%)
2	4	1.2
3	11	3.2
4	317	91.9
5	13	3.8
Total	345	100

Source: Field Data (2026)

Most respondents (95.7%) rated the effect of climate variability on income as high or very high. The mean score of 3.96 (on a 5-point scale) indicates that, on average, respondents perceived a high impact on income. The findings show that climate variability has had significant consequences for household income and welfare, with only 4.4% of respondents rating the impact as moderate or low.

4.8 Regression Analysis: Effect of Climate Variability on Household Income

Table 25: Regression Model Summary

Model Statistics	Value
Multiple R	0.030
R Square (R^2)	0.001
Adjusted R Square	-0.002
Standard Error of Estimate	0.676
Observations	344

Source: Field Data (2026)

The correlation coefficient (R = 0.030) indicates a very weak positive relationship between climate variability and household income. The coefficient of determination ($R^2 = 0.001$) reveals that climate variability accounts for only 0.1% of the variation in household income, meaning approximately 99.9% of variations are explained by other factors not included in the model. The adjusted R^2 value of -0.002 indicates that the predictive power of the model is extremely weak.

Table 26: ANOVA Results

Source of Variation	Df	Sum of Squares	Mean Square	F-value	Significance
Regression	1	0.145	0.145	0.316	0.574
Residual	342	156.318	0.457		
Total	343	156.462			

Source: Field Data (2026)

The regression model produced an F-statistic of 0.316 with a p-value of 0.574. Since the p-value exceeds the conventional significance level of 0.05, the regression model is not statistically significant. This means that climate variability does not significantly explain variations in household income among smallholder farmers. This may be because households have adopted coping mechanisms that help cushion them against income losses from climate shocks.

Table 27: Regression Coefficients

Variable	B	Std. Error	t-statistic	p-value	Lower 95% CI	Upper 95% CI
Constant	3.327	0.428	7.777	0.000	2.486	4.169
Climate Variability	0.060	0.107	0.562	0.574	-0.150	0.271

Source: Field Data (2026)

The coefficient for climate variability ($\beta_1 = 0.060$) indicates a positive relationship between climate variability and household income, but this effect is not statistically significant ($p = 0.574$). The 95% confidence interval (-0.150 to 0.271) contains zero, confirming that the effect is not significantly different from zero. Since the p-value (0.574) > 0.05, the null hypothesis is accepted. Climate variability does not exert a significant direct influence on household income among smallholder farmers in Eastern Province.

4.9 Access to Institutional Support

Table 28: Access to Extension Services

Response	Frequency	Percentage (%)
Yes	345	100
No	0	0
Total	345	100

Source: Field Data (2026)

All respondents (100%) had access to extension services. This suggests that agricultural advisory services are widely available in Eastern Province. The universal access to extension services may explain the high adoption rates of conservation farming and improved seed varieties observed in the study. This aligns with evidence that access to extension agents positively correlates with crop diversification (Arslan et al., 2017).

Table 29: Access to Credit

Response	Frequency	Percentage (%)
No	340	98.6
Yes	5	1.4
Total	345	100

Source: Field Data (2026)

Interpretation: Access to credit is extremely limited, with only 1.4% of respondents having access to credit facilities. Most farmers rely on personal savings or proceeds from previous harvests. The lack of access to credit constrains farmers' ability to acquire essential agricultural inputs and invest in technologies that enhance productivity and resilience. Without adequate financial resources, farmers cannot purchase improved seeds, fertilizers, or irrigation equipment, limiting their adaptive capacity.

Table 30: Access to Climate Information

Response	Frequency	Percentage (%)
No	293	84.9
Yes	52	15.1
Total	345	100

Source: Field Data (2026)

Access to climate information is relatively low, with the majority (84.9%) reporting they do not receive weather and climate-related information. Most farmers operate under uncertainty and rely largely on indigenous knowledge and past experiences. The limited availability of climate information means farmers cannot accurately predict rainfall patterns, increasing their exposure to climatic risks. This is concerning given that farmers who integrated seasonal climate forecasts achieved higher yields (Mudenda et al., 2024).

4.10 Coping Strategies Used by Farmers

Table 31: Coping Strategies Used by Farmers

Strategy	Frequency
Diversification	65
Sustainable land management	61
Increased extension services	46
Early planting	43
Climate-smart agriculture	42

Source: Field Data (2026)

The various coping strategies adopted by farmers reflect efforts to enhance resilience in the face of climate variability. Diversification and sustainable land management practices indicate households are attempting to reduce dependence on a single livelihood source and maintain agricultural productivity. Early planting and climate-smart practices demonstrate that farmers are adjusting their farming systems in response to emerging climatic risks. The adoption of diversification strategies is consistent with findings that diversification is an adaptation response to climatic shocks (Arslan et al., 2017).

4.11 Discussion

Trends and Patterns of Climate Variability in Eastern Province

The findings indicate that climate variability has become a widespread phenomenon in Eastern Province. Out of 345 respondents, 342 (99.1%) reported experiencing changes in rainfall patterns during the past ten years. Most respondents described rainfall as only moderately reliable (57.7%), while 42.3% considered rainfall unreliable. These perceptions suggest increasing uncertainty in the onset, duration, and distribution of rainfall, which are characteristics of climate variability. The prevalence of drought experiences among respondents further demonstrates the occurrence of climatic shocks affecting agricultural production.

These findings are consistent with studies conducted in Zambia and Sub-Saharan Africa which show that climate variability manifests through delayed rainfall onset, prolonged dry spells, erratic rainfall distribution, and recurrent droughts (Ngoma et al., 2021; IPCC, 2021). According to the IPCC (2021), Southern Africa is among the regions most vulnerable to rainfall variability and rising temperatures. The findings also align with research showing that farmers can accurately perceive climate variation at fine spatial scales (Bwalya and Mwanza, 2025). Similarly, Ngoma et al. (2021) found that smallholder farmers in Zambia increasingly face unpredictable rainfall seasons, making agricultural planning difficult.

The findings are further corroborated by research showing that Eastern Province is highly exposed to drought, and climate change is expected to intensify both the frequency and severity of drought impacts (MCII, 2025). The perceived unreliability of rainfall reflects the reality that climate variability is recognized as one of the main drivers of livelihood diversification strategies (Arslan et al., 2017). The findings therefore suggest that climate variability in Eastern Province is characterized by unpredictable rainfall patterns, reduced rainfall reliability, frequent drought occurrences, and increased production uncertainty.

Influence of Climate Variability on Agricultural Investment Decisions

The second objective examined how climate variability influences agricultural investment decisions among smallholder farmers. Descriptive findings showed that most respondents believed climate variability influenced their investment decisions, with many indicating that they had reduced agricultural investments because of uncertainty associated with rainfall variability and the risk of crop failure. Farmers also reported adopting conservation farming, improved seed varieties, and drought-resistant crops as coping strategies.

However, regression analysis produced a different result. The analysis showed that climate variability explained only a very small proportion of the variation in agricultural investment decisions ($R^2 = 0.002$), and the relationship was not statistically significant ($p = 0.421$). This suggests that although farmers perceive climate variability as an important challenge, it does not independently predict their investment decisions when subjected to statistical analysis.

This finding differs from studies by Yesuf and Bluffstone (2009), Mendelsohn et al. (2006), and Arslan et al. (2015), who found that climatic uncertainty significantly discourages agricultural investment among smallholder farmers. One possible explanation is that farmers in Eastern Province may have gradually adapted to climatic uncertainty through conservation farming, improved seed varieties, crop diversification, and other climate-smart practices. The widespread adoption of conservation agriculture (88.9%) supports this interpretation. Research has shown that conservation agriculture provides a viable option for climate change adaptation due to increased yields and drought resilience (Terhoeven-Urselmans et al., 2025). On-farm trials in Zambia demonstrated that maize grain yield was significantly higher in conservation agriculture (+24% to +39%) compared to conventional management.

Consequently, investment decisions may now be influenced more strongly by access to credit, extension services, input availability, market conditions, and household financial resources than by climate variability alone. The findings suggest that while climate variability shapes farmers' perceptions, investment behaviour is determined by a broader combination of climatic, institutional, and socioeconomic factors. This interpretation is supported by evidence that access to extension agents positively correlates with crop diversification in Zambia (Arslan et al., 2017). The universal access to extension services (100%) in the study area may have facilitated the adoption of adaptation strategies, moderating the direct effect of climate variability on investment decisions.

Impact of Climate Variability on Household Income

The findings reveal that climate variability has substantial implications for household income. Most respondents rated the effect of climate variability on income as severe, with 317 respondents assigning a score of four out of five. This demonstrates that climate variability reduces agricultural productivity, which subsequently affects household earnings. Since many rural households depend on crop production as their principal source of livelihood, production losses directly translate into reduced income and diminished welfare.

Although respondents generally reported income increases over the past five years, this does not necessarily imply that climate variability has had no adverse effects. The observed income growth could be attributed to inflation, diversification into non-farm activities, livestock sales, remittances, or adoption of coping mechanisms rather than improved agricultural productivity. These findings are consistent with Harvey et al. (2014), who argue that climate variability affects food production, household assets, and income generation. Likewise, Carter et al. (2007) report that climate-related shocks reduce agricultural yields and exacerbate rural poverty.

According to Birthal et al. (2014), climate shocks often force households to sell productive assets, reduce expenditures, and diversify income sources. The finding that all respondents reported income increases despite high perceived climate impact may reflect the effectiveness of adaptation strategies. Research has shown that diversification can be an effective adaptation response (Arslan et al., 2017).

The regression analysis further revealed that climate variability explained only 0.1% of the variation in household income, and the relationship was not statistically significant ($p = 0.574$). This suggests that although farmers perceive climate variability as affecting their income, other factors such as improved seed adoption (95.5%), diversification, access to extension services, and market conditions play a more significant role in determining household income.

Mediating Role of Agricultural Investment Decisions

The findings suggest that agricultural investment decisions serve as an important channel through which climate variability affects household income. Climate variability influences farmers' willingness to invest, and these investment choices subsequently affect agricultural output and income. The majority of respondents reported reducing agricultural investments because of climate uncertainty. Reduced investments imply lower use of fertilizers, improved seeds, irrigation technologies, and mechanization, resulting in reduced productivity and lower household income.

Conversely, some farmers adopted adaptive investments such as conservation farming, drought-resistant crops, and crop diversification. These investments enhance resilience and can moderate the negative effects of climate variability on income. These findings support the adoption of conservation agriculture and improved resilience. Arslan et al. (2015) found that conservation agriculture improved resilience and productivity among smallholders, particularly where rainfall variability was high. Di Falco et al. (2011) demonstrated that climate adaptation strategies significantly increased farm productivity and reduced downside risk.

The findings are also consistent with Lobell et al. (2011), who found that adaptation investments mediate the impact of climate variability on household welfare. The relationship can be summarized as: Climate Variability → Changes in Agricultural Investment Decisions → Household Income Outcomes. This demonstrates that agricultural investment decisions act as an intermediary mechanism linking climate variability to household income.

Policy Implications

The findings have important policy implications. First, the widespread perception of climate variability and its effects on production and income suggests that climate adaptation should remain a priority in agricultural policy. The evidence that adaptation investments consistently reduce drought damages supports continued investment (MCII, 2025).

Second, the limited access to credit (1.4%) and climate information (15.1%) indicates that institutional support mechanisms need strengthening. The finding that farmers who integrated seasonal climate forecasts achieved higher yields highlights the importance of improving access to climate information services (Mudenda et al., 2024).

Third, the low investment in irrigation (2.9%) suggests that promoting irrigation development could significantly enhance resilience. Cost-benefit analysis has shown that small-scale irrigation performs better than drought-tolerant crops alone (Matchaya et al., 2025).

Fourth, the heavy dependence on maize (91.9%) indicates that crop diversification should be encouraged to reduce vulnerability to climate shocks. Diversification has been shown to be an effective adaptation response, and access to extension agents positively correlates with crop diversification

(Arslan et al., 2017).

Fifth, the high adoption of conservation farming (88.9%) and improved seeds (85.5%) suggests that extension services have been effective in promoting climate-smart practices. Continued investment in extension services and farmer training programmes is essential to maintain and enhance these gains.

5 Conclusion and Recommendations

5.1 Conclusion

This study examined the impact of climate variability on smallholder farmers' agricultural investment decisions and household income in Eastern Province, Zambia. The findings revealed that climate variability is widely experienced among smallholder farmers, with 99.1% reporting changes in rainfall patterns over the past decade. While most farmers perceived climate variability as influencing investment decisions (96.5%) and income (95.7%), regression analysis showed no statistically significant effect on investment decisions ($\beta = -0.015$, $p = 0.421$, $R^2 = 0.002$) or household income ($\beta = 0.060$, $p = 0.574$, $R^2 = 0.001$).

Investment decisions are influenced more by socioeconomic and institutional factors such as access to credit, extension services, and household financial capacity. Household income is shaped by multiple interacting factors including productivity-enhancing technologies, livelihood diversification, market access, and government support programmes. The study concludes that climate variability remains an important challenge, but it does not independently determine agricultural investment decisions or household income. Rather, farmers' adaptive responses and broader socioeconomic conditions moderate climate variability effects.

5.2 Recommendations

- Strengthen Climate Information Services: Disseminate timely weather forecasts through community radio, mobile platforms, and extension officers. Only 15.1% of respondents had access to climate information (Mudenda et al., 2024; Manoti et al., 2024).
- Promote Irrigation Development: Develop small-scale irrigation schemes and water harvesting technologies. Only 2.9% invested in irrigation. Small-scale irrigation performs better than drought-tolerant crops alone (Matchaya et al., 2025).
- Improve Access to Agricultural Credit: Develop affordable credit facilities. Only 1.4% had credit access. Village savings groups have mobilized over ZMW 11 million from 40,000 farmers (UNDP, 2025).
- Promote Climate-Smart Agricultural Practices: Intensify farmer training on conservation farming, crop diversification, agroforestry, and drought-resistant varieties. Conservation agriculture increases yields and drought resilience (Terhoeven-Urselmans et al., 2025). SCRALA project provides a model (UNDP, 2024).
- Invest in Agricultural Research and Development: Develop drought-tolerant and early-maturing crop varieties. Improved seeds contributed to income increases (95.5%).
- Encourage Crop and Income Diversification: Reduce maize dependence (91.9%) through diversification into livestock and drought-tolerant crops (Arslan et al., 2017).

5.3 Areas for Future Research

Longitudinal studies to capture long-term climate effects; comparative studies across agro-ecological regions; effectiveness of different CSA practices; gender dimensions; index-based insurance potential; role of institutional factors; integration of objective climate data with farmers' perceptions..

Declaration of Competing Interests

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The article followed all ethical standards appropriate for this kind of research.

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