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Smallholder Farmers' Perceptions of Climate Variability and Land-Use Changes in Semiarid Gwayi Catchment Agroecosystems

Simon Peter Musinguzi [1,2,*], Bright Chisadza [2,3], Onalenna Gwate [4], Nkululeko Mpofu [3], Alban Mugoti [5], Bienvenu Akowedaho Dagoudo [2] and Margaret Macherera [3,6]

1 Department of Agriculture Production, Faculty of Agriculture, Kyambogo University, Kyambogo, Kampala P.O. Box 1, Uganda
2 Faculty of Agriculture, Uganda Martyrs University, Nkozi Campus, Kampala P.O. Box 5498, Uganda; bright.chisadza@stud.umu.ac.ug (B.C.); bienvenu.akowedaho@stud.umu.ac.ug (B.A.D.)
3 Department of Crop and Soil Sciences, Faculty of Agricultural Sciences, Lupane State University, Lupane P.O. Box 170, Zimbabwe; nmpofu@lsu.ac.zw (N.M.); mmacherera@lsu.ac.zw (M.M.)
4 Department of Geography and Geo-Information Sciences, Lupane State University, Lupane P.O. Box 170, Zimbabwe; ogwate@lsu.ac.zw
5 Department of Animal Science and Rangeland Management, Faculty of Agricultural Sciences, Lupane State University, Lupane P.O. Box 170, Zimbabwe; amugoti@lsu.ac.zw
6 CDUTCM-Keele Joint Health and Medical Sciences Institute, Chengdu 611137, China
* Correspondence: spmusinguzi@kyu.ac.ug; Tel.: +256-770700846

Abstract: Climate variability and land-use changes are critical challenges impacting agriculture globally, with Zimbabwe's Gwayi catchment area experiencing noticeable effects. This study investigated how smallholder farmers in the region perceive these changes and their influence on agricultural productivity and livelihoods. The research addresses the gap in understanding local farmer experiences with climate change and land-use modifications in the context of food security. A cross-sectional survey (n = 483) was conducted using self-administered questionnaires to capture demographic information, perceptions of climate variability, land-use changes, and their impacts on agriculture. The results indicate a trend of increasing droughts, dry spells, and heatwaves, alongside altered rainfall patterns and rising temperatures, corroborating the observed climate data. Environmental degradation, including deforestation, gully formation, and land expansion, exacerbates these changes. Consequently, farmers reported substantial reductions in crop yields, with 84.05% experiencing significant-to-very negative impacts, alongside declining livestock health (32.51% reporting very negative impacts), increased water scarcity (43.3% reporting drying water sources), and more frequent disease outbreaks. These challenges collectively contributed to heightened food insecurity, with 74.12% of households reporting negative impacts on their food supply. The study underscores the synergistic impacts of climate variability and land-use changes, highlighting the urgent need for climate-smart agricultural practices and sustainable land management to enhance resilience and ensure long-term food security for smallholder farmers in the Gwayi catchment.

Keywords: climate action; sustainable agriculture; zero hunger; farmer perceptions; Gwayi; Zimbabwe

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1. Introduction

1.1. Background of the Study

Climate variability and land-use/land-cover changes (LULCC) are global challenges that significantly impact agricultural systems worldwide. These phenomena are reflected in altered precipitation patterns, increased frequency of extreme weather events, rising temperatures, and shifting land-use practices, all of which threaten agricultural productivity and rural livelihoods [1–3]. Climate variability refers to the natural short- to medium-term fluctuations in climate conditions, whereas climate change represents long-term trends largely driven by human activities, such as greenhouse gas emissions and land degradation. Concurrently, LULCC, often a result of deforestation, urbanization, and agricultural expansion, exacerbates climate-related challenges by affecting soil quality, water availability, and ecosystem health [4].

In Sub-Saharan Africa, these challenges are particularly acute, given the heavy reliance on rain-fed agriculture and limited adaptive capacity. Climate change is projected to significantly alter temperature and precipitation patterns, both of which are crucial for crop growth and productivity [5,6]. These shifts can lead to reduced crop yields [7], increased pest and disease outbreaks [8], and greater susceptibility to droughts and floods [9]. Simultaneously, LULCC, often driven by population growth and economic pressures, has profound implications for agricultural land. Deforestation, soil degradation, and shifting land management practices alter the availability and quality of arable land, exacerbating the adverse effects of climate change [10,11].

Zimbabwe, where agriculture is a key economic sector, is no exception to these challenges. Smallholder agriculture, in particular, plays a pivotal role in ensuring food security, livelihoods, and economic stability, especially in rural communities [12,13]. The Gwayi catchment of Zimbabwe, a region with diverse ecosystems and significant agricultural potential, is particularly vulnerable to the combined impacts of climate variability and LULCC [14,15]. Understanding farmers' perceptions of these changes is crucial for several reasons. First, farmers' observations provide real-time, on-the-ground insights into environmental changes, which may not always be fully captured by scientific models [16,17]. Second, perceptions shape adaptive responses—farmers' beliefs about climate change and land-use dynamics influence the strategies they employ to mitigate risks and sustain productivity [18,19].

Studies suggest that farmers' perceptions significantly impact their adaptation strategies, influencing decisions on crop selection, irrigation techniques, and land management practices [20,21]. By integrating these perceptions into vulnerability assessments, adaptation strategies can be tailored to local realities, increasing their effectiveness and sustainability [22,23]. Moreover, understanding farmers' perspectives helps identify knowledge gaps and areas where targeted interventions, such as training and resource provision, can enhance adaptive capacity.

Despite extensive research on the impacts of climate change and LULCC, a critical gap remains in incorporating farmers' perceptions into policy-making and extension services. While many studies [21–23] focus on biophysical changes, fewer explore how smallholder farmers interpret and respond to these shifts. This study aims to bridge this gap by examining the experiences and perceptions of smallholder farmers in the Gwayi Catchment regarding climate variability and LULCC. This study will assess how these perceptions influence agricultural productivity, food security, and agroecosystem resilience. By offering a bottom-up perspective on these challenges, this research seeks to highlight the importance of farmer-driven adaptation strategies. In doing so, the study will identify key vulnerabilities and propose practical, locally adapted solutions to enhance the long-term sustainability of smallholder farming systems. These findings will contribute to informed

policy recommendations and targeted interventions that strengthen resilience in Zimbabwean agriculture. More broadly, this research aims to enrich the global discourse on climate change adaptation and sustainable agricultural practices, providing valuable insights for similar agroecosystems facing comparable challenges.

1.2. Conceptual Framework of the Study

This study adopts an integrated conceptual framework to examine the complex interactions between climate variability, land-use/land-cover change (LULCC), and smallholder farmer responses within the semi-arid agroecosystems of the Gwayi catchment. Grounded in theories of vulnerability and resilience, the framework combines scientific observations with farmers' perceptions to evaluate how agroecosystems respond to climate and land-use dynamics.

The framework posits that smallholder farmers' perceptions of climate variability and LULCC are central to shaping their land-use decisions and adaptation strategies. Climate variability—manifested through changes in temperature, rainfall patterns, and the frequency of extreme weather events—influences farmers' awareness and interpretation of environmental changes. This, in turn, informs decisions related to land management practices, such as crop diversification, irrigation, soil conservation, and other adaptive strategies.

Simultaneously, land-use changes, including agricultural expansion, deforestation, and settlement growth, may amplify the impacts of climate variability through feedback mechanisms that further destabilize local ecosystems. The interaction between these environmental factors is mediated by socio-economic conditions, including farmers' income levels, education, access to resources and information, and institutional support.

Figure 1 presents the key components and relationships of the conceptual framework. It emphasizes the cyclical and interlinked nature of environmental change and human responses, highlighting how perceptions, shaped by both direct experiences and socio-economic context, influence adaptive behavior. Ultimately, the framework serves to guide the investigation into how smallholder farmers in the Gwayi catchment respond to climate and land-use pressures, and how their actions affect the resilience and sustainability of their agroecosystems.

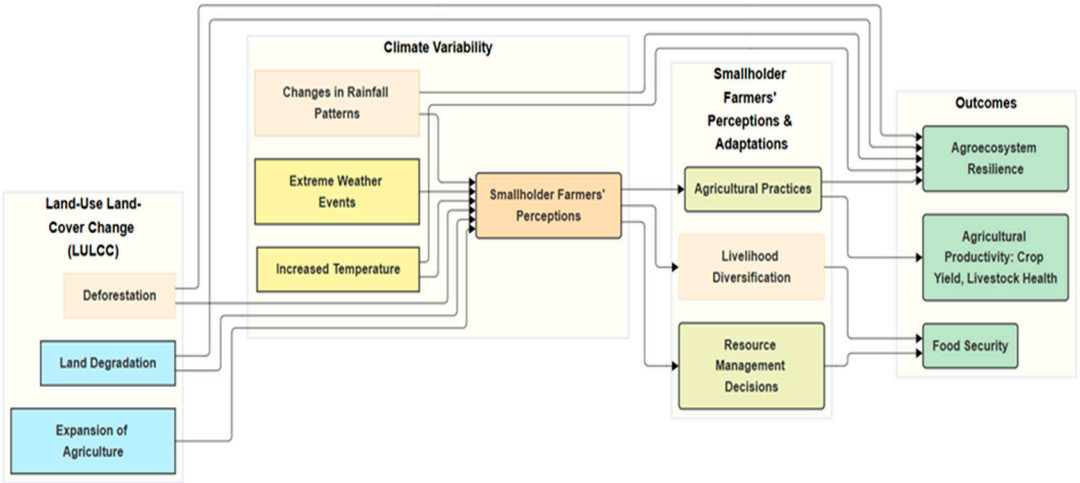

Figure 1. Conceptual framework of the study.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in the Gwayi catchment, encompassing a vast area of approximately 94,858 km^2 across Southern Zimbabwe (Figure 2). This region incorporates all of the Matabeleland North Province and parts of the Midlands Province. Notably, the catchment is further divided into five subcatchments: lower Gwayi, upper Gwayi, Shangani, Mbembesi, and Nata. These subcatchments may exhibit variations in climate due to their geographical distribution. The Gwayi catchment falls within agroecological Regions IV and V of Zimbabwe and is characterized by low rainfall, typically ranging from 450 mm to 600 mm annually. This semiarid environment experiences periodic seasonal droughts and even severe dry spells during the rainy season. These agroecological regions are distinguished by climatic and natural factors, such as rainfall patterns, soil quality, and vegetation types. Furthermore, the region experiences significant temperature variations, with an average minimum temperature of 5 °C and a maximum mean temperature of 35 °C. The dominant soil types are Kalahari coarse sandy soils and shallow clays derived from greenstone belts and basalts. These soils are inherently low in fertility [24]. Subsistence agriculture, primarily rainfed, is the main source of livelihood for rural communities within the catchment. Maize and sorghum are the dominant cultivated crops because of their adaptation to drier conditions [25]. Given these challenging environmental and agricultural constraints, this study examines how farmers perceive climate change, adapt their practices, and build resilience in the Gwayi catchment.

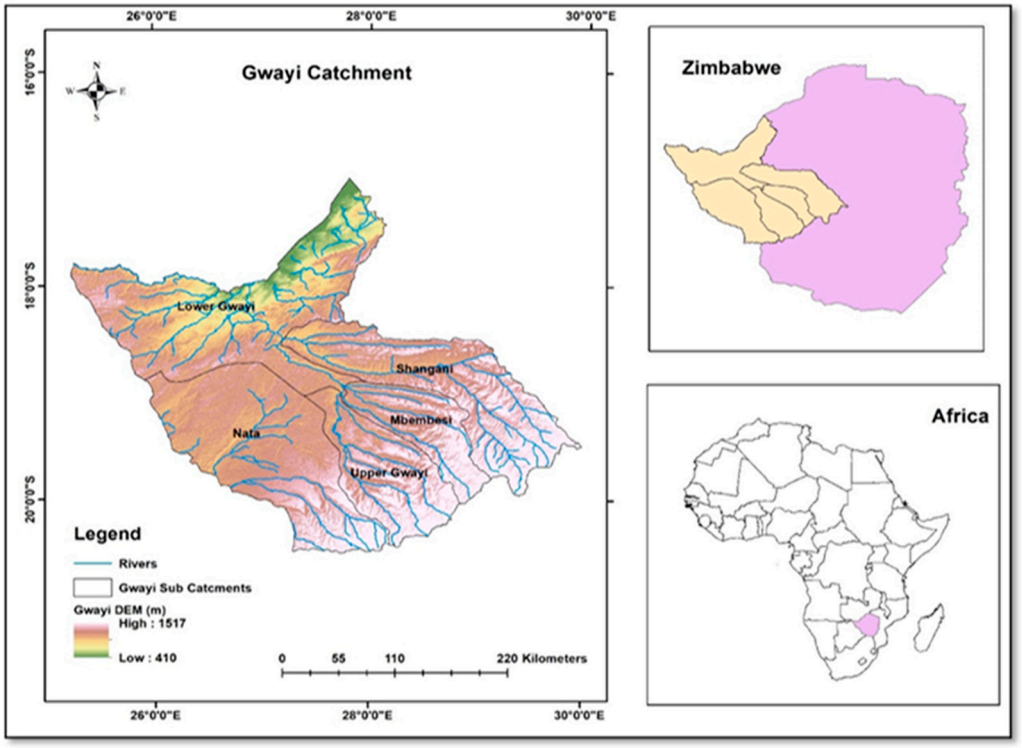

Figure 2. Gwayi catchment area of Zimbabwe.

2.2. Sampling

This study employed a multistage sampling approach to gather data from smallholder farmers in the Gwayi catchment, Zimbabwe (Figure 3). The unit of analysis for the study was the individual farm household. Five districts within the catchment were purposively chosen to represent the diverse climate and vegetation characteristics associated with rural agroecological crop and livestock farming communities (Table 1). Districts with

extensive tourist areas or mining activities were excluded to ensure a focus on agricultural communities. Population data from the 2022 Zimbabwe preliminary census report [26] were used to determine the total number of households in the five selected districts, which served as the sampling frame. The total number of households in the five districts was 135,801 [26]. Using a Raosoft calculator, which is based on [27] formula, with a 95% confidence level and a 5% margin of error, a target sample size of 487 households was determined. This translated to approximately 97–98 respondents per district (Table 1). Equation (1) [27] was also used to determine the final number of sampled wards within each selected district to ensure randomization. Prior to administering the questionnaires, a pilot test was conducted on a smaller group (10 respondents) to refine the instrument for clarity and ensure that it effectively captured diverse responses. A high response rate of 99.1% was achieved, with 483 completed household questionnaires obtained from the targeted sample of 487 households.

$$n = \frac{z_{\frac{\alpha}{2}}^2 \times N \times p(1-p)}{e^2 \times (N-1) + z_{\frac{\alpha}{2}}^2 \times p(1-p)} \quad (1)$$

where:

n is the sample size;

N is the population size;

z (α/2) is the critical value of the normal distribution at a confidence level of α;

e is the margin of error;

Where p is the sample proportion and $p(1 - p) = \sigma^2$ represents the variance of the estimator.

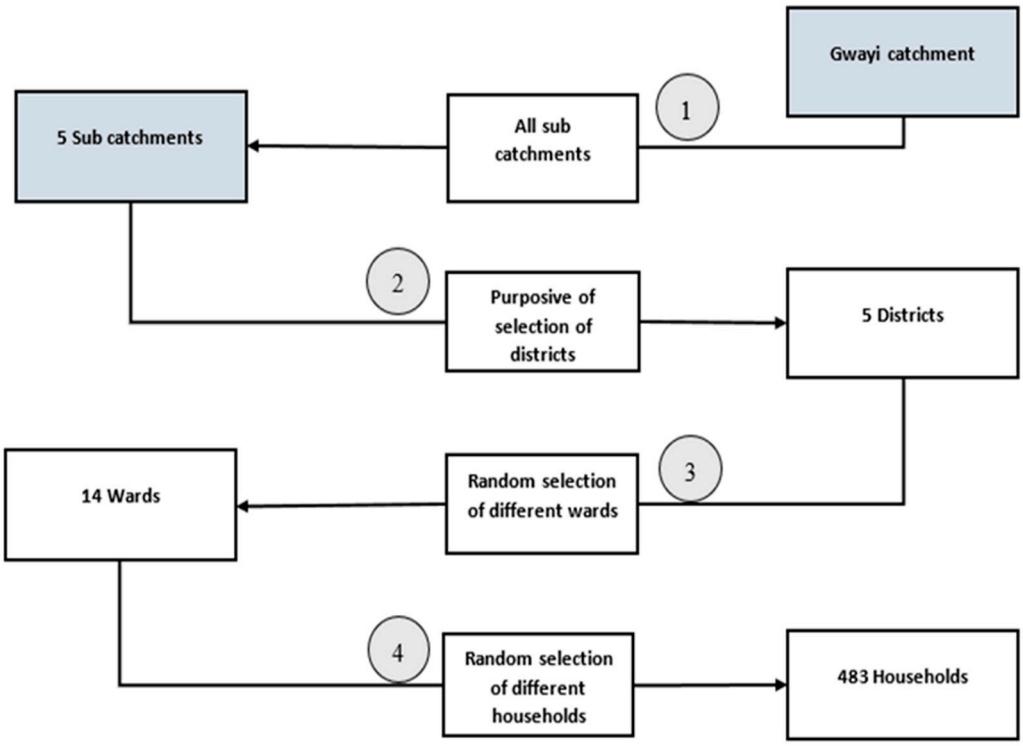

Figure 3. Multistage sampling approach (1–4 indicate the sampling steps).

Table 1. Sample size for each selected district.

Sub Catchment	Selected District	Households (Preliminary Census Report 2022)	Calculated HH Sample			Completed HH Questionnaires
			Total Number of Wards	Wards	Households (HH)	
Nata	Tsholotsho	26,668	22	3	98	98
Shangani	Lupane	23,028	28	3	97	97
Upper Gwayi	Umguza	28,358	19	2	97	96
Mbembesi	Bubi	18,252	23	3	97	96
Lower Gwayi	Binga	39,495	25	3	98	96
Total		135,801	117	14	487	483

2.3. Data Collection

A cross-sectional survey design was employed to collect data from 483 smallholder farmers residing within the Gwayi catchment of Zimbabwe during March and April 2024. This approach allows for the collection of data at a single point in time, providing a snapshot of current perceptions, practices, and experiences related to climate variability and land-use/land-cover changes (LULCC) [28]. It is particularly suited for assessing patterns and associations across a population without requiring follow-up over time. A self-administered household questionnaire, developed in accordance with [29] guidelines for clarity and comprehensiveness, served as the primary tool for quantitative data collection. The questionnaire comprised three sections. Section A gathered demographic details (e.g., age, education, and farming experience). Section B focused on exposure and experience, capturing the farmers' first-hand encounters with climate variability and land-use changes. This included questions on observed shifts in rainfall patterns, temperature, and land-cover changes over time. Section C, in contrast, explored the perceived impacts and implications of these changes on agriculture and livelihoods. It assessed farmers' perceptions of how these changes have affected crop and livestock productivity, food security, and overall farming sustainability. While Section B was observational and descriptive, Section C was evaluative and interpretive, measuring the extent and nature of the perceived effects of environmental changes on farmers' well-being and practices. Both closed-ended (e.g., Likert scale items and frequency ratings) and open-ended questions were used, allowing for the quantification of trends and capturing nuanced, individual perspectives. The standardized format ensured consistency, enabling reliable comparison across respondents. To enhance the findings and contextualize the quantitative results, qualitative data were collected through key informant interviews and focus group discussions. A total of 25 key informants, comprising extension officers, traditional leaders, and environmental officers (five from each of the five districts), were purposively selected based on their local knowledge, leadership roles, and experience with climate adaptation practices. These informants provided expert insights into observed environmental changes, institutional responses, and barriers to adaptation. Furthermore, ten focus group discussions (FGDs) were conducted across the study area, each consisting of twelve participants (including both men and women smallholder farmers) drawn from diverse socio-economic backgrounds. FGDs aimed to explore community-level perspectives, shared experiences, and collective strategies related to climate resilience and LULCC. Ethical clearance was obtained from the relevant extension services department and the Medical Research Council of Zimbabwe, and all participants were assured of confidentiality and anonymity through the use of non-identifiable data collection instruments. This study does not attempt to predict weather

events but rather captures farmers' perceptions of climate variability as experienced over time. While meteorological data are essential for climate modeling, farmers' perceptions provide critical insights into localized impacts and inform adaptation strategies.

2.4. Data Analysis

STATA version 14 was used to perform descriptive statistics on the survey data. Descriptive statistics can reveal trends, central tendencies, and variability within a dataset [30]. To examine the interactions between variables, chi-square tests were conducted to explore the associations between climate variability, land-use changes, and their impacts on crop yields, livestock health, and food security. The statistical significance of these relationships highlights the synergistic effects of these factors on agricultural systems and livelihoods. In addition to a quantitative analysis of the closed-ended questions, a thematic analysis was applied to the qualitative data obtained from open-ended responses. The process involved coding the responses to identify recurring themes and sub-themes, which were then categorized. These themes were subsequently quantified by counting their frequency of occurrence across responses. This allowed us to translate qualitative insights into quantifiable trends, which were then integrated with the quantitative findings for presentation in tables and figures where appropriate. This method allowed for the identification, organization, and interpretation of recurring themes within the farmers' responses, providing richer insights into their experiences and observations [31]. By combining quantitative and qualitative approaches, this analysis offers a comprehensive understanding of how climate variability and land-use changes jointly influence farming systems in the Gwayi catchment.

3. Results

3.1. Farmer Demographics and Agricultural Profile

The study participants represented a diverse group of smallholder farmers, with household heads averaging 50 years of age and possessing nearly two decades of farming experience. The average household size was six members, and income levels remained modest, averaging USD 166.09 per month. The gender distribution revealed a male majority (58.8%) but significant female participation (41.2%), which has implications for access to agricultural resources and inputs. Educational attainment varied, with secondary education being the most common (30%), potentially limiting the adoption of advanced climate adaptation strategies. Smartphone ownership among farmers was relatively high (57%), with WhatsApp (55%) and SMS (48%) emerging as the primary communication channels for agricultural extension services. Farmers were predominantly reliant on rain-fed farming (83.44%). Sorghum (65%), millet (45%), and cowpea (19%) were also cultivated (Figure 4). The dominant horticultural crops grown are shown in Figure 5. Livestock rearing involved goats (71%), poultry (65%), and cattle (53%) (Figure 6).

3.2. Farmer Observations of Climate Change and LULCC

3.2.1. Droughts and Dry Spells

About 70% of Gwayi catchment smallholder farmers reported experiencing droughts, dry spells, and heatwaves frequently (4–5 times or even every year) over the past five years, with an exceptionally high frequency (92.47%) of these extreme events reported by farmers in the Bubi district and a low percentage of farmers reporting the events "never" or "once" in the past five years (1.04% and 17.81%, respectively) (Table 2).

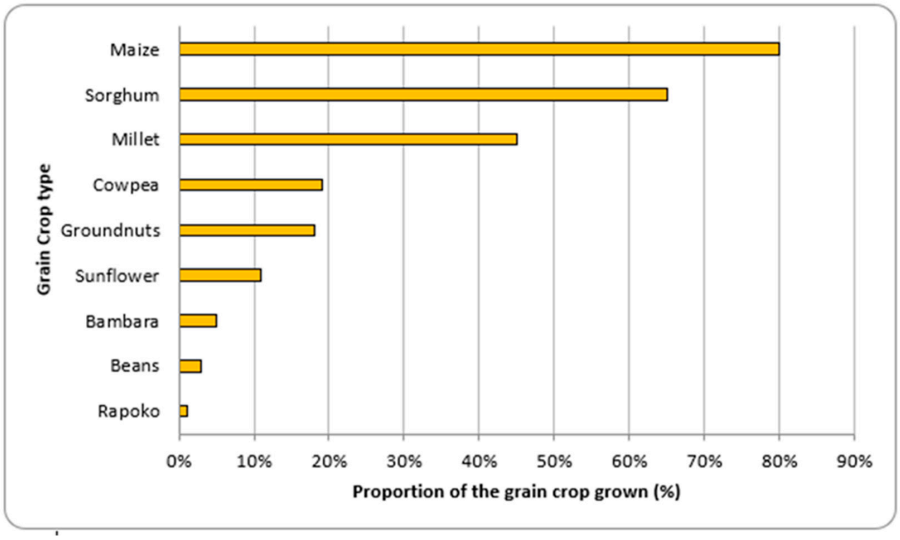

Figure 4. Proportion of farmers cultivating each major grain crop in the Gwayi catchment. Multiple responses were allowed. Therefore, totals exceed 100%.

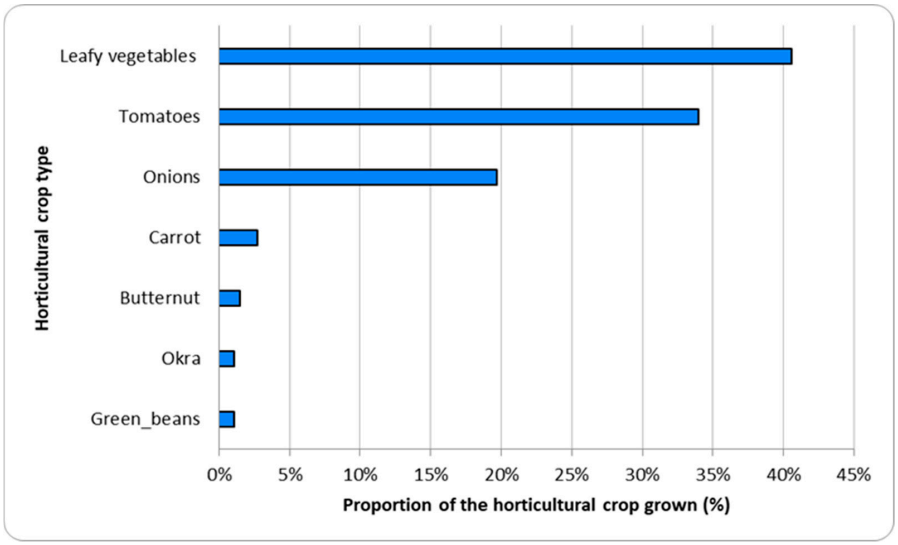

Figure 5. Proportion of farmers cultivating major horticultural crops. Multiple responses permitted; totals may exceed 100%.

Table 2. Severe droughts and heatwaves experienced over the past five years in the Gwayi catchment.

District	Percent Response (%)				
	Never	**Once**	**2–3 Times**	**4–5 Times**	**Every Year**
Binga	2.22	33.33	20.00	18.89	25.56
Bubi	0.00	5.38	92.47	2.15	0.00
Lupane	1.67	19.17	71.67	3.33	4.17
Tsholotsho	0.00	2.22	90.00	3.33	4.44
Umguza	1.11	28.89	70.00	0.00	0.00
Overall Proportion	1.04	17.81	69.15	5.38	6.63

N.B: Overall proportion (%) represents the percentage of all surveyed farmers (n = 483) across districts who selected each response option.

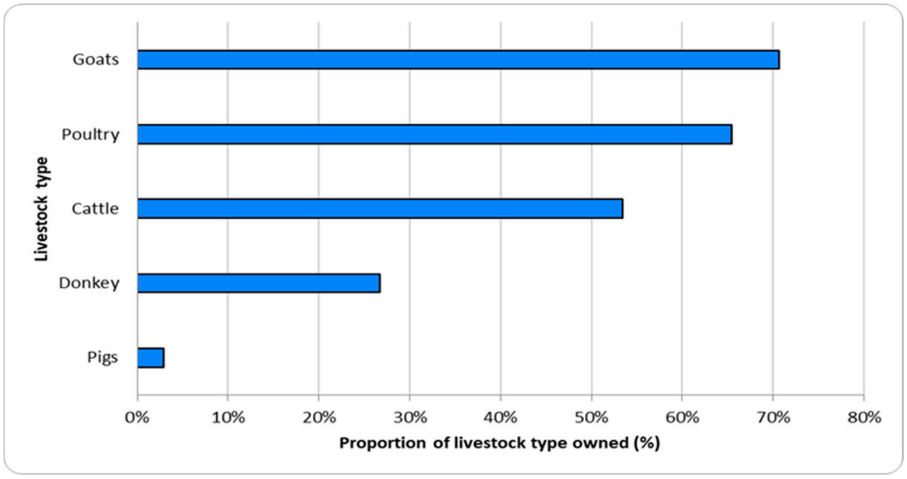

Figure 6. Proportion of farmers owning different livestock species. Farmers often keep more than one type. Hence, percentages exceed 100%.

3.2.2. Perceived Changes in Rainfall Patterns and Temperature over the Past Decade (2014–2024)

Smallholder farmers in the Gwayi catchment reported observing significant shifts in weather patterns over the past decade. Approximately 33.75% of the respondents noted an increased frequency of dry spells and droughts (Table 3), while 19.46% reported a decline in overall rainfall (Table 3). The co-occurrence of reduced precipitation and rising temperatures was reported by 9.32% of farmers. Additionally, 20.91% of the farmers reported more erratic rainfall and a delayed rainy season. Notably, the Umguza district had the highest percentage of farmers reporting erratic rainfall. The unpredictability of rainfall was identified as a severe challenge, particularly concerning planting schedules and water availability for both crops and livestock. A participant from Tsholotsho district described this shift:

Table 3. Reported changes in rainfall and temperature from 2014 to 2024 in the Gwayi catchment.

District	Percent Response (%)				
	Increased Frequency of Dry Spells/Droughts	**Decreased Rainfall Amounts**	**Higher Temperatures**	**More Erratic Rainfall**	**Late Start of Rains**
Binga	32.22	30.00	8.89	13.33	15.56
Bubi	62.37	5.38	23.66	8.60	0.00
Lupane	32.50	35.83	5.00	9.17	17.50
Tsholotsho	38.89	10.00	10.00	14.44	26.67
Umguza	2.22	11.11	0.00	63.33	23.33
Overall Proportion	33.75	19.46	9.32	20.91	16.56

N.B: Overall proportion (%) represents the percentage of all surveyed farmers (n = 483) across districts who selected each response option.

> *"We used to plant in October following consistent seasonal patterns. Now the rains are so unreliable that planting often gets delayed until December or even January, leaving our crops vulnerable to early dry spells".* (Male farmer, age 54, Tsholotsho)

While crop diversification was identified as a potential adaptation strategy, farmers reported systemic challenges in implementation. A respondent from Umguza explained:

> *"Although we recognize drought-resistant crops like millet and sorghum perform better, accessing quality seeds remains problematic. When available, their cost is prohibitive for most households in our community".* (Female farmer, age 41, Umguza)

Key informant interviews with extension personnel highlighted growing difficulties in providing reliable guidance:

> *"Our traditional planting recommendations have become obsolete. With such unpredictable onset of rains, we increasingly rely on short-term weather forecasts rather than historical patterns".* (Agricultural extension officer, 8 years of service, Gwayi catchment)

The compounding effects of climate change were particularly evident in pastoral systems, as reported by a Binga cattle farmer:

> *"The situation grows dire each season—our grazing lands have become barren, and traditional water sources have disappeared. Last year alone, I lost seven head of cattle to drought-related conditions".* (Pastoralist, age 62, Binga)

3.2.3. Reported Changes in Landscape and Land-Use Practices

Approximately 28% of the surveyed farmers reported observing signs of land degradation, with the highest proportion of these observations (72%) recorded in the Bubi district. Reports of drying water sources were highest in Lupane (68.33%) and Tsholotsho (70%), contributing to an overall response rate of 43.3% across the catchment. Deforestation was reported by 18.2% of respondents, with the Umguza district having the highest proportion at 52.22%. Additionally, 6.6% of farmers observed the drying of wetlands, while 0.41% noted increased flooding. Only 3.5% of respondents indicated no noticeable change in their surrounding landscape (Table 4). Separately, 59% of farmers identified overgrazing as a major environmental concern (Figure 7), and 30% reported the adoption of new crop varieties as part of their adaptation strategies.

Table 4. Changes in forest and water sources and landscape.

District	What Changes Have You Noticed in the Forests, Water Sources, and Landscape					
	Percent Response (%)					
	Deforestation	**Land Degradation**	**Drying up of Water Sources**	**Increased Flooding**	**Drying up of Wetlands**	**No Change**
Binga	11.11	16.67	57.78	1.11	0.00	13.33
Bubi	25.81	72.04	2.15	0.00	0.00	0.00
Lupane	0.83	16.67	68.33	0.83	10.83	2.50
Tsholotsho	6.67	22.22	70.00	0.00	1.11	0.00
Umguza	52.22	14.44	11.11	0.00	20.00	2.22
Overall Proportion	18.22	27.95	43.27	0.41	6.63	3.52

N.B: Overall proportion (%) represents the percentage of all surveyed farmers (n = 483) across districts who selected each response option.

N.B: Data reflect perceptions of change rather than quantified temporal records.

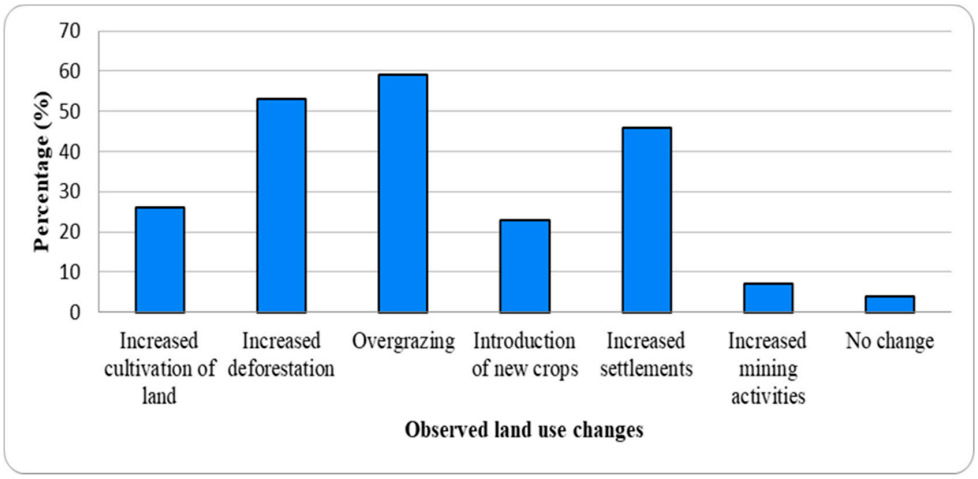

Figure 7. Farmer-reported land-use changes observed in recent years in the Gwayi catchment.

3.3. Farmer Perceptions of the Impacts of Climate Variability and Land-Use Changes

3.3.1. Impact of LULCC on Agricultural Activities and Agroecosystems

Most respondents (76.19%) perceived that land-use and land-cover change had a negative impact on their farming activities, with 54.45% reporting a significant impact and 21.74% indicating a moderate impact (Figure 8). In contrast, 23.81% of farmers either perceived a lesser impact (13.66%) or were unsure about the effects (10.14%). Regarding the perceived causes of these changes (Figure 9), the most frequently cited factor was reduced or erratic rainfall patterns, mentioned by 39.1% of the respondents, followed by increased temperatures, noted by 30.2%.

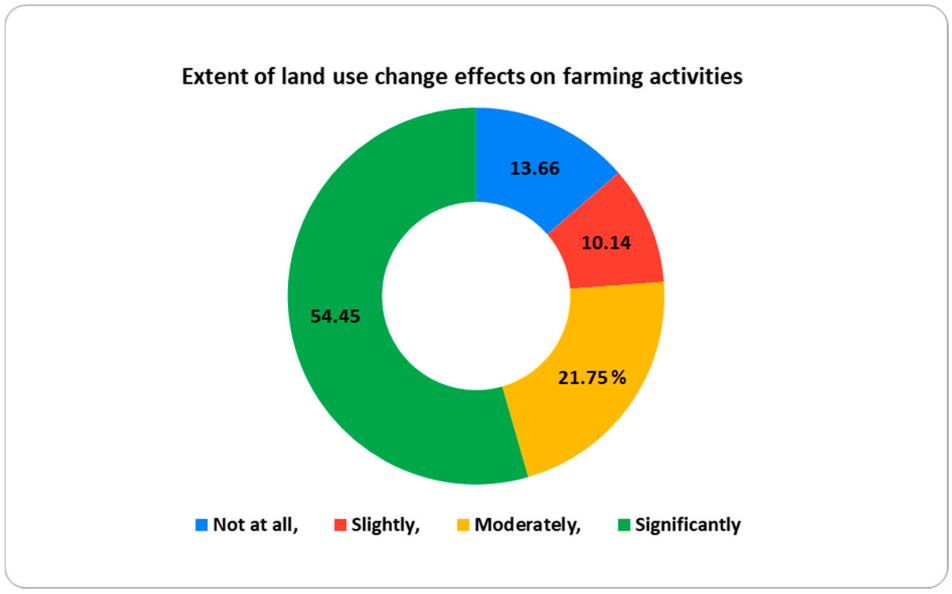

Figure 8. The extent to which land-use changes have impacted farming activities.

3.3.2. Reported Impacts of Climate Variability on Crop Yields and Livestock Health

On crop farming, all districts reported at least some decrease in grain crop yields due to droughts, dry spells, and heatwaves. About 44.51% of the farmers reported experiencing "very negative impacts", highlighting substantial yield reductions and threats to food security. Only 0.83% reported either no impact or a slight decrease in productivity (Table 5). Figure 10 depicts the poor condition of a maize crop in Tsholotsho District, illustrating the adverse effects of prolonged dry spells on crop performance.

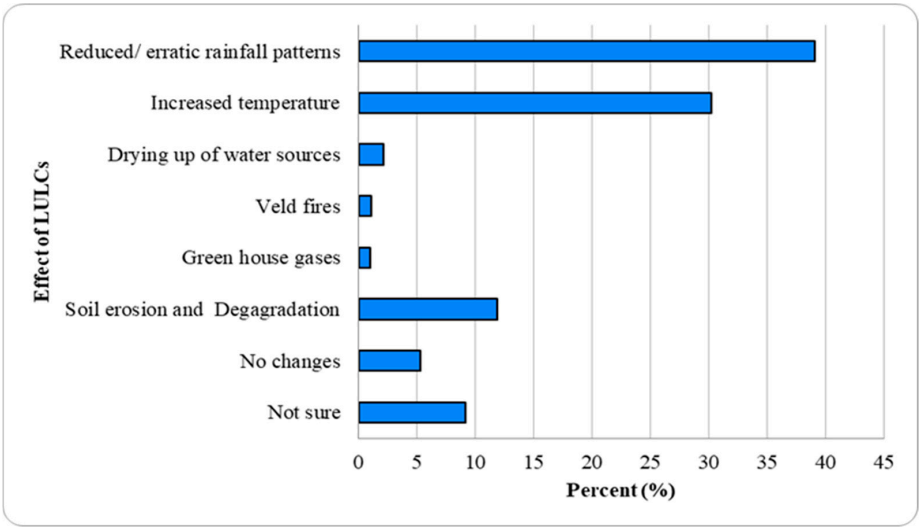

Figure 9. Effects of land-use changes on Gwayi agroecosystems.

Table 5. Perceived impact of droughts, dry spells, and heatwaves on average grain yield in the Gwayi catchment.

District	% Response				
	No Impact	Decreased Slightly	Decreased Moderately	Decreased Significantly	Very Negatively Impacted
Binga	3.33	3.33	13.33	52.22	27.78
Bubi	1.08	0.00	6.45	51.61	40.86
Lupane	0.00	0.00	8.33	26.67	65.00
Tsholotsho	0.00	0.00	18.89	52.22	28.89
Umguza	0.00	20.00	7.78	18.89	53.33
Overall Proportion	0.83	4.35	10.77	39.54	44.51

Figure 10. The 2022/23 season crop conditions as of 26 March 2023 in Tsholotsho (Source: author, fieldwork).

The impact of climate variability in the Gwayi catchment extends beyond crop yields and also affects livestock health and productivity (Table 6). Although generally perceived

as less severe than crop-related impacts, a substantial proportion of respondents reported challenges in the livestock sector. Specifically, 33.13% of farmers indicated that their livestock had been negatively affected, with 15.53% experiencing moderate impacts and 17.6% reporting very negative impacts due to droughts, dry spells, and heatwaves. Notably, the Lupane district had the highest percentage (57.5%) of farmers reporting adverse impacts on livestock, possibly reflecting environmental constraints such as diminished grazing quality, reduced water availability, and increased exposure to heat stress and disease. These findings underscore growing concerns about the long-term sustainability of livestock-based livelihoods in the catchment. Furthermore, the impacts of climate variability have also affected household food security, with several respondents reporting reduced food self-sufficiency and increased reliance on food aid or external sources. The findings also indicate that 74.12% of the smallholder farmers reported negative impacts on their food security due to extreme weather events, whereas only 25.88% experienced no direct effects. Farmers have employed various coping strategies to mitigate climate impacts, though their effectiveness remains constrained by systemic challenges. Qualitative data revealed three primary coping mechanisms:

1. Dietary adjustments

During extreme droughts, many households reduced food consumption and relied on wild foods. As one Lupane participant explained:

> *"During the last drought, we only ate one meal a day. We collected wild fruits and vegetables to supplement"* (focus group discussion, Lupane);

2. Livelihood diversification

Some farmers sought off-farm labour, though opportunities were limited. A Binga farmer described this challenge:

> *"We try to find work outside the farm—building houses or road work—but jobs are hard to come by. When we find work, the pay is too little"* (individual interview, Binga);

3. Social knowledge networks

Communities leveraged collective wisdom to share adaptive practices. One participant noted:

> *"We learn a lot from each other. When one farmer tries a new drought-resistant crop, we all discuss the results. Sharing information is key to surviving these hard times"* (focus group discussion, Umguza).

However, local leaders expressed concerns about the sustainability of these approaches. A Binga community leader emphasized:

> *"These coping mechanisms are like using a bucket to stop a flooding river. We're worried about the future—our children won't survive on wild foods alone. We need real solutions like irrigation and drought-resistant seeds"* (key informant interview, Binga).

3.3.3. Synergistic Impacts of Climate and Land Use on Farming Systems and Livelihoods in the Gwayi Catchment

Chi-square tests revealed statistically significant associations between several key variables (Table 7). A strong association was found between drought frequency and crop yield impact ($\chi^2 = 141.513$, $p < 0.001$), indicating a significant relationship between the occurrence of droughts and their adverse effects on agricultural productivity. Similarly, a significant association was observed between drought impact and livestock health ($\chi^2 = 102.593$, $p < 0.001$), highlighting a relationship between drought severity and negative impacts on animal health and productivity.

Table 6. Perceived impact of droughts, dry spells, and heatwaves on livestock health and productivity in the Gwayi catchment.

District	No Impact	Decreased Slightly	Decreased Moderately	Decreased Significantly	Very Negatively Impacted
Binga	20.00	16.67	16.67	31.11	15.56
Bubi	12.90	0.00	11.83	44.09	31.18
Lupane	4.17	1.67	13.33	23.33	57.50
Tsholotsho	0.00	0.00	22.22	50.00	27.78
Umguza	16.67	26.67	14.44	20.00	22.22
Overall Proportion	10.35	8.49	15.53	33.13	32.51

Table 7. Chi-square test results for various categorical variables.

Independent Variable	Dependent Variable	Test Statistic	χ^2 Value	df	*p*-Value
Drought Frequency	Crop Yield Impact	Pearson Chi-Square	141.513	16	0.000
		Likelihood Ratio	55.805	16	0.000
Drought Impact	Livestock Health	Pearson Chi-Square	102.593	16	0.000
		Likelihood Ratio	96.484	16	0.000
Land-Use Changes	Rainfall Patterns	Pearson Chi-Square	611.937	400	0.000
		Likelihood Ratio	568.908	400	0.000
Rainfall Patterns	Landscape Changes	Pearson Chi-Square	122.220	20	0.000
		Likelihood Ratio	114.681	20	0.000
Food Security	Land-Use Changes	Pearson Chi-Square	166.094	100	0.000
		Likelihood Ratio	185.419	100	0.000

N.B df is degrees of freedom.

The analysis also showed a highly significant association between land-use changes and rainfall patterns ($\chi^2 = 611.937$, $p < 0.001$), suggesting a strong relationship between alterations in land management and shifts in local precipitation. Furthermore, a significant link was identified between changes in rainfall patterns and landscape degradation ($\chi^2 = 122.220$, $p < 0.001$), indicating a relationship between erratic/reduced rainfall and the deterioration of natural resources. Finally, a strong association was found between food security and land-use changes ($\chi^2 = 166.094$, $p < 0.001$), suggesting a significant relationship between unsustainable land practices and the ability of communities to secure sufficient food.

4. Discussion

4.1. Perceptions of Climate Variability

The consistent perception among smallholder farmers in the Gwayi catchment of increasingly frequent droughts, dry spells, and heatwaves (Table 2) underscores their direct experience with the changing climate, a reality increasingly documented in semi-arid regions of Sub-Saharan Africa [31,32]. The demographic and socioeconomic profile of these farmers is characterized by a significant reliance on rain-fed agriculture (83.44%), a key finding of this study, which exacerbates their vulnerability to climate variability, as highlighted in the broader literature [33,34]. Their constrained adaptive capacity is further underscored by a low average monthly income of USD 166.09, a limitation consistent with studies showing that financial resources hinder climate resilience [35,36]. Additionally, the

varied educational attainment, with secondary education being most common (30% in our sample), may limit the adoption of advanced adaptation strategies, as suggested by other research [35–37]. While the relatively high adoption of mobile technology, with 57% owning smartphones and 55% using WhatsApp for agricultural communication, offers avenues for disseminating crucial climate information [22], the limited uptake of advanced climate adaptation strategies suggests that access to information alone is insufficient. This finding echoes the challenges identified by [37–39] in other rural African contexts, where structural barriers, such as limited extension support and access to essential drought-tolerant inputs, impede the translation of climate awareness into effective on-farm action. The validation of farmers' experiential knowledge through these findings challenges top–down adaptation planning that may overlook local realities. Recognizing both the awareness and the persistent constraints is crucial for designing locally relevant extension services and investing in timely and accessible early warning systems.

4.2. Observed Land-Use and Landscape Changes

The reported landscape transformation, marked by significant land degradation (28%), deforestation (18%), and the depletion of water sources (43%), indicates a concerning synergy between climatic stress and potentially unsustainable land management practices. This observation is in line with extensive research in dryland environments by [40,41], which demonstrates how environmental pressures, often compounded by livelihood demands, drive negative land-use changes that lead to environmental degradation. The notable geographic variations, such as the higher incidence of land degradation in Bubi (72%), potentially linked to the environmental impacts of increased mining activities [42–44], and the severe water scarcity reported in Lupane (68.33%) and Tsholotsho (70%), highlight the spatial heterogeneity of environmental vulnerability within the Gwayi catchment. These disparities necessitate geographically targeted interventions. The observed settlement expansion (50%) and increased land cultivation (26%), while potentially representing responses to demographic growth and food insecurity, present a dual-edged sword. Without sustainable land management practices, these trends risk further exacerbating land degradation, illustrating a scenario where adaptation efforts could inadvertently lead to maladaptation [42]. The consistent reporting of changes like wetland drying (7%) and increased overgrazing (59%) by the communities lends strong credence to local environmental monitoring and underscores the importance of incorporating local ecological knowledge into broader environmental assessments [45].

4.3. Impacts on Agriculture and Livelihoods

The significant disruptions to crop yields and livestock productivity reported by farmers (Tables 5 and 6) illustrate the impacts of climate variability on agricultural livelihoods in the Gwayi catchment. The substantial proportion (44.51%) experiencing "very negative impacts" on grain crop yields due to increased droughts, dry spells, and heatwaves reinforces the growing unsuitability of traditional cropping systems [40], particularly the heavy reliance on maize (80%), under evolving climatic conditions [39]. This finding aligns with broader regional analyses by [46] and the [47], which document the escalating threats posed by climate change to agricultural production across Sub-Saharan Africa. Similarly, the reported deterioration of livestock health, particularly pronounced in Lupane, where 57.5% noted negative impacts (our finding) [47], reflects the increasing challenges of feed and water scarcity resulting from prolonged dry periods. The high percentage of farmers (over 74%) reporting negative impacts on their food security due to extreme weather events [6,20] underscores the direct translation of environmental stress into household vulnerability. This critical finding emphasizes the urgent need for development planning to prioritize

adaptive agricultural practices that not only sustain production but also ensure consistent food access and nutritional security for these communities. The empirical evidence from this study provides a strong foundation for informing resilience policies aimed at bolstering household nutrition and promoting diversified livelihood strategies.

4.4. Farmer Adaptation Strategies and Resilience Gaps

The diverse adaptation strategies employed by farmers, ranging from dietary adjustments and livelihood diversification to leveraging social knowledge networks (qualitative findings from our study), demonstrate a significant degree of local agency and resourcefulness in the face of climate challenges. However, the persistent issues of food insecurity and productivity losses suggest that these efforts are often insufficient to overcome systemic vulnerabilities. The identified structural barriers, including limited access to improved seeds for drought-resistant crops like sorghum (65%) and millet (45%), inadequate availability of water harvesting technologies, and the lack of timely and relevant agro-climatic information, represent critical constraints hindering the widespread adoption of effective adaptation measures, a challenge also highlighted by [45,46]. The continued reliance on rain-fed agriculture (83.44%) [47,48] further exacerbates these limitations, particularly when compared to regions with access to irrigation infrastructure [48]. While the study highlights the crucial role of traditional knowledge and social capital in building resilience, as evidenced in focus group discussions, these informal mechanisms require strengthening through formal institutional support to ensure long-term sustainability and scalability [49]. The statistically significant associations revealed by the chi-square analysis between climate variability (drought frequency) and agricultural impacts (crop yield impact: $\chi2 = 141.513$, $p < 0.001$; livestock health: $\chi2 = 102.593$, $p < 0.001$) [47–49], as well as the interconnectedness of climate stress, land-use decisions, and food security (land-use changes and rainfall patterns: $\chi2 = 611.937$, $p < 0.001$; changes in rainfall patterns and landscape degradation: $\chi2 = 122.220$, $p < 0.001$; food security and land-use changes: $\chi2 = 166.094$, $p < 0.001$), empirically validate the farmers' perceptions and underscore the complex interplay of factors affecting their livelihoods. These findings support the use of perception-based data as a valuable source of information while also emphasizing the potential for future research to integrate this with objective meteorological and remote-sensing data [50–52] for a more comprehensive understanding.

Despite its contributions, the study has limitations. It relies on self-reported data, which may be subject to recall bias or misinterpretation. The absence of meteorological or satellite-based validation data limits the precision of certain observations. However, this limitation also opens pathways for future mixed-method research that combines farmer knowledge with geospatial and instrumental datasets.

4.5. Limitations of the Study

While this study offers valuable insights into smallholder farmers' perceptions of climate variability and land-use changes, several limitations should be acknowledged. First, the study relies primarily on self-reported data obtained through questionnaires. Although such experiential knowledge is essential for understanding local adaptation behaviors, it may be subject to recall bias and may not always align with objective, instrument-based climate records. Due to resource constraints and the scope of this research, it was not feasible to incorporate meteorological or satellite remote-sensing data for cross-validation. Future research should integrate these objective data sources to triangulate farmer perceptions and enhance the accuracy and reliability of trend assessments. Second, the statistical analysis employed chi-square tests to explore the associations between key categorical variables such as drought frequency, land-use changes, and food security. While

useful for identifying significant relationships, this method does not account for potential confounding variables. Given the exploratory nature of the study, advanced statistical techniques such as multivariate regression were not applied. Future research should adopt such methods, using control variables like gender, income level, and access to extension services to capture more nuanced interactions and causal pathways. Moreover, combining quantitative and qualitative approaches will enhance the depth, robustness, and policy relevance of future studies in this area.

5. Conclusions

This study examined the experiences and perceptions of smallholder farmers in the Gwayi catchment regarding climate variability and land-use change, with a focus on their impact on agricultural production and food security. The findings reveal a complex interplay of challenges, where increasing drought frequency, erratic rainfall patterns, and rising temperatures, key indicators of climate change, intensify existing socioeconomic vulnerabilities. Additionally, unsustainable land-use practices, such as deforestation and land degradation, further threaten the resilience of farming communities. The results highlight that most farmers in the region face significant food security disruptions and have a limited capacity to adapt to climate-induced shocks. Decreasing crop yields, reliance on unsustainable coping strategies such as reducing daily meals, and difficulties in securing alternative income sources are widespread. These findings align with the broader trends observed in Sub-Saharan Africa, where climate variability disproportionately affects smallholder agricultural systems. To address these challenges, climate-responsive policies must prioritize sustainable land management, conservation agriculture, and agroforestry to improve soil and water conservation. Strengthening extension services and expanding training on climate-smart farming techniques, such as drought-tolerant crops and improved water harvesting methods, are critical for enhancing farmers' adaptive capacity. While this study provides valuable insights, certain limitations must be acknowledged. The reliance on self-reported data may introduce biases, as farmers' perceptions of climate variability may not always align with meteorological records. Future research should integrate long-term climate data and explore the role of emerging technologies, such as remote sensing and precision agriculture, in improving adaptation strategies. In conclusion, the increasing impacts of climate variability and land-use change pose significant threats to smallholder farmers in the Gwayi catchment. Tackling these challenges requires a coordinated, multistakeholder approach that integrates policy support, scientific innovation, and community-driven adaptation strategies. Through promoting sustainable agricultural practices, improving access to financial and technical resources, and strengthening institutional support systems, it is possible to increase resilience and safeguard food security for vulnerable communities. The policy recommendations presented in this study provide a general framework. Future research should focus on developing detailed implementation pathways and conducting feasibility analyses to ensure their practicality. Furthermore, analyzing the differential impacts of response strategies across various farmer groups, including gender and income levels, is crucial for formulating more targeted and equitable policies.

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