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The impact of climate variability and change on farm productivity in Mazowe district, Zimbabwe: An exploration of farmers' adaptation strategies

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Abstract

The primary aim of this study was to examine the perceived impact of climate variation and change on agricultural productivity using the Mazowe district as a case study. The study's specific goals were to ascertain farmers' level of knowledge regarding the effects of climate variability and change, examine how farmers perceive these effects on farming output, and ascertain how climate adaptation strategies affect agricultural production. A cross-sectional research design and a mixed-method technique were used to investigate the impact of climate change. Qualitative and quantitative data was collected using interviews with key informants and semi-structured survey questions. Commercial farmers, extension agents, district administrators, district representatives from the Agricultural and Rural Development Authority, district representatives from the Lands, Agriculture, Fisheries, Water, Climate and Rural Development, as well as district Grain Marketing Board (GMB) officials in the Mazowe district were included in the study's target audience. Both simple random sampling and purposeful sampling were used in the investigation. The study found that while climate change had a negative influence on agricultural production, adaptation to the shift had a considerable positive benefit. According to the study, farmers were also aware of the negative effects and potential dangers of climate variability and change. The study recommended education and training programs for farmers regarding the impacts of climate variation and change to ensure the adoption of innovative adaptive strategies such as smart agriculture, artificial insemination, and underground water harvesting.

1. Introduction

Sub-Saharan African countries have been found more vulnerable to the impacts of climate variation and change, and Zimbabwe is no exception. In Zimbabwe, climate variability and change have been of concern, and these have caused a decline in agricultural production, which ultimately hamper national food security (Brown et al., 2012). As reported by Food and Agriculture Organization FAO (2022), Zimbabwe's food security and agricultural production have significantly declined over the past three decades. This has also been witnessed by the decline in the contribution of the agriculture sector to gross domestic product (GDP) from over 30% to less than 20% between 2000 and 2020 (Runganga and Mhaka, 2021). In addition, over the past decade, Zimbabwe has witnessed a significant decline in the production of major crops such as maize and wheat (FAO, 2022). These have been attributed to, among other factors, climate variability and change (Jiri, 2020; Mavhura et al., 2022). With the changing climate, agricultural production in Zimbabwe is expected to see a 33% yield reduction by 2030(FAO, 2022). The decline in agricultural production in Zimbabwe has been a national concern as its economic growth is dependent on the agricultural sector output (Runganga and Mhaka, 2021).

Improving agricultural production, particularly maize production, has been the main focus of the government of Zimbabwe towards achieving the Vision 2030 Agenda, where Zimbabwe is expected to become an Upper middle-income economy (Government of Zimbabwe, 2021). For instance, in the National Development Strategy 1 (NDS1)

(2021-2025), one of the priority areas of the Zimbabwean government is increased agricultural production, food security and nutrition. Specifically, the goal of NDS1 is to increase food self-sufficiency and maintain the country's position as a regional breadbasket until the year 2025. The main goals are to increase food self-sufficiency from the current 45 percent to 100 percent by 2025 and reduce food insecurity from the current peak of 59 percent to below 10 percent in 2020 (Government of Zimbabwe, 2021). Nevertheless, climate variability and change are a threat to the achievement of these national objectives. In doing so, climate change adaptation and mitigation are a strategy to achieve the national objectives.

In this regard, there have been efforts by the Government of Zimbabwe and other stakeholders to put in place policies and strategies to address the adverse impacts of climate variation and change and promote the adoption of adaptation strategies (Mavhura et al., 2022). Nevertheless, the policies tend to be ineffective as they have been drafted based on little empirical evidence. As argued by Mumbengegwi (2020), using agricultural policy instruments to affect agricultural activities without empirical knowledge may result in inappropriate use of policy instruments, thereby producing unintended results. Therefore, this study intends to add empirical evidence to make significant contributions to both practice and policy by understanding the climate variability and change effects and exploring the farmers' adaptation strategies in Zimbabwe using micro-level data. The study's focus is on the intensive farming region of Zimbabwe, Mazowe district.

The intensive farming region in Zimbabwe, popularly known as Region II, is among the five major farming regions in the country, with an average rainfall between 750 and 1000 mm (FAO, 2022). In this region, both crop and livestock farming are practiced. The major crops grown in this region are maize, flue-cured tobacco, wheat, coffee, cotton, sugar beans, and other horticultural crops, while cattle, poultry, and pig production are also practiced (FAO, 2022). This region covers Mashonaland West, Mashonaland East, and Mashonaland Central provinces and is considered the stronghold of agricultural production in Zimbabwe. According to FAO (2022), region II has the highest contribution of 33% to the total agricultural output of Zimbabwe. Nevertheless, despite being intensive, the region is one of the regions prone to climate variability and change and extreme weather conditions (Mavhura et al., 2022; Nyahwo et al., 2020). Precisely, over the past two decades, the region has been vulnerable to drought, localised intense precipitation, pests and diseases, long dry spells, and storms (Mavhura et al., 2022, Tawodzera and Ncube, 2020). These have been found to have adverse effects on agricultural production in the region, resulting in a 20-30% decline in the production of major cash crops such as maize and tobacco over the past decade (FAO, 2022). On the other hand, livestock production declined by 34.3% between 2010 and 2021 (Government of Zimbabwe, 2022). Mazowe district is one of the districts in Region II that has been mostly vulnerable to climate variability and change (Mavhura et al., 2022; Newsham et al., 2021). Over the past decade, decreasing rainfall amounts, rising temperatures, long dry spells, and short wet seasons have been witnessed in the district (Basera, 2020; Chingombe and Siziba, 2021; Newsham et al., 2021). These adversely impacted agricultural activities in the district resulting in adaptation strategies such as shifting to drought-resistant crops, practicing irrigation, practicing climate-smart agriculture, water harvesting, practicing Pvumvudza conservation agriculture, planting short-term varieties, and practicing agroforestry (Mavhura et al., 2022). According to Basera (2020) and Newsham et al. (2021), the decline in maize and tobacco production in Mazowe district over the past two decades has been largely caused by climate change and extreme weather conditions.

Intergovernmental Panel on Climate Change reports show that greenhouse gas emissions have been changing the global climate. Africa is experiencing water stress, low yields from rain-fed agriculture, high food insecurity and malnutrition, rising sea levels, and increasing arid and semi-arid land as a result of this development. Extreme weather events, such as floods, drought, and tropical storms, are also anticipated to surge in occurrence and force across Africa (IPCC, 2007). These forecasts are in agreement with contemporary climatic trends in southern Africa, including Zimbabwe. The impact of exposure to climate change and variability is worsened by the limited capacity of civil society, the private sector, and government actors to mitigate appropriately these emergent threats. It is widely recognized that Africa is one of the most vulnerable regions in the world due to widespread poverty, limited coping capacity, and its highly variable climate (Madzwamuse, 2010; United Nations Framework Convention on Climate Change (UNFCCC), 2007). Chagutah (2010) argues that Zimbabwe is predominantly susceptible due to its substantial dependence on rain-fed agriculture and climate-sensitive resources.

There is relatively limited empirical research on the impacts of climate variation and change, as well as the adaptation strategies of farmers in the intensive farming region of Zimbabwe. The study aims to bridge the notable research gap by examining the climate variability and change effects on farm output and farmers' adaptation strategies in Zimbabwe using the case study of Mazowe district. The study's specific goals were to ascertain farmers' level of knowledge regarding the effects of climate variability and change, examine how farmers perceive these effects on farm output, and ascertain how climate adaptation strategies affect agricultural production. The rest of the paper is organised as follows. Section 2 presents the theoretical framework used in the paper, while Section 3 gives a summary of the empirical literature. Section 4 presents the methodology and the empirical model specification. Section 5 presents the empirical findings and the discussion of the results. Section 6 concludes the study.

2. Theoretical framework

The main theories underpinning the research are the Cobb-Douglas theory and the Sustainable Livelihoods Framework (SLF).

2.1 Cobb-Douglas production theory

The study is theoretically grounded on the Cobb-Douglas theory propounded by Charles Cobb and Paul Douglas in 1927. The theorists developed the equation to explain the model commonly known as the Cobb-Douglas production function presented as follows:

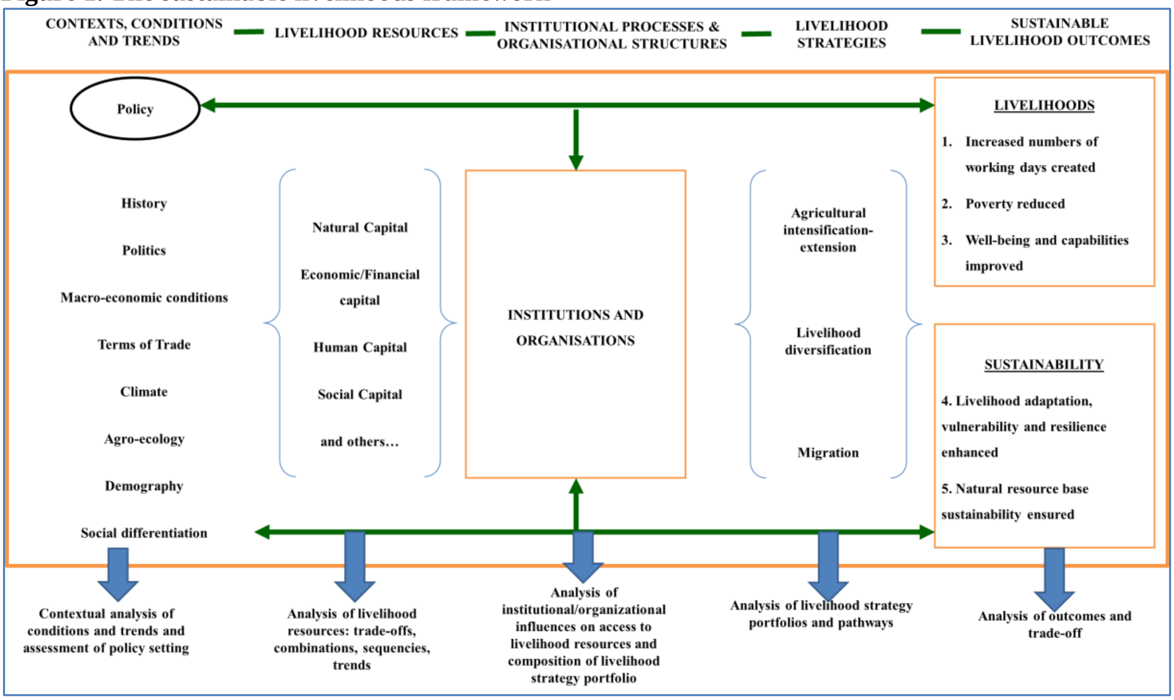
$$Q = AK^{\alpha}L^{\beta} \quad \text{.........(1)}$$

Where: Q = production output; A= technical knowledge reflecting technological improvements; K = level of capital, L = amount of labour, α and β represent elasticities of production output to K and L, respectively. The theory states that output depends directly on levels of capital (K) and labour (L) and that part of the output, which is not explained by K and L inputs, is explained by technical change represented by A (Ishikawa, 2021).

2.2 Sustainable livelihoods framework

The study also borrows the theoretical lens of the Sustainable Livelihoods Framework advanced by Scoones (1998). The framework has two main aspects, the environmental and social dimensions and these are essential for sustainable livelihoods. The environmental dimension involves the sustainability of the natural resource base which represents sources of livelihood. This Sustainable Livelihoods Framework can be diagrammatically presented, as shown in Figure 1.

Figure 1. The sustainable livelihoods framework



Source: Adopted from Scoones (2019)

As shown in Figure 1, climate change is among the contexts and conditions that influence the sustainable livelihoods of communities, while livelihood adaptation strategies such as agricultural intensification and diversification enhance resilience, leading to sustainable livelihoods. In this study, agricultural production represents the source of livelihoods of the farmers in Mazowe district, which are impacted by contextual external shocks such as climate variability and change. Hence, this Sustainable Livelihoods Framework has been found relevant to the present study, which aims to examine the climate variability and change effects and explore the farmers' adaptation strategies in

Zimbabwe.

3. Empirical literature

A significant number of empirical studies have been carried out across Europe to examine climate change effects. Among these is the study by Van-Passel et al. (2018), which employed the Ricardian analysis of the effects of climate change on agricultural production in Europe. Farm-level data was gathered using a sample of 41,030 farmers across Western Europe. Data was analyzed using the median quantile and the ordinary least square regression (OLS). The results revealed that European agriculture was sensitive to climate change as significant losses in agricultural output occurred. Besides using a large sample, the study left out the adaptation strategies of farmers and their effects, thereby underestimating their potential effects on agriculture.

More so, Eitzinger et al. (2019) assessed the effects of climate change on tomato and Cocoa production in Jamaica. Primary data was gathered using survey questionnaires and analysed using descriptive and t-test analyses.

The study revealed significant differences between the climate change effects on tomatoes and cocoas, as small reductions in cocoa production were found due to the high resistance of the crop to temperature increases. Climate change was found to have adverse effects on tomato production compared to Cocoa. These results are important to this present study. Nevertheless, the major difference is that the present study is not a comparative analysis of the effects of climate change but an analysis of the perceived effects of climate change on maize production.

Kasimba (2018) also researched the effects of climate change on crop production in Zimbabwe using a case study of Guruve district. Both qualitative and quantitative research methodologies were employed. Structured questionnaires and interviews were employed to collect data from the farmers. Variables considered included rainfall, crop diseases, and temperature. The study found that climate variability and change negatively affect crop productivity as a result of high temperatures, insufficient rains, and outbreaks of crop diseases. Besides being relevant to this present study, the research by Kasimba (2018) failed to consider the adaptation strategies of the farmers, which this current study takes into consideration to come up with sound recommendations for policy and practice.

In summing up the reviewed empirical studies, there is an agreement among scholars and researchers that climate variability and change negatively impact agricultural production. All the reviewed studies found that climate variability and change have significant negative effects on agriculture, especially on livestock and crop production and productivity. In addition, some of the studies also found that climate change adaptation strategies have positive effects on agricultural production. Nevertheless, there is a dearth of empirical studies in the context of Mazowe district, as previous studies have focused on other districts in Zimbabwe. This study, therefore, aims to fill the existing knowledge gap by examining the perceived impacts of climate variation and change as well as climate change in Mazowe district.

4. Methodology

The theoretical model for the study was the log-transformation linear function of the Cobb-Douglas production function as follows:

$$lnQ = lnA + \alpha lnK + \beta lnL \ldots\ldots (2)$$

Where: lnQ = natural logarithm of production output; lnA= natural logarithm of technical knowledge reflecting technological improvements; lnK = natural logarithm of the level of capital, lnL = natural logarithm of the amount of labour, α and β represent elasticities of production output to K and L respectively. The theory states that output depends directly on levels of capital (K) and labour (L) and that part of the output, which is not explained by K and L inputs, is explained by technical change represented by A (Ishikawa, 2021).

Based on the Cobb-Douglas production function and empirical model specifications of Bai *et al.* (2022) and Omondi (2019) with some modifications, the model for this study takes the following form:

$$Y = \beta_0 + \beta_1 CVC + \beta_2 CCA + \beta_3 LUC + \beta_4 AGL + \mu_i \ldots\ldots (3)$$

Where: Y = farm output, CVC = climate variability and change, CCA = climate change adaptation, LUC = land under cultivation in hectares, AGL = agricultural labour force measured by the economically active population at the farm, and μ_i = error term.

Farming output was the dependent variable, which was proxied by maize output as maize is the major crop in Mazowe (FAO, 2022). Primary data for this variable was collected using a structured questionnaire where respondents indicated the average change of maize output in tonnes for the period 2021 to 2022. The four-Likert scale (1 = decreased, 2= no change, 3= not sure and 4 =increased) was used where respondents indicated whether, on average, maize output decreased, remained constant, or increased during the study period. Farming output was considered maize because it is the common crop grown by most farmers in Mazowe district. Climate variability and change (CVC_i), Climate Change adaptation (CCA), land under cultivation in hectares (LUC), and Agricultural labour force measured by economically active population (AGL) are the independent variables.

Climate variability and change was the main independent variable of interest in this research. This variable was measured using indicators such as rainfall and temperature variability. Data was gathered using a structured questionnaire using a five-point Likert scale on all the indicators. Thereafter, the weighted mean of the Likert scale responses was therefore used as the measure for CVC. For this variable, a negative coefficient was expected as several studies such as Cunha *et al.* (2022), Maitah *et al.* (2022), Omondi (2019) and Peichl *et al.* (2019) have found a significant negative effect.

Climate change adaptation (CCA) of the farmers was measured using various adaptation strategies employed by the farmers to reduce the adverse impacts of climate variation and change. These strategies included crop diversification, irrigation, drought-resistant crops, changing planting time, land use management, and mixed farming. Weighted mean scores were computed to come up with an index to measure climate change adaptation. A positive effect was expected as studies such as Gorst *et al.* (2018), Mavhura *et al.* (2022) and Musetha (2017) found positive effects of climate change adaptation strategies such as irrigation on agricultural production.

Land under cultivation (LUC) represents a significant capital input for agricultural production based on the Cobb-Douglas model. The prior expectations for this variable were a positive effect. According to the Cobb-Douglas theory, an increase in capital leads to increased output. In addition, Belloumi (2018) and Mubenga-Tshitaka *et al.* (2021) found positive effects of land under cultivation on agricultural production.

The agricultural labour force (AGL_i) was measured using the size of the labour force at the farm. Previous studies such as Belloumi (2018) and Mubenga-Tshitaka *et al.* (2021) have found that the agricultural labour force has a positive effect on agricultural production.

Qualitative data was analysed using the NVIVO software package. Themes in line with the research objectives and questions were identified from the recorded interviews after transcribing the information. There are various options available for organising qualitative data. According to Patton (2002), three major frameworks have their sub-methods. In organising and reporting qualitative data, there are storytelling approaches, case study approaches, and analytical approaches. The current study can be classified under the analytical framework. This framework has four main components; processes, issues, questions, and sensitising concepts. Qualitative information may be organised to express critical processes, in our case, the perception of farmers concerning climate variability and change and its effect on agricultural output. "Distinguishing important processes becomes the analytical framework for organising qualitative descriptions" Patton (2002, p439). The issues approach entails that the data be presented in such a way that the key issues are highlighted. In this study, some of the key issues were crop diversification, short-season varieties, and climate-smart agriculture. Qualitative data can be organised on a question-by-question basis, in the case of structured open-ended questions. This approach is very much related to the key issues approach. Data can be presented in line with sensitising concepts. The current analysis did not rely on one approach. The main characteristic of the study is the use of "cross-case analysis", where answers from different informants to similar questions were grouped.

As Sarantakos (1993) argues, there are no set rules to guide researchers on interpretation. Sarantakos, however, gives some hints as to how to conclude from qualitative information. Of interest to this study, out of the twelve tactics discussed are the following: "counting, noting patterns and themes, clustering, factoring, noting relationships between variables, finding intervening variables, building a logical chain of events and making conceptual and theoretical coherence" (Sarantakos, 1993 pp309-310). In establishing the beliefs and attitudes of various stakeholders on climate change issues, the above processes were followed. Counting refers to identifying vital and repeated issues. The noting patterns and themes involve identifying trends in the material or data gathered. Clustering involves the grouping of actors and processes that have similar patterns into categories and themes. Factoring refers to "reducing data and identifying patterns of action", which enables the researcher to reveal the factors that underlie a process (Sarantakos, 1993 p309). Sarantakros (1993 p310) further argues that by "means of analysing and categorising data and interrelating variables, one moves from data to constructs and from there to theories".

5. Findings and the discussion of the results

The response rate for the survey questionnaire and key informant interviews was 89.1%. The researcher distributed a total of 192 questionnaires to selected commercial farmers in Mazowe district. Out of these questionnaires, 183 were collected by the researcher whilst nine questionnaires were not answered by the target respondents. Out of the 183 questionnaires collected, 12 of them were found to be invalid. As a result, only 171 questionnaires were found to be correctly filled and were considered valid for analysis. This, therefore, represented a successful survey response rate of 89.1%.

Table 1: Socio-demographic information of participants

Demographic Variable	Frequency (n)	Percentage (%)
Gender:		
Male	106	58.6
Female	75	41.4
Age:		
18-30 years	20	11.0
31-40 years	38	21.0
41-50 years	34	18.8
51-60 years	49	27.1
Over 60 years	40	22.1
Highest level of education:		
Primary education	52	28.7
Secondary education	64	35.4
Tertiary education	65	35.9
Years of farming/working experience:		
Less than 5 years	10	5.5
5-10 years	43	23.8
11-15 years	25	13.8
16-20 years	53	29.3
Over 20 years	50	27.6
Marital status:		
Single	24	13.3
Married	84	46.4
Widowed	39	21.5
Divorced/Separated	34	18.8

Source: Author's computations

The results in Table 1 show that most of the commercial farmers in Mazowe district are between 30 and 60 years old (66.9%). These results indicate that most of the commercial farmers in Mazowe district are males (58.6%). 35.9% of the respondents reported that they have attained tertiary education and the rest (64.1%) have either primary or secondary education.

5.1 Qualitative findings

This section presents the findings from the qualitative key informant interviews. The research questions represented the main themes of the study and the findings from the interviews are presented according to the research questions as follows:

Level of awareness of farmers about climate change effects and threats

The key informants indicated that most of the farmers in Mazowe district were aware of the climate change effects and threats. Precisely, eight key informants indicated high levels of awareness among farmers, whilst four key informants indicated low levels of awareness among the farmers. Two of the key informants who indicated a high level of awareness among the farmers in Mazowe district were ARDA officials who remarked: *Yes, farmers in this district*

[Mazowe district] are aware of the climate shifts. This is because the farmers have been receiving training and education on climate change from the media and Agritex officers, as well as from experiences. (Participant 2, Key Informant, ARDA official). *The majority of Mazowe's farmers are aware of the climatic changes. This is noticeable as most of them are increasingly embracing climate change coping strategies, although some farmers are financially crippled to implement some strategies.* (Participant 3, Key Informant, ARDA official).

Similar sentiments were also made by an official from the Ministry of Lands, Agriculture, and Rural Resettlement who participated in the key informant interviews. This participant stated: *In my view, most commercial farmers know climate change effects and threats given the increased utilizations of climate change adaptation methods, such as smart farming, quarantining cattle from other regions because of January disease, and practicing irrigation because of early cutting off of rainfall. On livestock, farmers in the district are now doing artificial insemination (buying bull semen and injecting it in a female cow). This is done at the Vet field station.* (Participant 10, Key Informant, Ministry of Lands, Agriculture and Rural Resettlement official).

More so, other key informants who were AGRITEX officers reported that the commercial farmers in Mazowe district were aware of the effects and threats of climate variability and change. This key informant had the following to say: *Yes, I can say that the farmers are aware of the impacts and threats of climate change and variability…. However, the level of awareness still not to be satisfactory but there is noticeable evidence of awareness… Some of the threats mentioned by the farmers in the previous workshop included reduced crop yield, increased deaths of livestock, very low farm output as well as poor quality crops and livestock that face low market value as well as a reduced farm labour force which is now resorting to artisanal mining (chikorokoza)* (Participant 4, Key Informant, AGRITEX officer).

Nevertheless, a few of the key informants indicated that the level of awareness regarding climate change effects and threats was still low among the farmers in Mazowe district. The following responses were some of the substantiating statements obtained from the key informant interviews: *Although farmers frequently get training and education on climate change, the level of awareness among them regarding climate change effects and threats is still low as some of the farmers are still using primitive methods of climate change adaptation such as intercropping, mulching, and crop rotation whilst there are some innovative and more effective adaptation strategies such as smart agriculture and irrigation farming (*Participant 1, Key Informant, Agritex officer).

Qualitative findings obtained from key informant interviews have revealed that the majority of the commercial farmers in Mazowe district are aware of the effects and threats and impacts of climate variation and change. However, there is still a lack of awareness among a few farmers in the same district.

Perceived impacts of climate variation and change on Farming

Most of the participants provided varied responses but with similar perceptions that climate variability and change negatively impacted farming. One of the longest-serving AGRITEX officers in Mazowe district had this to say: *Climate variability and change are impacting farmers in the district, particularly in maize production to a greater extent. Mazowe district was one of the districts that produced a larger amount of maize in the country, but now maize production has been affected due to climatic changes and variability. Precisely, the decline in maize and tobacco production in the district over the past few decades has been largely caused by climate change and extreme weather conditions…. Farmers who planted early got good yields, but late planters were affected since the plants sunk. (*Participant 4, Key Informant, AGRITEX officer).

Furthermore, one of the interviewed officials from the Ministry of Lands, Agriculture, and Rural Resettlement noted that: *There is no doubt that climate change is posing negative adverse effects on farming activities of the farmers as crop and livestock production have been declining over the past decade… (*Participant 5, Key Informant, Ministry of Lands, Agriculture and Rural Resettlement official).

Similar perceptions were also provided by other two key informants who pointed out that:
Climate shifts have had negative effects on agricultural production in the district as witnessed by the decline in rainfed crops such as maize. This has been evidenced by the decline in quantities of maize delivered to GMB by the commercial farmers in Mazowe district. (Participant 6, Key Informant, GMB official). *I have observed that the district has become more vulnerable to climate changes witnessed by low rainfalls and high temperatures, leading to poor agricultural productivity and production.* (Participant 8, Key Informant, AGRITEX officer). *Climate variability and change have had and continue to have negative effects on the farmers in the district. Although there are other factors contributing to a decline in agricultural production in the district, such as the political environment and lack of financial assistance, climate variability, and change are the leading primary factors* (Participant 10, Key Informant, Ministry of Lands, Agriculture and Rural Resettlement official).

The excerpts from the key informants have shown that the participants had similar perceptions regarding the negative effects of climate variation and change on farming in Mazowe district.

Effects of climate change adaptation strategies of the farmers on agricultural production

All the participants in the key informant interviews provided similar viewpoints that the adoption of climate change adaptation strategies had positive effects on agricultural production. One of the AGRITEX officers who took part averred that: *A variety of climate change adaptation strategies, including crop diversification, supplementary irrigation and harvesting, planting drought-resistant crops, and planting short-season varieties, have been introduced to Mazowe farmers. Most of the strategies are widely being employed by the farmers, leading to the reversal of the declining trend in agricultural production brought about by climate variability and change* (Participant 1, Key Informant, AGRITEX officer)

Key informant 7 also indicated that climate change adaptation strategies of the farmers in Mazowe district were attributable to the increase in agricultural crop production in the district: *Through collaborative efforts by ARDA, Agritex, Ministry of Lands, Agriculture and Rural Resettlement, farmers in Mazowe have been introduced to several climate change adaptation strategies, namely crop diversification, supplementary irrigation and harvesting, planting of drought-resistant crops and planting short-season varieties, to mention but a few. According to my observations, these strategies are very effective and sustainable... The good part of it is that most farmers are implementing them* (Participant 7, Key Informant, AGRITEX officer). *...Farmers employing innovative strategies such as smart agriculture have been realizing large harvests. The bumper harvests witnessed following the Pfumvudza program indicate that climate change adaptation strategies positively enhance agricultural production by lessening the negative impacts of climate variation and change* (Participant 6, Key Informant, GMB official).

The aforementioned quotations from the key informants demonstrate that the climate change adaptation strategies employed by the farmers in Mazowe district have had positive effects on agricultural production and productivity.

Alternative sustainable adaptation strategies to address climate variability and change

Lastly, the study aimed to find alternative sustainable climate change adaptation strategies that may be employed to address climate variability and change in Mazowe district. From the key informant interviews undertaken, several innovative and sustainable climate change adaptation strategies were suggested. One of the key informant interviews stated: *To lessen the negative impacts of climate variation and change, Mazowe farmers should use hybridization, practicing cross-breeding, and intercropping, agroforestry, thus planting gum trees for tobacco farmers to use to burn tobacco and avoid deforestation, planting Cyprus trees for furniture and act as windbreaks as well as planting star grass or burner grass to prevent soil erosion and increase feeds for livestock in addition to relying on the strategies previously mentioned.* (Participant 8, Key Informant, AGRITEX officer).

Similarly, two district officials from ARDA who took part in the interviews stated that: *Integrating livestock into crop production systems, improving soil quality, and minimizing off-farm flows of nutrients and pesticides are some of the alternative strategies that farmers in Mazowe can use to lessen the negative impacts of climate variation and change.* (Participant 2, Key Informant, ARDA official). *These are some of the alternative strategies that can be employed by farmers in Mazowe to reduce the adverse impacts of climate variation and change, including integrating livestock with crop production systems, improving soil quality, and minimizing off-farm flows of nutrients and pesticides* (Participant 3, Key Informant, ARDA official).

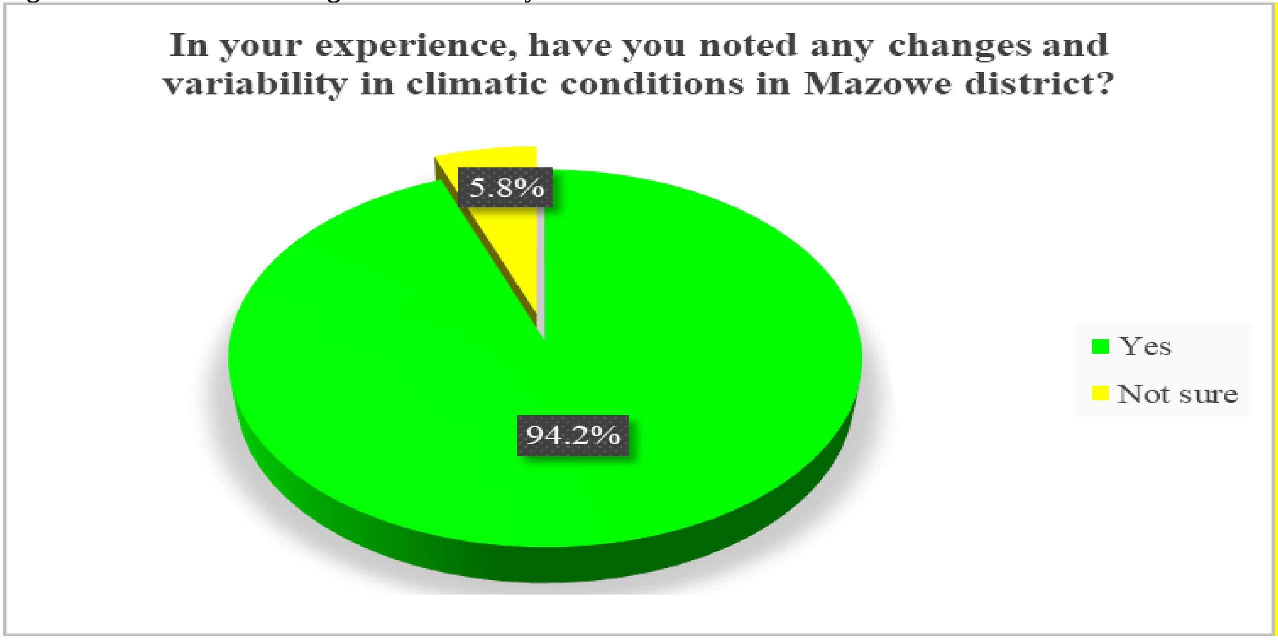
One of the key informants, a district official from the Ministry of Lands, Agriculture, and Rural Resettlement, had this to say: *... there is a need to shift from primitive strategies to innovative and sustainable strategies such as practicing irrigation, climate-smart agriculture, artificial insemination, conservation agriculture, planting short-term varieties, and practicing agroforestry, just to mention a few* (Participant 10, Key Informant, Ministry of Lands, Agriculture and Rural Resettlement official).

Key informants noted that various sustainable climate change adaptation strategies can be employed by the farmers in Mazowe district to lessen the effects of climate variation and change and improve agricultural production.

Level of awareness of farmers about climate change effects and threats

Participants in the survey were first asked if they had noted any changes and variability in climatic conditions. The responses to the question are presented in Figure 2.

Figure 2: Awareness of changes and variability in climatic conditions



Source: Survey data, 2023

A majority of the participants (94.2%) highlighted that they had noted changes and variability in climatic conditions, whilst 5.8% were not sure. These findings imply that the farmers in Mazowe district are aware of the climate changes and variability. The study aimed to determine the level of awareness of farmers about climate variability and change effects. Findings from qualitative research indicated that farmers in Mazowe district were aware of the impacts of climate variation and change on farming. The high levels of awareness could be attributable to the collaborative efforts of stakeholders in educating the farmers in Mazowe district on climate variability and change. This level of awareness may also be a result of the increasing adoption of climate change adaptation strategies. The results show that there is a high level of awareness of climate change effects and threats among farmers in Mazowe district. The results are similar to those of Musetha (2017) who revealed high levels of awareness of South African farmers about climate change effects and threats. Byishimo (2018) also found a high level of awareness of climate change among farmers in Rwanda. In their study, Dhliwayo *et al.* (2022) found that most of the farmers in Chiredzi district were aware of climate variability effects and coping strategies. The results also concur with the sustainable livelihoods framework, which predicts that human capital in terms of knowledge enhances livelihood adaptation and reduces vulnerability to external shocks such as climate variability and change.

Furthermore, those who had noted changes and variability in climatic conditions were required to highlight the main indicators of climate variability and change in Mazowe district. The results in Table 2 show some of the indicators of changes and variability in climatic conditions noticeable in Mazowe district.

Table 2: Main indicators of climate variability and change in Mazowe district

Indicator	**Mean**	**Std. dev.**
Long dry-spells	4.53	1.113
Low and unpredictable rainfall	4.64	0.851
Rising temperatures	4.53	1.019
Drought	4.05	1.091

Indicator	Mean	Std. dev.
Short wet seasons	4.64	0.629
Crop and livestock pests and diseases	4.62	0.783

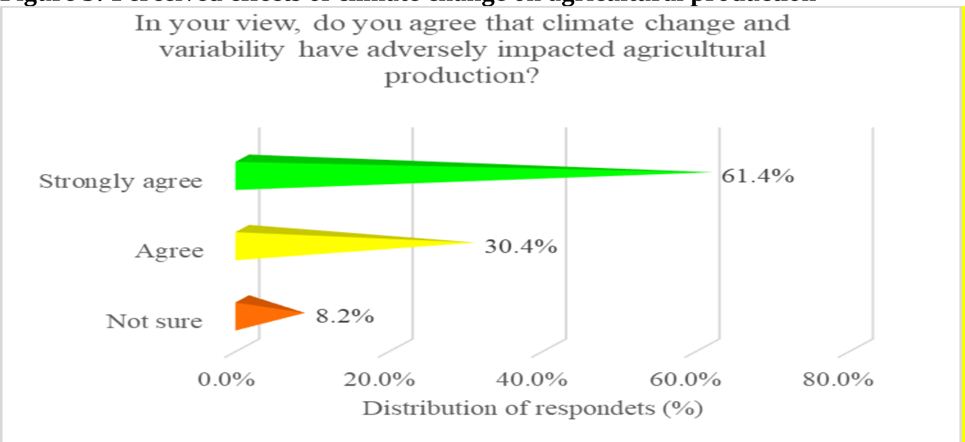
Source: Survey data, 2023

The results presented in Table 2 show a mean statistic of 4.64 and a standard deviation of 0.851 showing that the highest number of participants agreed strongly that they had witnessed low and unpredictable rainfall in the Mazowe district. Participants also agreed strongly that they had noted short rain seasons in Mazowe district, as indicated by the mean of 4.64 accompanied by a standard deviation of 0.629. Other indicators of climate variability and change noted by the commercial farmers in Mazowe district were found to include crop and livestock pests and diseases, cyclones, floods, too much humidity, too much wind, and very low temperatures.

Perceived impact of climate variation and change on farming

In this regard, the commercial farmers in Mazowe district who participated in the survey were asked to indicate if they agreed or disagreed that climate variability and change have adversely impacted agricultural production in the district. The responses to this question were distributed as illustrated in Figure 3.

Figure 3: Perceived effects of climate change on agricultural production



Source: Survey data, 2023

The findings in Figure 3 show that 61.4% of the participants representing the majority agreed strongly that climate variability and change have adversely impacted agricultural production in Mazowe district, whilst 30.4% agreed. Nevertheless, only 8.2% of the participants were not sure and none disagreed, showing that climate variability and change have had adverse effects on agricultural production in Mazowe district.

Table 3: Impacts of climate variation and change on agricultural production

Impacts of climate variation and change	N	Mean (M)	Std. dev. (SD)
Reduction in maize output	171	4.33	1.227
Loss of arable land	171	4.30	1.047
Reduction in crop yields	171	4.63	0.781
Food insecurity	171	4.65	0.626
Poor livestock health	171	4.14	1.025
Reduction in ground and surface waters	171	4.29	1.140

Loss of grazing pastures	171	4.44	0.812
Decline in land under cultivation	171	4.51	0.863
Decline in agricultural labour force	171	4.49	0.996

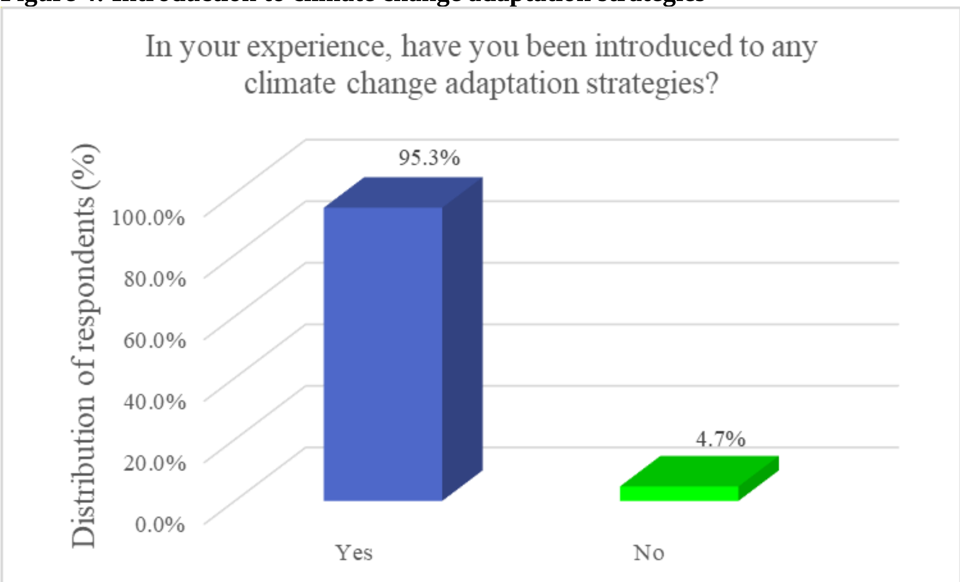
Source: Survey data, 2023

Consequently, the participants in the survey were required to indicate how climate variability and change have impacted agricultural production in Mazowe district. The results are summarized in Table 3. Results show mean scores of at least 4.00, indicating that the majority of the participants were in agreement with the perceived impacts of climate variation and change. As shown here, the majority of the participants agreed that climate variability and change resulted in a reduction in maize output, loss of arable land, reduction in crop yields and food insecurity, poor livestock health, reduction in ground and surface water, and loss of grazing pastures. Additionally, the mean statistic of 4.51 shows that the majority of the participants agreed strongly that climate variability and change resulted in a decline in land under cultivation. A significant proportion of the participants, as evidenced by the mean of 4.49, also showed that the highest percentage of the participants agreed that climate variability and change in Mazowe district resulted in a decline in the agricultural labour force.

Alternative sustainable adaptation strategies to address climate variability and change

The participants in the survey were asked to indicate if they had been introduced to any climate change adaptation strategies. The distribution of the responses to the question is presented in Figure 4.

Figure 4: Introduction to climate change adaptation strategies



Source: Survey data, 2023

The findings in Figure 4 show that 95.3% of the study participants, representing the majority, have been introduced to climate change adaptation strategies, whilst the minority (4.7%) have not been introduced to any climate change adaptation strategies. The results show that most of the farmers in Mazowe district had been introduced to climate change adaptation strategies. Furthermore, the participants were asked to indicate their level of agreement with climate change adaptation strategies that have been employed by the farmers in Mazowe district. The responses are summarized in Table 4.

Table 4: Climate change adaptation strategies employed in Mazowe district

Climate change adaptation strategy:	N	Mean (M)	Std. dev. (SD)
Crop diversification	171	4.71	0.539

Supplementary irrigation and water harvesting	171	4.67	0.736
Using drought-resistant crops	171	4.82	0.774
Planting short-season varieties	171	4.61	0.929
Practicing climate-smart agriculture	171	2.31	0.769
Pfumvudza conservation agriculture	171	4.63	0.585
Practicing agroforestry	171	4.31	1.053

Source: Survey data, 2023

The descriptive statistics in Table 4 show the various climate change adaptation strategies employed by commercial farmers in Mazowe district. A majority of the participants agreed strongly that farmers in Mazowe district practiced crop diversification, supplementary irrigation, water harvesting, drought-resistant crops, planting short-season varieties, Pfumvudza conservation agriculture, and agroforestry. Other climate change adaptation strategies highlighted by the study participants included crop rotation, winter ploughing, use of greenhouses, intercropping, hybridization, shift cultivation, cross-breeding, and the use of the ridging system.

5.2 Results of the regression analysis

Precisely, the study undertook regression analysis to examine the perceived impacts of climate variation and change on farming output and to determine the effect of climate adaptation strategies on agricultural production. The regression analysis was also meant to test the research hypothesis stated in Section 1.

Table 5: Model diagnostics tests

Test	**Statistic**	**Prob.**
Breusch-Pagan test for heteroskedasticity	Chi2(1) = 32.75	0.0807
Shapiro-Wilk test for normality of residuals	W= 0.98	0.0861
RESET test for model specification	F (3, 163) = 18.30	0.1000

Source: Author's computations

The results presented in Table 5 show that the Breusch Pagan test estimated a Chi-square statistic of 32.75 with a probability value (p-value) of 0.0807, which is greater than 0.05, implying the absence of heteroskedasticity. More so, the Shapiro-Wilk test estimated a statistic of 0.98 with a p-value of 0.0861, which is greater than 0.05, such that the null hypothesis could not be rejected at a 5% level of significance implying the normality of residuals. The Ramsey RESET test estimated an F-statistic of 18.30 and a p-value of 0.1000, meaning the model was correctly specified with no omitted variables. From these results, the assumptions for the multiple linear regression were satisfied such that the regression model was estimated and the results are presented in Table 6.

Table 6: Regression results

Variable	Coef.	Std. Err.	T-ratio	P>|t|
lnCVC	-.63027	.1131629	-5.57	0.000
lnCCA	.28211	.0714595	3.95	0.000
lnLUC	.26007	.0483547	5.38	0.000
lnAGL	.35071	.0628529	5.58	0.000
Cons	-.36624	.1267465	-2.89	0.000

Number of obs = 171
F(4, 166) = 53.85
Prob > F = 0.0000
R-squared = 0.5648
Adj R-squared = 0.5543
Root MSE = .15101

More so, regression analysis revealed that climate variability and change negatively impacted agricultural production in Mazowe district. A statistically significant negative coefficient (-0.63) and p-value (0.000) were found for the climate variability and change variable. This means that increased climate variability and change can significantly reduce maize production in Mazowe district. Precisely, the results show that a 1% change in climate variability is reducing maize output in Mazowe by 0. 63%. These results led to the failure to reject the hypothesis that climate variability and change have significant negative effects on agricultural production. The conclusion reached is that climate variability and change negatively impact agricultural production in Mazowe district. The results met the priori expectations and concur with the Ricardian theory which predicts that variations in agricultural production can be explained by changes in climatic factors.

The findings also confirm the results of previous related studies. For instance, the findings of this present study corroborate the results of the study by Van-Passel *et al.* (2018), which analysed the effects of climate change on agricultural production in Europe and revealed that European agriculture was negatively impacted by climate change. Similarly, Peichl *et al.* (2019) found that climate variation and change resulted in maize yield reduction in Germany. More so, the present results are comparable to those of Cunha *et al.* (2021), who studied the effects of climate change on Brazil's agriculture and found negative impacts of climate variation on agricultural production. Negative effects of climate change were also confirmed by Estrada *et al.* (2022), who found that climate variation and change account for about 70% of losses and reductions in crop yields in Mexico. The results are also in tandem with those of Omondi (2019), who concluded that climate change negatively affects livestock and crop production in Kenya. The results are also comparable to those of Mavhura *et al.* (2022), who found negative impacts of climate variation and change on agricultural production. Nevertheless, the present findings contradict those of Dhliwayo *et al.* (2022), who found that climate variation and change had no significant changes in crop yields. In conclusion, the present results support results from previous studies.

The adaptation strategies have been found to have positive effects on agricultural production in Mazowe district. Regression analysis revealed a statistically significant positive coefficient of 0.28 (p=0.000) for the climate change adaptation variable. The results imply a 1% change in the climate change adaptation would result in increased maize output by approximately 0.28%. These results led to the acceptance of the research hypothesis that climate change adaptability has significant positive effects on agricultural production. From the results, it can be inferred that the adoption of climate change adaptation strategies by the farmers in Mazowe district improved agricultural production in the district by lessening the adverse impacts of climate variation and change.

The present results are in line with the findings of previous related studies. In essence, the study by Cunha *et al.* (2021) confirmed the important role of climate change adaptation on agricultural production by revealing that irrigation is effective in counteracting the adverse effects of climate change. The results are also similar to those of Gorst *et al.* (2018), who examined the link between climate change adaptation and crop productivity in Pakistan and revealed significant positive effects of climate change adaptation on crop productivity. The study by Musetha (2017) also found that climate change adaptation strategies such as planting different varieties, crop diversification, different planting dates and shortening of planting periods had positive effects on agricultural production in South Africa. More so, the results of this study support those obtained by Mavhura *et al.* (2022), who found that climate change adaptation strategies such as crop and land use management, use of short-season varieties, crop diversification, mixed-farming, intensified irrigation and drought-resistant crops had a positive influence on crop yields in Zimbabwe.

Regression results revealed significant positive effects of land under cultivation on agricultural production in Mazowe district. A positive coefficient of 0.26 for land under cultivation was found to be statistically significant at a 5% level, as indicated by the p-value of 0.000. This implies that a 1% increase in the land under cultivation would increase maize output by about 0.26%. Nevertheless, the results indicated that climate variability and change resulted in a decline in land under cultivation. This, therefore, implies that a decline in land under cultivation due to climate variability and change leads to a decline in agricultural production in Mazowe district. These findings concur with the Cobb-Douglas theory which predicts that output depends directly on levels of capital which is land in this context. Belloumi (2018) revealed that land under cultivation had significant positive effects on crop production in Southern and Eastern African (ESA) countries. Among East African countries, Mubenga-Tshitaka *et al.* (2021) also found that land under cultivation had significant positive effects on agricultural output. Similar results were also obtained by Bai et al. (2022), who found that land under cultivation has significant positive effects on agricultural productivity. Jiri (2020) also found that land under cultivation as the key input resource has a significant impact on crop production.

Regression analysis indicated a statistically significant positive coefficient for the agricultural labour force. The coefficient of 0.35 was found to be statistically significant at a 5% level. The results imply a 1% increase in the agricultural labour force would increase maize output by 0.35%. These results show that the agricultural labour force positively influences agricultural production. This is further confirmed by the descriptive results, which indicate that climate variability and change resulted in a decline in the labour force on the farms, leading to a decline in agricultural production. These results also concur with the Cobb-Douglas theory, which predicts that output depends directly on levels of labour. Nevertheless, increasing the labour force may lead to reduced productivity, as predicted by the Cobb-Douglas theory. The results are comparable to those of Belloumi (2018), who found that the agricultural labour force had significant positive effects on crop production in Southern and Eastern African (ESA) countries. Similarly, Mubenga-Tshitaka *et al.* (2021) found that the agricultural labour force had positive effects on agricultural production.

6. Conclusion

Based on the study's findings, the main conclusion derived from this study is that climate variability and change have significant negative effects on agricultural production in the intensive farming region of Zimbabwe, particularly in Mazowe district. This, therefore, means that education and training programmes should be continued so that all farmers are aware and know how to mitigate the effects. This can be done through workshops and seminars targeting the farmers in climate change-prone regions such as Mazowe district. These will aid in improving awareness among the farmers regarding climate change and its effects. The other conclusion derived from the findings was that the adoption of climate change adaptation strategies by farmers in Mazowe district has the potential to boost agricultural production by minimizing the adverse impacts of climate variation and change. More so, based on the research findings, the study concludes that most of the farmers are aware of the various impacts of climate variation and change which make them implement climate change adaptation strategies. The study also concluded that land under cultivation and labour force are critical input factors for enhanced agricultural production. The study recommends that the Government of Zimbabwe should ensure maximum support to commercial farmers through interventions and policies that aim to address climate variability and change. This is because implementation of climate change adaptation strategies is expensive and may also require government support. The commercial farmers should work together as a community in Mazowe district and are encouraged to employ alternative sustainable climate change adaptation strategies such as irrigation, hybridization, and agroforestry to curb the effects of climate change and variability.

[1]This paper is based on a postgraduate study conducted at the Great Zimbabwe University. The authors wish to thank two anonymous reviewers for their valuable comments on the earlier drafts of this paper. The usual disclaimer applies.

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