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# El Niño's Effects on Southern African Agriculture in 2023/24 and Anticipatory Action Strategies to Reduce the Impacts in Zimbabwe

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**Abstract:** The frequency of El Niño occurrences in southern Africa surpasses the norm, resulting in erratic weather patterns that significantly impact food security, particularly in Zimbabwe. The effects of these weather patterns posit that El Niño occurrences have contributed to the diminished maize yields. The objective is to give guidelines to policymakers, researchers, and agricultural stakeholders for taking proactive actions to address the immediate and lasting impacts of El Niño and enhance the resilience of the agricultural industry. This brief paper provides prospective strategies for farmers to anticipate and counteract the El Niño-influenced dry season projected for 2023/24 and beyond. The coefficient of determination $R^2$ between yield and ENSO was low; 11 of the 13 El Niño seasons had a negative detrended yield anomaly, indicating the strong association between El Nino's effects and the reduced maize yields in Zimbabwe. The $R^2$ between the Oceanic Nino Index (ONI) and rainfall (43%) and between rainfall and yield (39%) indirectly affects the association between ONI and yield. To safeguard farmers' livelihoods and improve their preparedness for droughts in future agricultural seasons, this paper proposes a set of strategic, tactical, and operational decision-making guidelines that the agriculture industry should follow. The importance of equipping farmers with weather and climate information and guidance on drought and heat stress was underscored, encompassing strategies such as planting resilient crop varieties, choosing resilient livestock, and implementing adequate fire safety measures.

**Keywords:** early warning; El Niño-Southern Oscillation (ENSO); climate services; weather; climate information



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## 1. Introduction

El Niño, a cyclical climate event marked by unusually warm ocean temperatures in the equatorial Pacific, considerably impacts weather patterns worldwide [1,2]. The El Niño Southern Oscillation (ENSO), which can be in the El Niño, La Nina, or neutral phase, is a component. The effects of ENSO on local agro-climate factors alter vegetation patterns and the interannual agricultural production variability, which varies among crop types and regions. El Niño occurrences frequently cause lower rainfall and protracted dry spells in southern Africa, causing severe problems for the agricultural industry and rural communities [3]. Countries in which the entire crop cycle is affected by drier-than-average weather conditions are mainly concerned, as water deficits could curtail plantings and yields with compounding negative impacts on final production. Zimbabwe is one of the countries in the region's vulnerable agricultural belt and has frequently experienced the detrimental effects of El Niño in the past [4,5]. There is a greater than 90% probability that El Niño will persist through 2023, and forecasts indicate that the likelihood of a moderate-to-strong El Niño event will extend into 2024. Given the forecast for El Niño in 2023/24, there is a need for anticipatory action to be used by countries at risk of being affected by El Niño in 2023/24 and the future.

Annually, climate scientists collaborate to generate a consensus forecast for the upcoming rainfall season to provide an early warning about the expected conditions. The Global Early Warning—Early Action (EWEA) initiative seeks to convert forecasts and early warnings into proactive measures [1]. It is expected that the current El Niño effects and the increased air temperatures caused by climate change will likely impact food security in many regions of southern Africa due to the abnormal seasonal rainfall, which is either below or above normal levels [2]. While the existing literature has extensively explored the link between El Niño and its effects on global climate patterns, there is a notable gap regarding the specific context of Southern Africa, particularly Zimbabwe. Rainfall patterns during El Niño events tend to be the reverse of those caused by La Niña in southern Africa [6,7]. Although a few studies have examined the broad impacts of El Niño on the region, limited attention has been given to tailored strategies for mitigating the agricultural consequences at the country level [7,8]. This paper aims to address this gap by focusing on El Niño's implications on Zimbabwe's agricultural sector and by providing recommendations to farmers for preparing for the upcoming dry season.

This brief paper aims to inform farmers about the implications of a potentially reduced rainfall season and the measures they can take to protect their crops and livelihoods. Such impact-based information with long lead times may also substantially support the shift towards more anticipatory and preventative risk management, as urged in several international frameworks such as the Sendai Framework for Disaster Risk Reduction [9,10]. With an El Niño event forecasted for the 2023–2024 season, it is crucial to equip farmers with knowledge about drought- and heat-stress-tolerant crop varieties and adequate fire protection measures. Based on the Sendai Framework, the Ministry of Agriculture in Zimbabwe has developed a Drought Risk Management Strategy and Action Plan (2017–2025), which provides a framework for implementing mitigation measures to improve drought readiness [11,12]. This brief paper evaluates the proposed activities outlined in the plan, highlighting their potential effectiveness in safeguarding farmers and ensuring agricultural sustainability. The proposed activities are grouped as strategic, tactical, and operational drought risk management [13,14]. Ultimately, this paper seeks to inform policymakers, researchers, and agricultural stakeholders about the importance of proactive measures for combatting the short- and long-term effects of El Niño and building a more resilient agricultural sector [2,12,15,16].

This brief highlight the implications of the El Niño-induced rainfall season on agriculture in Zimbabwe and other southern African countries. It explores the specific risks of drought, flood, and heat stress to crop production, including reduced yields and water scarcity. This paper also examines the drought management of crops more than livestock, given their higher share of calories in total food consumption, particularly in low-income countries, and their importance for food security in southern Africa, particularly Zimbabwe [16–18]. Additionally, this brief examines the increased fire hazards during dry seasons and the consequential challenges farmers face, such as crop losses and environmental degradation. Building upon this understanding, the subsequent sections of this paper will discuss the strategies proposed by the Ministry of Agriculture's Drought Risk Management Strategy and Action Plan (2017–2025) to mitigate these implications effectively.

*El Niño Mechanisms and Their Influence on Rainfall in Zimbabwe*

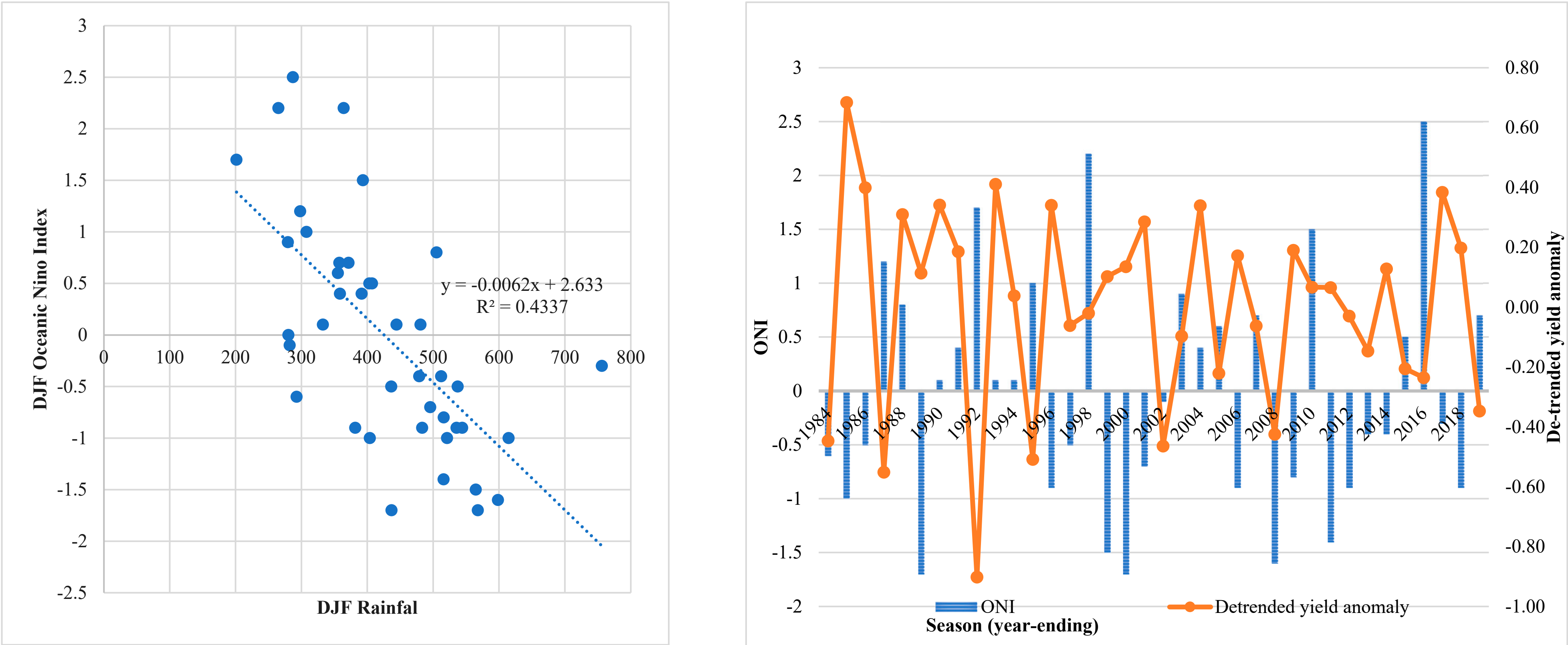
According to Baudoin et al. [3], the El Niño Southern Oscillation (ENSO) significantly impacts Zimbabwe's weather patterns. The ENSO is a meteorological phenomenon typified by changes in air pressure and sea surface temperatures (SSTs) throughout the tropical Pacific Ocean [1,2]. El Niño and La Nina are the two primary ENSO phases. Warmer-than-average SSTs predominate in the eastern and central equatorial Pacific during an El Niño phase [19,20]. On the other hand, cooler-than-average SSTs in the same area characterise the La Nina phase [13]. To illustrate the recurring pattern of ENSO states and to highlight the frequency of El Niño events and their effects on maize production in Zimbabwe, Figure 1 displays the maize yield anomalies from 1982 to 2023. This graphical representation shows that, from 1982 to the present, El Niño events have recurred irregularly, appearing every two to six years [3,17].

The coefficient of determination ($R^2$) is a statistical measure in a regression model that determines the proportion of variance in the maize yield and ENSO events. Figure 1a indicates that December, January, February (DJF) and the Oceanic Nino Index (ONI) negatively correlate with yield, although the $R^2$ is too low. One thing worth noting is that, although $R^2$ was low, 11 out of the 13 El Niño seasons had a negative detrended yield anomaly, clearly indicating the strong association between El Niño and the reduced yields in Zimbabwe (Figure S1). The relationship between the yields and ENSO is not necessarily linear, as La Nina has no equal and opposite effect on El Niño. The $R^2$ between ONI and rainfall (43%) and between rainfall and yield (39%) indirectly shows the association between ONI and yield. However, other factors affect rainfall and yield, making the direct association between ONI and yield non-linear (Figure 1b).

Figure 1b highlights the five strongest El Niño events in the past 40 years. Three of these five El Niño seasons—1982/83, 1991/92, and 2015/16—corresponded with severe and widespread agricultural droughts across Zimbabwe, while a fourth season, 2009/10, resulted in a drought in the southern and eastern parts of Zimbabwe [9,16]. The fifth El Niño season did not result in the widespread dry conditions in Zimbabwe that are typically observed following El Niño events (Table S1). This was due to an unusual state of regional climate drivers that year, including an abnormally strong Angola low, very high sea surface temperatures near southern Africa, and abnormal regional wind patterns [1,21,22].

This oscillation between El Niño and La Niña events and their associated climatic changes has substantial implications for regions such as Zimbabwe. The prediction and understanding of these climatic oscillations are of critical importance for effective agricultural planning and the development of mitigating strategies against the impacts of these events.

Warmer SSTs in the tropical Pacific during El Niño events change the atmospheric circulation, shifting the subtropical jet stream and reducing the strength of the trade winds [1,2,6]. Reduced rainfall due to these changes may affect Zimbabwe and other regions, worsening drought conditions and posing difficulties for agricultural production, based on examinations of the CHIRPS rainfall [21,22]. Figure 2 depicts the frequency of below-average precipitation in southern Africa between 1982 and 2023 (rain in the bottom tercile of the historical 40-year rainfall record). Climatologically, the number of times that below-average rainfall should have been recorded is 33%; however, most parts of Zimbabwe and other southern African countries experienced below-average rainfall 60–80% of the time during El Niño events (Figure 1), indicating a historically higher than expected probability of low precipitation during El Niño, which is almost double the normal risk of dry conditions [12,18,23].




(**a**) (**b**)

**Figure 1.** (**a**) DJF rainfall vs. DJF Oceanic Nino Index (ONI) and (**b**) ONI and detrended yield.

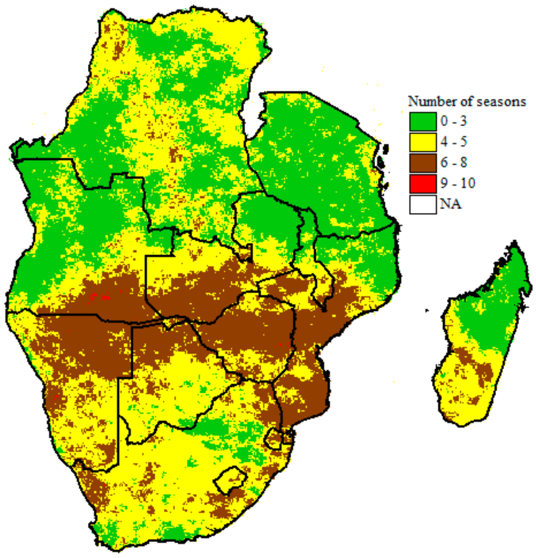



**Figure 2.** The frequency of below-average rainfall in southern Africa over a 40-year period from 1982–2023.

Although most El Niño occurrences have led to below-average rainfall in Zimbabwe, not all have had the same effects [6,8,16]. The Angola Low, Botswana High, and sea surface temperatures in the Indian and Atlantic Oceans are some of the regional and local climate causes that contribute to these fluctuations in ENSO's influence on rainfall [1]. El Niño exhibits various types, such as Eastern Pacific El Niño and Central Pacific El Niño. Perhaps this variability in El Niño types is also one factor contributing to the fluctuations in ENSO's impact on rainfall.

Over 90% of the time, an El Niño event is likely to occur during the main crop growing season of 2023–2024, according to the June 2023 NOAA CPC ENSO probabilistic projection (Figure 3). The current El Niño forecast can be a valuable tool for decision-making, helping farmers and policymakers foresee and prepare for probable drought conditions given the historical frequency of preceding El Niño outcomes in Zimbabwe [17].

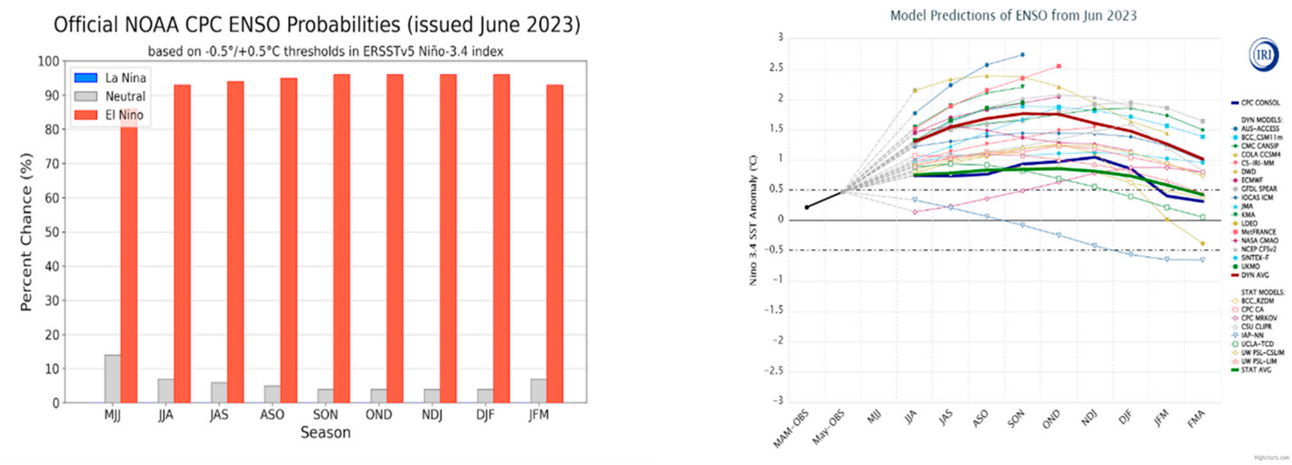



**Figure 3.** NOAA Climate Prediction Center (CPC) ENSO forecast for June 2023.

This brief report acknowledges the importance of this climate phenomenon in impacting drought occurrences in Zimbabwe by integrating information on ENSO within the discussion of climate drivers. It is emphasised by including ENSO-related statistics and forecasts how crucial it is to consider these elements when formulating plans to reduce drought and boost agricultural resilience [15].

## 2. Implications of a Low Rainfall Season on Agriculture in Zimbabwe

### *2.1. Drought and Heat Stress Risks to Crop Production*

Zimbabwe's agricultural sector heavily relies on rainfall for crop production, making it particularly vulnerable to the adverse impacts of El Niño-induced low rainfall seasons. During these periods, reduced precipitation and increased temperatures exacerbate drought and heat stress risks, leading to the following significant challenges for farmers:

Reduced crop yields, especially maize: Insufficient rainfall and prolonged dry spells negatively affect crop yields, resulting in lower productivity and compromised food security. Crops such as maize, a staple in Zimbabwe, are particularly susceptible to drought stress, reducing yields and causing potential crop failures (Figure 4).

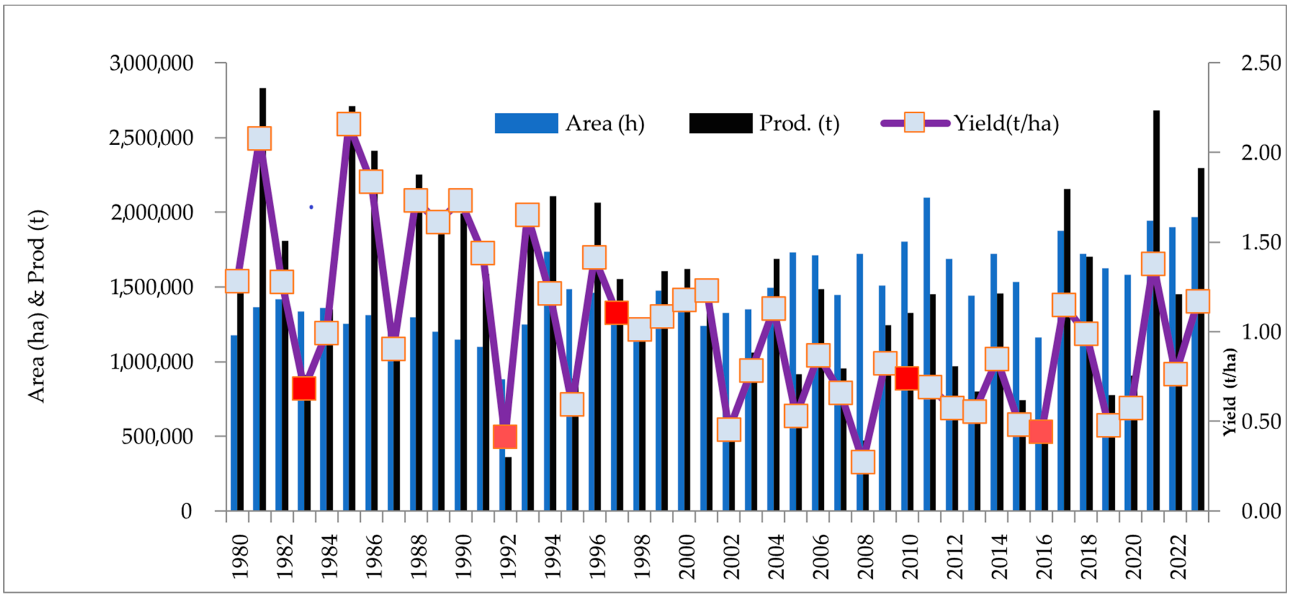



**Figure 4.** El Niño years (red points) and historical maize production from 1980–2023 in Zimbabwe.

Water Scarcity: Decreased rainfall reduces water availability for irrigation and crop cultivation. This scarcity amplifies farmers' challenges, especially in rain-fed agricultural systems, where irrigation infrastructure may need improvement. As a result, farmers may need help to maintain adequate soil moisture levels and meet the water requirements of their crops.

### *2.2. Increased Fire Hazards and the Need for Adequate Protection*

The dry conditions associated with El Niño-induced dry seasons elevate the risk of wildfires in Zimbabwe, posing additional threats to agricultural productivity and natural resources.

- Crop Losses due to Fires: Uncontrolled fires can destroy crops, leading to substantial economic losses for farmers. In addition to direct crop damage, fires can affect soil fertility and microbial activity, further impairing agricultural productivity.
- Environmental Degradation: Wildfires harm agricultural land and contribute to environmental degradation by destroying vegetation, depleting biodiversity, and releasing large amounts of carbon dioxide into the atmosphere. These ecological disruptions have long-term implications for sustainable agriculture practices and ecosystem resilience.

The following sections will discuss the strategies outlined in Zimbabwe's Ministry of Agriculture's Drought Risk Management Strategy and Action Plan (2017–2025) for combatting these challenges effectively.

## 3. Overview of the Strategy's Objectives and Framework

The Ministry of Agriculture in Zimbabwe recognised the urgent need to address the challenges posed by drought. It developed the Drought Risk Management Strategy and Action Plan (2017–2025) as urged by several international frameworks, such as the Sendai Framework for Disaster Risk Reduction [3,8,24]. The strategy serves as (a) an early warning system for quick response and (b) a thorough analysis of the effects of prior droughts and why specific groups of people, communities, and industries are more susceptible to those effects. It also includes (c) coordinated drought action plans that link reactions to the early warning systems, which include anticipated responses by various institutions for how to handle (i) moderate drought, (ii) severe drought, and (iii) extreme drought with suitably increasing responses. The plan aims to enhance the country's capacity to manage droughts effectively, minimise their impacts on agriculture, and ensure the sustainability of rural livelihoods. Given the high probability of recurrent weather patterns under El Niño conditions, the potential effects on crop production can be mapped to support interventions that minimise adverse impacts. This brief paper proposes a level of tactical and operational decision-making to be followed by the agriculture sector to safeguard farmers' livelihoods and improve drought readiness for the upcoming agricultural seasons (Table 1).

**Table 1.** Proposed proactive measures to mitigate the impact of drought-induced shocks.

| Adaptation and Mitigation Measures | Strategy | Tactical | Operational |
|---|---|---|---|
| Distribution of farming inputs and seeds of drought-tolerant crop varieties well before planting seasons, promoting small grains in marginal lands. | | ✔ | |
| Promotion of capacity development and support for farmers for implementing water-harvesting techniques, especially conservation agriculture and water harvesting techniques. | ✔ | ✔ | ✔ |
| Rehabilitation of irrigation intakes, canals, and other water points, such as constructing new dams. | ✔ | ✔ | ✔ |
| Developing the capacity of smallholder farmers in marginal lands and providing support for post-harvest management and processing to minimise losses | | ✔ | ✔ |
| Distribution of feed and provision of livestock health support, with particular emphasis on chemicals, to ensure a regular dipping regime and appropriate livestock vaccination. | | ✔ | ✔ |
| Monitoring of cyclones, preparation of actionable advisories, and provision of humanitarian assistance (such as unconditional cash transfers) to vulnerable households upon early warnings and ahead of landfall. | ✔ | ✔ | ✔ |
| Provision of cash for work (ideally via government social protection systems) to facilitate support for the rapid construction/reinforcement of community infrastructures (e.g., evacuation centres for livestock and water drainage systems). | | | ✔ |
| Forecast-based financial products, such as agriculture insurance, yield-based insurance, and weather index insurance | ✔ | ✔ | ✔ |

In Zimbabwe, the Ministry of Agriculture stepped up efforts to increase drought readiness for the forthcoming 2023–2024 growing season to protect farmers from the projected El Niño effects and lessen the effects of drought. These programmes cover a wide range of activities, such as encouraging the growth of drought-tolerant plants, restoring and developing irrigation systems, adopting water-efficient practices and early warning information systems, developing strategies for raising livestock, promoting water harvesting and conservation methods, creating strategic grain reserves, and establishing post-harvest management procedures (Table 1).

### *3.1. Importance of Implementing Appropriate Mitigation Measures*

In Zimbabwe, the agriculture sector, especially smallholder farmers, commonly encounters many obstacles such as inadequate and unpredictable rainfall, diminishing soil fertility, insufficient investment, high cost of inputs, poor markets, scarcity of labour and draught animals for farming, inadequate physical and institutional infrastructure, poverty, and repeated food insecurity. Drought is a major cause of low maize production in Zimbabwe.

The adverse effects of drought on agricultural productivity and rural communities must be minimised using suitable mitigation measures. By implementing proactive solutions, Zimbabwe can increase its resilience in the face of drought occurrences and lessen its long-term socioeconomic and environmental effects. To effectively handle drought concerns, the Drought Risk Management Strategy underlines the significance of a multifaceted strategy that combines scientific research, policy measures, and community involvement. The plan focuses on prevention, preparedness, and effective response to provide a solid foundation for sustainable agriculture amid climatic uncertainty. Focus on improving drought readiness for the 2023–2024 agricultural season.

#### 3.1.1. Promotion of Drought-Tolerant Crops

There is a growing apprehension in southern Africa regarding the potential decrease in precipitation due to global warming. Several studies have determined that the average precipitation in Zimbabwe has decreased by 10%, or 100 mm, during the past century. The coefficient of determination ($R^2$) was found to be low. Out of the 13 El Niño seasons observed, 11 had a negative detrended yield anomaly (Table S2). This demonstrates a substantial correlation between El Niño and the decreased crop yields in Zimbabwe. The link between yield and ENSO is not strictly linear, as La Nina has no equivalent and opposite impact to El Niño. The correlation coefficient (R2) between the Oceanic Niño Index (ONI) and rainfall is 43%, whereas the correlation coefficient between rainfall and yield is 39%. This indirectly demonstrates the relationship between ONI and yield. Therefore, to mitigate the effects of meteorological uncertainties, the agricultural industry in Zimbabwe must adequately and strategically plan for any of ENSO's events. In Zimbabwe, cultivating drought-tolerant crops is one of the primary tactics for reducing the effects of drought on agriculture. Through research and development strategies, farmers can obtain better cultivars that show improved resilience to water scarcity and heat stress in Africa, especially in Zimbabwe; adopting drought-tolerant maize cultivars, such as the Drought Tolerant Maize for Africa (DTMA) variety, has shown encouraging results [25].

#### 3.1.2. Investment in Irrigation Rehabilitation and Development

Investing in irrigation development and reconstruction is essential for overcoming the problems caused by insufficient rainfall. In Zimbabwe, the irrigation infrastructure can be improved to reduce farmers' reliance on rainfall and mitigate the effects of dry seasons, and irrigation schemes can be expanded. The Ministry can significantly increase agricultural productivity and lessen vulnerability to climatic swings by prioritising investments in irrigation infrastructure and giving farmers the required skills and resources to adopt efficient irrigation practices.

#### 3.1.3. Adoption of Efficient Water Utilisation Practices

Efficient water utilisation practices are crucial in ensuring sustainable agricultural production, particularly during dry seasons. Encouraging farmers to adopt water-saving techniques such as drip irrigation, mulching, and conservation agriculture (Pfumvudza) can significantly reduce water waste and optimise efficiency.

#### 3.1.4. Early Warning Information and Drought Monitoring

Timely access to accurate and reliable information is essential for farmers to make informed decisions and take proactive measures in response to impending drought conditions. The World Meteorological Organization emphasises the "Early Warnings for All" initiative to ensure that everyone on Earth is protected from hazardous weather, water, or climate events through life-saving early warning systems by the end of 2027 [8,14]. Establishing and strengthening early warning information systems and drought monitoring mechanisms are crucial. For example, the Zimbabwe Meteorological Services Department provides farmers with regular weather forecasts and drought updates, enabling them to plan and adjust their agricultural activities accordingly.

Crop yields are impacted by drought, which makes raising livestock significantly more difficult. The livestock sector must be resilient to guarantee food security and preserve rural livelihoods [26,27]. The resistance of the livestock industry to drought conditions can be strengthened by putting into practice techniques like improved feed management, breeding programmes for heat- and drought-tolerant cattle breeds, and diversification of small livestock enterprises. In Zimbabwe, for example, introducing drought-tolerant forage crops such as cowpea and lablab has successfully produced substitute feed sources during the dry seasons.

#### 3.1.5. Water Harvesting and Conservation Techniques

To collect and store rainwater during the wet season for usage during dry months, water harvesting and conservation techniques are crucial. These methods include creating ponds, dams, and rooftop rainwater gathering systems. For instance, installing modest water harvesting systems in communal areas of Zimbabwe has increased agricultural outputs and improved rural livelihoods.

#### 3.1.6. Strategic Grain Reserves and Post-Harvest Management

Building and maintaining strategic grain stores is essential for food security during a drought. The nation can guarantee a sufficient food supply during times of scarcity by hoarding grains during excellent crop seasons. Enhancing post-harvest management techniques, such as adequate crop drying, storage, and processing, can lower losses and increase farmers' access to food and cash. In Zimbabwe, post-harvest losses have been successfully decreased by adopting efficient post-harvest management measures, such as hermetic storage bags.

## 4. The Way Forward

With an emphasis on the forthcoming El Niño event, this brief study has underlined the effects of the dry season on agriculture in Zimbabwe and on similar countries in Southern Africa. The suggested short- to medium-term actions include encouraging the use of climate-smart agriculture such as conservation agriculture (Pfumvudza), drought-tolerant crops, irrigation rehabilitation and development, efficient water use, early warning information systems, livestock production strategies, water harvesting, strategic grain reserves, and countries purchasing agriculture insurance to protect farmers and increase agricultural resilience [28]. The African Risk Capacity (ARC), through its insurance subsidiary ARC Insurance Ltd., is a sovereign insurance pool which provides African governments with index-based macro drought coverage (in a later stage, also flood coverage) [29]. The Sendai Framework for Disaster Risk Reduction calls for a change towards more anticipatory and preventive risk management, and ex-ante data on the geographical configuration of risk, leveraged by impact-based forecasts with lengthy lead times, can facilitate drought mitigation. Furthermore, livestock production strategies, water harvesting techniques, and strategic grain reserves contribute to ensuring food security and sustainability in the face of climate uncertainties.

This brief additionally suggests acknowledging that drought resilience is a continual undertaking that necessitates ongoing study, collaboration, and monitoring, utilising early warning monitoring, risk assessment, risk mitigation, and preparedness measures. [17,19,30]. More research is needed to identify crop kinds and livestock breeds more resilient to drought and heat stress [31–33].

## 5. Conclusions

The dry seasons in Zimbabwe and the unreliable weather patterns caused by ENSO events such as El Niño present challenges that necessitate assertive measures for safeguarding farmers' crops and ensuring sustained agricultural output. Farmers who exclusively depend on rainfed production should be motivated to adopt climate-proof strategies, including but not limited to using conservation agriculture/Pfumvuza, utilizing water harvesting techniques, selecting livestock and crop species that are water-stress-tolerant, practising crop intensification, purchasing weather-based insurance, and applying weather and climate information to enhance productivity. A low value of the coefficient of determination ($R^2$) was observed in this study. Eleven of the thirteen observed El Niño seasons exhibited a negative detrended yield anomaly (Figure S2). This unequivocally establishes a significant correlation between the effects of El Niño and Zimbabwe's agricultural productivity reduction. The correlation between yield and ENSO is not inherently linear, given that La Nina does not exert a reciprocal and antithetical influence on El Niño. However, other factors affect rainfall and yield, making the direct association between the Oceanic Nino Index (ONI) and yield non-linear. This paper suggests that the agriculture sector adheres to a series of strategic, tactical, and operational decision-making principles to enhance farmers' readiness for future agricultural seasons and protect their livelihood interests. Zimbabwe has the potential to improve its agricultural resilience and contribute to the broader goal of developing a more climate-resilient agricultural sector in Southern Africa through the adoption of these approaches and by emphasising the need for ongoing research, collaboration, and monitoring.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/atmos14111692/s1, Table S1. ONI; Table S2. ANOVA of ENSO events, ONI, December, January, and February rainfall and maize yields; Figure S1. DJF ONI vs the detrended yield anomaly; Figure S2. DJF ONI vs the detrended yield anomaly.

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