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El Niño Effects on Southern African Agriculture in 2023/24, Anticipatory Action Strategies to Reduce the Impacts in Zimbabwe

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Abstract: The brief paper utilises Zimbabwe as a case study to discuss the effects of El Nino in Southern Africa. It offers potential adaptation and mitigation measures for farmers to prepare for the forecasted El Nino-influenced rainy season 2023/24 and the future. To reduce climate and weather hazards connected with El Nino, the brief report suggests anticipatory action methods be applied in southern Africa, using Zimbabwe as a case study. To protect farmers' livelihoods and enhance drought readiness for the forthcoming agricultural seasons, the paper suggests a degree of strategic, tactical, and operational decision-making that the agriculture industry should adhere to. It emphasised the significance of providing farmers with knowledge and advice regarding drought and heat stress, including cultivating crop varieties and livestock and sufficient fire safety precautions. The brief paper calls to advocate for anticipatory action to avert El Nino in Southern Africa.

Keywords: early warning; El Nino-Southern Oscillation (ENSO); Climate services; weather; and climate information

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 Nia, or neutral phase, is a component. The effects of ENSO on local agro-climate factors alter vegetation patterns and 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 where 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 experienced the detrimental effects of El Niño in past events [4,5]. 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.

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While existing literature has extensively explored the link between El Niño and its effects on global climate patterns, there is a notable gap in the specific context of Southern Africa, particularly Zimbabwe. Rainfall patterns during El Niño events tend to be the reverse of 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 briefing paper aims to address this gap by focusing on the implications of El Niño on Zimbabwe's agricultural sector and providing recommendations for farmers to prepare for the upcoming dry season.

The relevance of this brief paper lies in the urgency to disseminate information and advice to farmers regarding 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. Moreover, the Ministry of Agriculture in Zimbabwe has developed a Drought Risk Management Strategy and Action Plan (2017–2025), which presents a framework for implementing mitigation measures to improve drought readiness [11,12]. The Zimbabwe Drought Risk Management Strategy and Action Plan were derived from international frameworks such as the Sendai Framework for Disaster Risk Reduction [11]. 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 to combat the short- and long-term effects of El Niño and build a more resilient agricultural sector [2,12,15,16].

This brief paper proposes the implications of El Niño induced rainfall season on agriculture in Zimbabwe and other southern African countries. The report explored the specific risks of drought, flood, and heat stress to crop production, including reduced yields and water scarcity. The paper examined crops' drought management more than livestock, given their high share of calories in total food consumption, notably in low-income countries and their importance for food security in southern Africa, particularly Zimbabwe [16–18]. Additionally, we examined 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 the 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.

1.1. El Niño Mechanisms and its 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, Figure 1 displays the anomalies in the Nino 3.4 region from 1982 to 2023. This graphical representation shows that, from 1950 to the present, El Niño events have recurred irregularly, appearing every 2 to 6 years [3,17].

Figure 1 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, experienced severe and widespread agricultural droughts across Zimbabwe, while a fourth, 2009/10, had a drought in the southern and eastern parts of Zimbabwe [9,16]. The fifth of the El Niño seasons did not experience the widespread dry conditions in Zimbabwe typically received during El Niño events due to an unusual state of regional climate

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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].

Figure 1 illustrates the irregular yet recurring nature of ENSO. 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 Nino 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 examining CHIRPS rainfall [21,22]. Figure 1 depicts the frequency of below-average rainfall in southern Africa throughout the 10 El Nino events between 1982 and 2013 (rain in the bottom tercile of the historical 40-year rainfall record). While climatologically, the number of times that below-average rainfall should have been recorded is 33%, 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, almost double the normal risk of dry conditions [12,18,23].

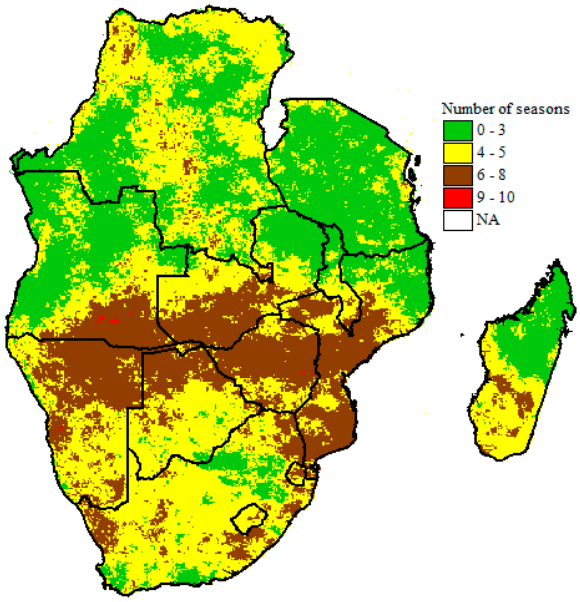

Figure 1. Number of El Niño DJFM seasons in below normal tercile (out of 10). The climatologically expected number is 3.

Although most El Nino 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 contributing to these fluctuations in ENSO's influence on rainfall [1].

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 significant challenges for farmers.

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Reduced crop yields, especially maise: Insufficient rainfall and prolonged dry spells negatively affect maise yields, resulting in lower production and compromised food security. Crops such as maise, a staple in Zimbabwe, are particularly susceptible to drought stress, reducing yields and potential crop failures (Figure 2).

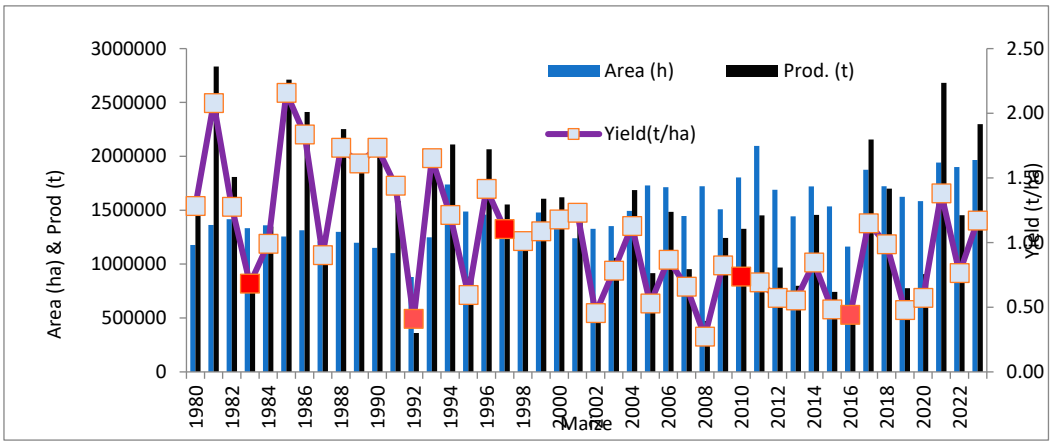

Figure 2. El Nino years (red points) and historical maise production 1980-2023 in Zimbabwe.

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 to be improved. 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 and ecosystem resilience.

The following sections will discuss the strategies outlined in the Ministry of Agriculture's Drought Risk Management Strategy and Action Plan (2017–2025) to combat these challenges effectively. The Zimbabwe Ministry of Agriculture's drought risk management strategy and action plan (2017–2025)

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 in several international frameworks such as the Sendai Framework for Disaster Risk Reduction [3,8,24]. It serves as 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. c) coordinated drought action plans that link reactions to the early warning systems of a), and 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 aimed to enhance the country's capacity to manage droughts effectively, minimise their impacts on agriculture, and ensure the sustainability of rural livelihoods. Given the

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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. The brief paper proposed 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).

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 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, early warning information systems, developing strategies for raising livestock, water harvesting and conservation methods, creating strategic grain reserves, and establishing post-harvest management procedures (Table 1).

Table 1. Anticipatory actions [12].

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 to farmers on water-harvesting techniques, especially conservation agriculture and water harvesting techniques.	✓	✓	✓
Rehabilitation of irrigation intakes, canals, and other water points. Construction of new dams.	✓	✓	✓
Developing the capacity of smallholder farmers in marginal land and providing support on 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 financings, such as agriculture insurance, such as yield-based insurance and weather index insurance	✓	✓	✓

3.1. Importance of implementing appropriate mitigation measures

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 to drought occurrences and lessen the 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 response to provide a solid foundation for sustainable agriculture amid climatic uncertainty. Focus on improving drought readiness for the 2023–2024 agricultural season.

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 Nino forecast can be a valuable tool for decision-making, helping farmers and

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policymakers foresee and prepare for probable drought conditions given the historical frequency of preceding El Niño outcomes in Zimbabwe [17].

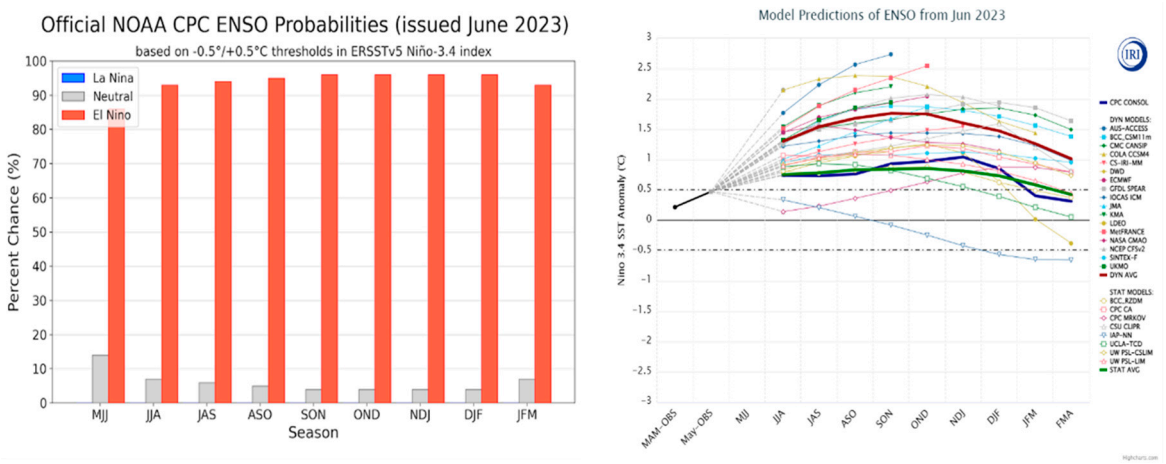

Figure 3. NOAA Climate Prediction Center (CPC) ENSO forecast for June 2023.

The 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].

3.1.1. Promotion of drought-tolerant crops

In Zimbabwe, cultivating drought-tolerant crops was one of the primary tactics for reducing the effects of drought on agriculture. Through research and development, farmers can obtain better cultivars that show improved resilience to water scarcity and heat stress. In Southern Africa, especially 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 to overcome the problems caused by insufficient rainfall. In Zimbabwe, irrigation infrastructure can be improved to reduce farmers' reliance on rainfall and 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

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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. Livestock production strategies

Crop yields are impacted by drought, and raising livestock is made 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 like 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 output 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. Way forward

With an emphasis on the forthcoming El Nino event, the brief study has underlined the effects of the dry season on agriculture in Zimbabwe and 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 to purchase agriculture insurance to protect farmers and increase agricultural resilience [28]. 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 cover (in a later stage also flood) [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.

4.1. Research, collaboration, and monitoring to enhance drought resilience in the agricultural sector

It is essential to recognise that drought resilience is an ongoing process that requires continuous research, collaboration, and monitoring based on Monitoring Early Warning, Risk assessment, Risk Mitigation, and Preparedness responses [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

El Nino and the dry seasons in Zimbabwe present difficulties that require aggressive steps to protect farmers and guarantee sustained agricultural production. The Drought Risk Management

Strategy of the Ministry of Agriculture and the suggested activities provide a thorough framework for reducing the effects of drought and improving drought preparation. Zimbabwe can increase its agricultural resilience and support the overarching objective of creating a more climate-resilient agricultural sector in Southern Africa by implementing these strategies and highlighting the significance of continued research, collaboration, and monitoring.

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