INITIATIVE ON
Digital Innovation
CGIAR

Type
Briefing

Area
Limpopo Basin

Date
26 June 2023

El Niño impacts in the Limpopo River Basin

Summary (June 2023)

Higher-than-average temperatures are predicted for the Limpopo Basin from June to November 2023

A delay in the onset of the rainy season in November is predicted

A reduction in rainfall and higher temperatures induced by the 2023 strong El Niño event are expected for the Limpopo Basin from January to March 2024

Historic data suggests a negative impact of El Niño on maize yields of the following season in South Africa, Mozambique and Zimbabwe.

El Niño is here

As of June 2023, there is widespread consensus among climate prediction centers that an El Niño event has developed.

Reports from the National Oceanic and Atmospheric Administration (NOAA) of the United States, show that the initial “weak” El Niño is very likely to transition into a “strong” event towards the Northern Hemisphere winter 2023-2024.

An El Niño event is declared when a sustained increase in sea surface temperatures (SST) is observed over the central and eastern equatorial Pacific Ocean, as a result of weakening in trade winds from the west, allowing the accumulation of anomalously warm waters (**see Box 1**).

Seasonal forecasts from dynamical climate models are now available with higher reliability, since the “spring predictability barrier” of the El Niño-Southern Oscillation (ENSO) has been overcome (Jin et al., 2008).

Monthly predictions of sea surface temperature anomalies indicate that El Niño conditions will most likely reach a maximum during November 2023 to February 2024.

What can we expect for the Limpopo River basin in southern Africa?

Lower rainfall and higher-than average temperatures are forecast for the six-month period from June to November 2023 (**Figure 1**)

As this period covers an important part of the dry season, the forecast anomalies are generally very low. However, anomaly forecasts for November, roughly the start of the rainy season, predict a negative impact on rainfall in the Limpopo Basin.

Lower-than-average rainfall could delay planting dates in 2023 for crops such as maize, until rainfall permits emergence in rainfed systems. A direct consequence of a late maize planting could be a decrease in yields due to thermal and water stress at the end of the 2023/24 season.

Mean temperatures (**Figure 1b**) are predicted to be above the average during the period June to November 2023. In November, high temperatures accompanied by rainfall deficits could favor conditions of water deficit and environmental stress on maize seedlings.

Stress conditions should continue to be monitored in the coming months as the current El Niño event evolves and upcoming forecasts are released.

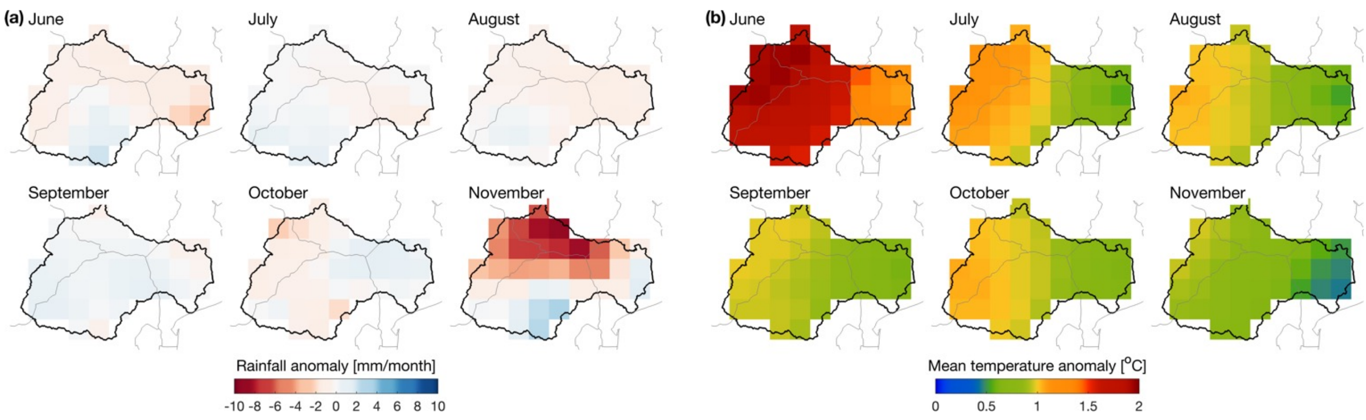

Figure 1. *Maps of anomalies of (a) monthly total rainfall and (b) mean air temperature predicted by 8 General Circulation Models from C3S for the months of June through November 2023 in the Limpopo River basin. Forecasts are initiated in June.*

Expected impacts of the El Niño event on Limpopo agroclimatic conditions in 2024

Reliable forecasts are not yet available for the summer of 2023/24. However, an analysis of the impacts of previous El Niño years gives an idea of what to expect.

The maps in **Figure 2** show: a) average rainfall, b) temperature, c) reference evapotranspiration (ET0) calculated using the method from Allen et al. (1998), and d) number of warm days (days with a maximum temperature above 35 ºC).

The maps show that El Niño causes rainfall and temperature anomalies that imply unfavorable conditions for crops. The combination of low rainfall and high temperatures should lead to drought conditions over the region. Consequently, higher thermal and water stress and a reduction in yields should be expected.

Evapotranspiration anomalies (**Figure 2c**) indicate higher atmospheric water demand and water consumption by plants, which could increase the negative water balance throughout the growing season. The impact could be compounded by the high number of days with extreme temperatures (**Figure 2d**), which are associated with heat stress and significant reductions in maize yields (Lobell et al., 2013).

Experience shows that the water deficit stress during the flowering and grain filling stages significantly reduces maize yields in non-drought tolerant cultivars (Sah et al., 2020). Potential conditions of water scarcity and environmental stress for crops such as maize in the Limpopo Basin should raise concerns in the region.

As the dominant system in the Limpopo Basin corresponds to rainfed maize, decisions must be taken to try to maintain yields using maize cultivars tolerant to water and thermal stress, or promoting management practices to retain soil moisture, increasing water use efficiency.

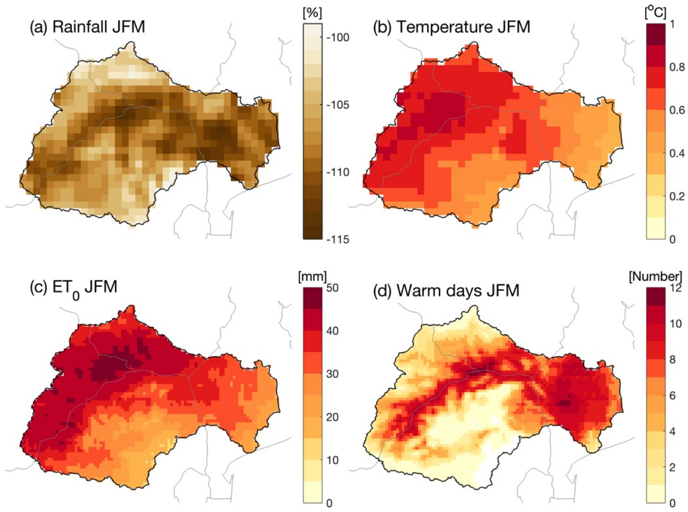

Figure 2. *Maps of average (January-February-March, JFM) (a) total rainfall, (b) air temperature, (c) reference evapotranspiration (ET0), and (d) number of warm days during El Niño years. (a) and (b) are calculated using monthly data from ERA5 reanalysis for the period 1950-2022. (c) and (d) are calculated using daily data from AgERA5 reanalysis for the period 1979-2022.*

Box 1. Tracking and predicting El Niño

El Niño results from higher-than-normal sea surface temperatures (SST) in the tropical Pacific Ocean. The region 5N-5S, 170W-120W (white rectangles below) is looked at to monitor and predict global ENSO conditions. The maps below show predictions of SST anomalies from June to November 2023.

The **El Niño 3.4** index is calculated by taking the mean three-month SST anomalies over the 5N-5S, 170W-120W region. A global El Niño or La Niña event is declared when the index shows anomalies exceeding +/- 0.5ºC that persist for three consecutive months.

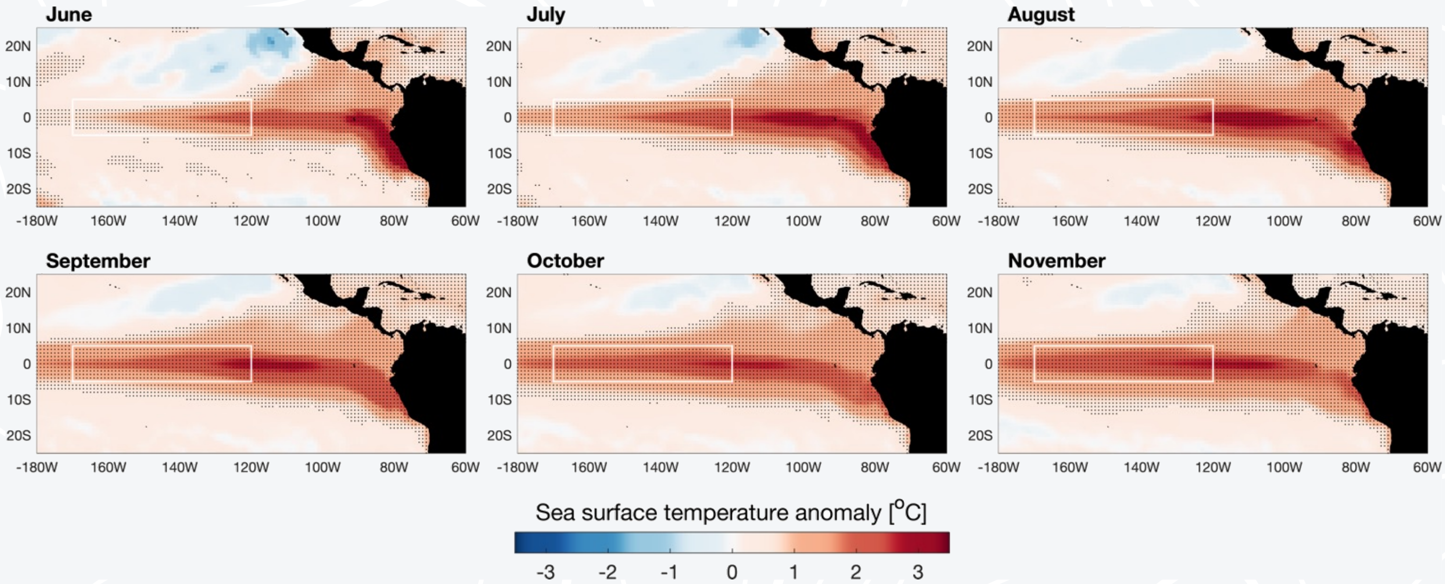

Figure 3. Maps of sea surface temperature anomalies (SSTa) predicted by eight General Circulation Models from C3S for the months of June through November 2023. Forecasts are initiated in June. The white rectangle shows the El Niño 3.4 region. Black dots represent the area with SSTa higher than 0.5 ºC.

Expected impacts of the El Niño event on Limpopo maize yields in 2024

What has been previously observed in the Limpopo Basin in terms of maize yields and El Niño? The seasonal climate anomalies presented are associated with adverse maize growth and production conditions.

The historical record of maize yields at the country level in South Africa, Mozambique and Zimbabwe, shows that El Niño years are associated with a mean decline in maize yields (**Figure 4**).

However, the scattering in **Figure 4** also shows that not all El Niño years fit the average, and there are years with maize yields above the average.

Furthermore, the range of El Niño 3.4 index forecasts from June to November 2023 (dashed lines in **Figures 3 and 4**) indicate a higher chance of a "strong" El Niño event according to dynamical models.

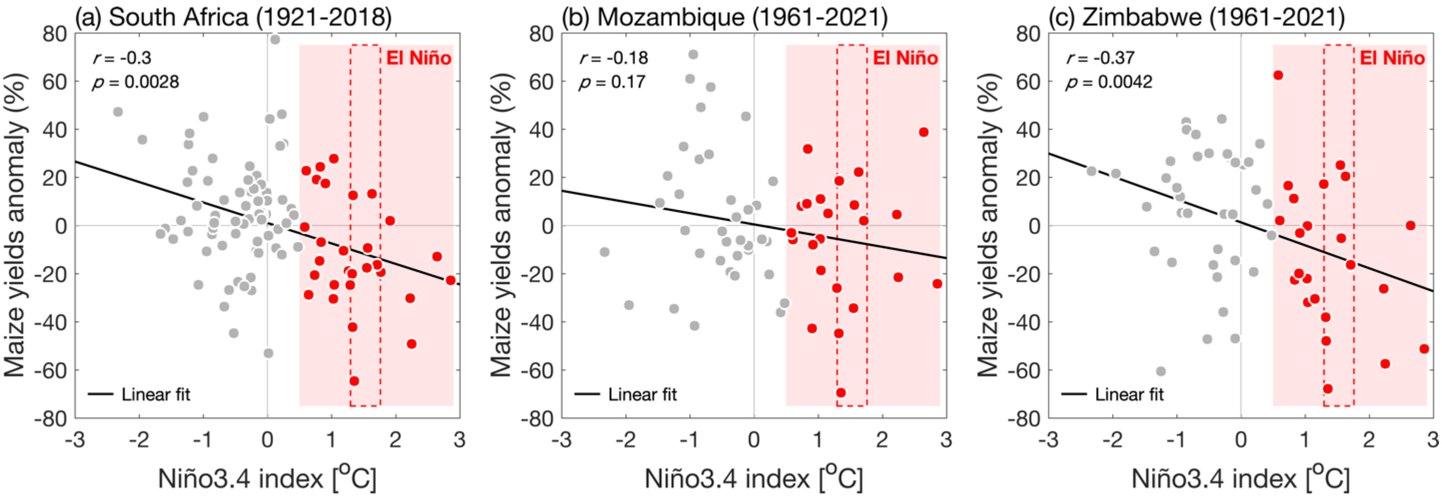

Figure 4. *Relationship between the El Niño 3.4 index in November and historical maize yields of the following year (expressed as percentage of the historical average). Red area represents El Niño years. The red dotted rectangle represents the predicted range of El Niño 3.4 index from June to November 2023. The Spearman correlation coefficient (r) and the p value for statistical significance are displayed. Solid line is the linear fit.*

Understanding variation in El Niño impacts on maize yields in southern Africa

Figure 4 shows that not all El Niño events are associated with a decline in maize yields. Similarly, Figure 5 shows that not all El Niño events are associated with a lower rainfall amounts and an increase in temperatures, evapotranspiration and the number of warm days across the region, as summarized in Figure 3.

For example, 1959 corresponded to a year of high rainfall (77% higher than average) and also low temperatures (-1.3 oC below the average) in the Limpopo River Basin, a year of maize yields 27% above the interannual mean in South Africa.

These "discrepancies" might be explained by differences in sea surface temperatures in the Pacific Ocean, timing and other seasonal phenomena such as the Madden-Julian Oscillation (MJO), which can significantly affect maize yields in the Limpopo Basin (Anderson et al., 2020), especially during El Niño years (Pohl et al., 2007).

As MJO consists of two main parts, the "wet" and the "dry" phases lasting between 30 and 60 days, the intensity of these phases could determine seasonal anomalies for summer 2023/24 in the Limpopo Basin.

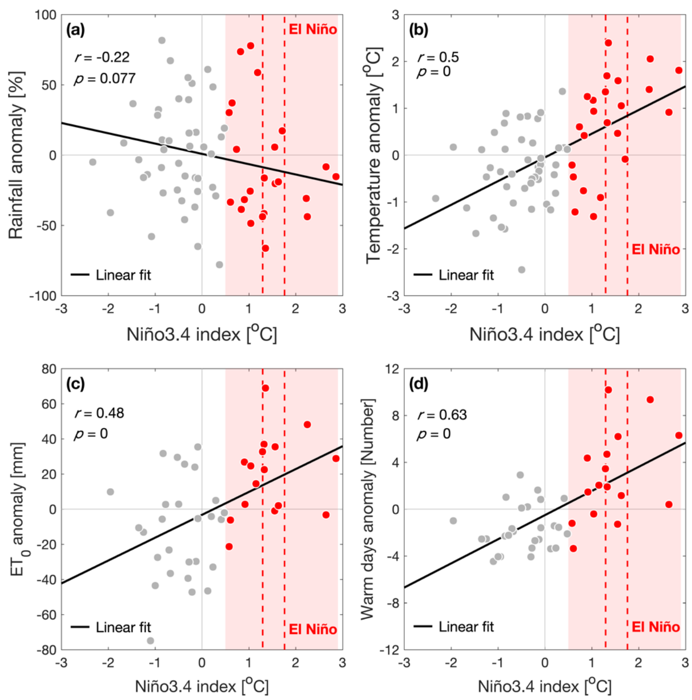

Figure 5. *Scatter plots between El Niño 3.4 index and mean (a) total rainfall, (b) air temperature, (c) reference evapotranspiration (ET0), and (d) number of warm days in the Limpopo River basin. Each point represents a specific year and regional mean. (a) and (b) are calculated using monthly data from ERA5 reanalysis for the period 1950-2022. (c) and (d) are calculated using daily data from AgERA5 reanalysis for the period 1979-2022. The Spearman correlation coefficient (r) and the p value for statistical significance are displayed. Solid line is the linear fit. The red dotted rectangle represents the predicted range of El Niño 3.4 index from June to November 2023.*

Management of river flows in an El Nino event.

Declining rainfall will result in reduced river discharge (flow), resulting in negative impacts for users of the water for livelihoods, and placing stress on the river ecosystem. The e-flow directions produced by IWMI (see Volume 7 https://limpopo-eflows.iwmi.org/) provide tables of flow that are required to protect the ecosystem as well as the beneficiaries of a functional ecosystem.

The recommended e-flows are lower during dry years such as due to El Nino, mimicking natural processes and helping build resilience of the ecosystem without compromising its quality. The Digital Innovation Initiative is working to assist with implementation of e-flows and is providing digital tools that will enable water resource managers to manage river flows to ensure a sustainable river and use of the water.

Conclusion

The occurrence of an El Niño event in 2023/24 is almost certain. The historical record is also clear regarding the average anomalies that El Niño induces in the Limpopo River Basin and its potential to impact production of highly important crops such as maize.

It is important to keep tracking seasonal anomaly forecasts in the following months, continue the transfer of information to farmers from meteorological and agricultural extension services, and to take timely decisions regarding possible options to mitigate the potential impact of seasonal rainfall deficits and other factors.

As the maize growing season approaches, it is important to monitor the status of the MJO, which could be decisive in terms of the magnitude of the influence of El Niño in Limpopo.

CGIAR Initiative on Digital Innovation

Research-based evidence and solutions for digital innovations to accelerate transformation of agrifood systems, with an emphasis on inclusivity and sustainability.

More information: on.cgiar.org/digital

Brief prepared by: Carlo Montes (The International Maize and Wheat Improvement Center).

Methodologies

2023 Projected rainfall and temperature anomalies

6-months (June-November) seasonal forecasts were obtained from the Copernicus Climate Change Service (C3S) multi-system (released in June 2023) (https://cds.climate.copernicus.eu/). Eight General Circulation Models (GCMs) were used, which have a variable number of ensemble members, which were averaged to obtain one forecast per model. Finally, the multi-model ensemble was used to generate the forecasts of this document.

Anomalies of sea surface temperature, total rainfall, and mean temperature from the following models were used:

- CMCC (SPS3.5)
- DWD (GCFS2.1)
- ECMWF (System 5)
- Météo-France (System 8)
- UKMO (GloSea6)
- JMA (CPS3)
- ECCC (GEM5-NEMO)
- NCEP (CFSv2)

Historical maize yield data

Obtained from the Columbia University's Twentieth Century Crop Statistics, v1 (https://sedac.ciesin.columbia.edu/data/set/food-twentieth-century-crop-statistics-1900-2017) and from FAOSTAT.

ERA5 and AgERA5 reanalysis data

Obtained from the Copernicus Climate Data Store (https://cds.climate.copernicus.eu/cdsapp#!/home).

References

Allen, R. G., L. S. Pereira, D Raes, and M. Smith. 1998. Crop evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56, FAO, Rome, 300, 6541, 1998.

Anderson, A., R. Seager, W. Baethgen, and M. Cane. 2017. Crop production variability in North and South America forced by life-cycles of the El Niño Southern Oscillation. Agricultural and Forest Meteorology. 239, 151-165.

Anderson, W. B., Han, E., Baethgen, W., Goddard, L., Muñoz, Á. G., & Robertson, A. W. (2020). The Madden-Julian Oscillation affects maize yields throughout the tropics and subtropics. Geophysical Research Letters. 47, e2020GL087004.

Jin, E.K., J. L. Kinter III, B. Wang, C.-K. Park, I.-S. Kang, B. P. Kirtman, J.-S. Kug, A. Kumar, J.-J. Luo, J. Schemm, J. Shukla & T. Yamagata. 2008. Current status of ENSO prediction skill in coupled ocean–atmosphere models. Climate Dynamics. 31, 647-664.

Lobell, D. B., G. L. Hammer, G. McLean, C. Messina, M. J. Roberts, and W. Schlenker. 2013. The critical role of extreme heat for maize production in the United States. Nature Climate Change. 3, 497-501.

Pohl, B., Y. Richard, and N. Fauchereau. 2007. Influence of the Madden-Julian Oscillation on southern African summer rainfall. Journal of Climate. 20, 4227-4242.

Sah, R.P., M. Chakraborty, K. Prasad, M. Pandit, V. K. Tudu, M. K. Chakravarty, S. C. Narayan, M. Rana, and D. Moharana. 2020. Impact of water deficit stress in maize: phenology and yield components. Scientific Reports. 10, 2944.