Spatio-temporal analysis of droughts in Limpopo province and their impacts on maize production

Ferreira, N. C. R.*; Bracho-Mujica, G; Nelson, W; Lam, Q. D.; Abdulai, I; Rötter, R.
* nicole.resende@uni-goettingen.de
Georg-August-Universität Göttingen, Tropical Plant Production and Agricultural Systems Modelling

BACKGROUND

Global climate change

Droughts can be worsened, due to the increase of temperature, changes in rainfall patterns, and increasing in the frequency and intensity of extreme events (Drumond et al. 2019, IPCC 2014).

Agricultural droughts

High temperatures can result in higher water deficits during the summer season, and that will lead to decreased soil moisture and more frequent and severe agricultural droughts (Adams & Peck 2008).

It is important to understand the spatio-temporal patterns of droughts in different regions to create mitigation and adaptation measures that take into account the drought's impact and to support ideotyping for different crops considering a specific environment.

Objectives

The goal of this research is to study drought patterns in Limpopo and to evaluate how these droughts are expected to occur in future scenarios. Another important target is to relate how droughts may affect maize production in the region.

DATA

Study region and observed climate data

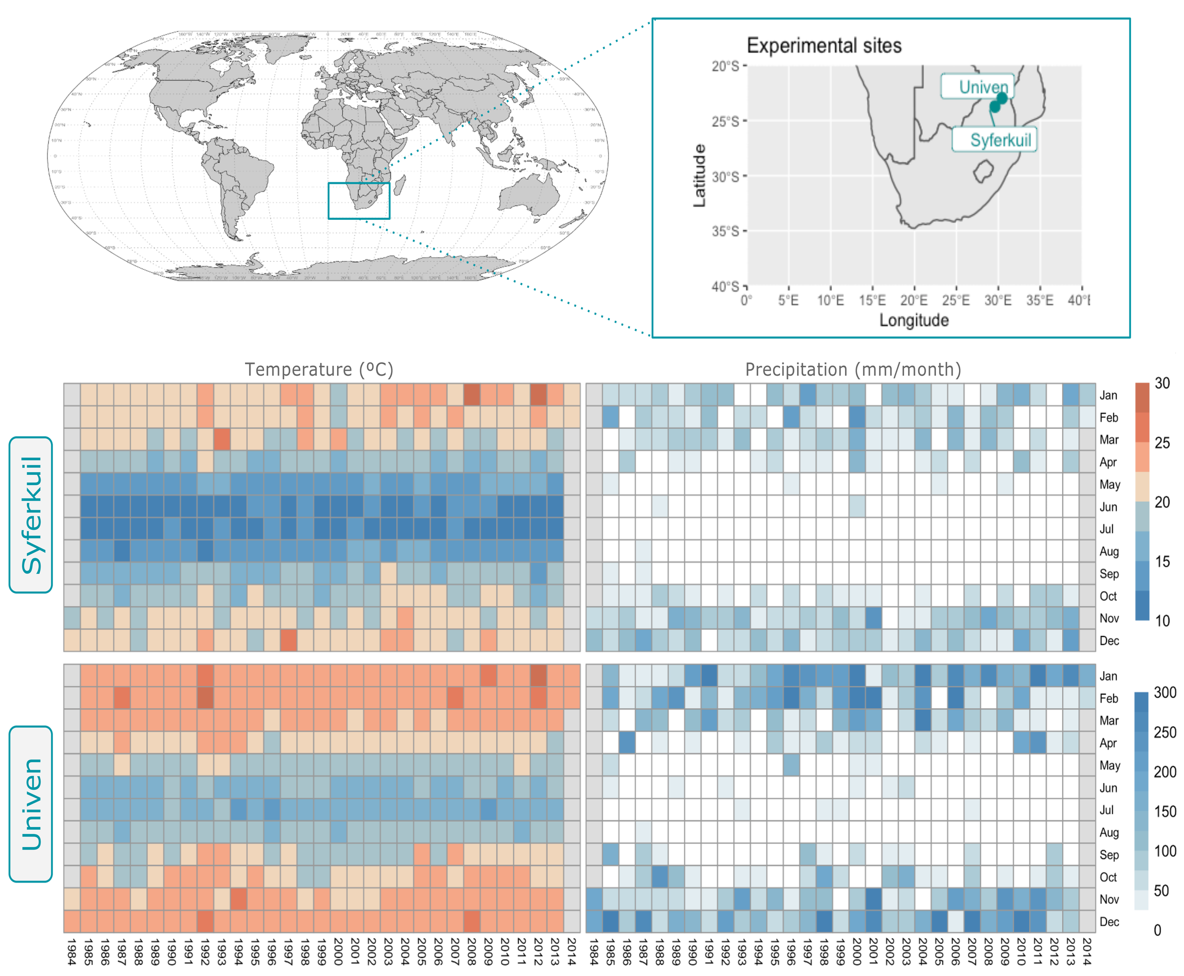

Fig 1. Experimental sites in Limpopo (Univen, Syferkuil), and observed precipitation and temperature (monthly climatology) for these sites.

- The site Univen has higher volumes of accumulated precipitation when compared to the Syferkuil site.
- There is great variability of precipitation, mostly in the Univen site.
- In both sites, the higher volumes of precipitation are concentrated in the months between November and February.
- The temperature in Univen is higher than in Syferkuil. On the Syferkuil site, we observe an increase in temperature from 2003, mainly in January.

Climate projections

Simulated climate data from CMIP6 - precipitation (adjusted, ISIMIP)

Climate models (0.5º x 0.5º resolution):

- IPSL-CM6A-LR
- MRI-ESM2-0
- MPI-ESM1-2-HR
- GFDL-ESM4
- UKESM1-0-LL

+ Ensemble

Period: NDJF → Important for maize production

Scenarios / time-slices

- Historical → 1981-2010
- SSP1-2.6
- SSP3-7.0
- SSP5-8.5

2021-2050, 2051-2080

APPROACH

Drought indices

Table 1. Climate indices to characterize droughts.

Index	Description	Units
PRCPTOT	Total precipitation (accumulated per month)	mm
MaxPR	Maximum daily precipitation	mm
DD	Dry days - Number of days without precipitation	Days
WD	Wet days - Number of days with precipitation	Days
LDP	Longest Dry Period - Consecutive days without precipitation	Days
LWP	Longest Wet Period - Consecutive days with precipitation	Days
RX5D	Maximum consecutive 5-day precipitation	mm
SPI	Standardized Precipitation Index	-

Drought conditions (DC) thresholds

Table 2. Quantile calculated with historical data (model ensemble) to define drought conditions in Univen and Syferkuil site.

Index	Quantile	Univen				Syferkuil			
		Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb
PRCPTOT	q < 0.1	67.0	70.4	94.7	59.5	74.1	76.4	81.6	84.0
MaxPR	q < 0.1	22.5	21.1	27.8	24.0	19.7	19.2	24.8	25.6
WD	q < 0.1	5.6	6.7	6.8	5.4	7.6	8.7	8.5	7.0
LWP	q < 0.1	2.6	3.0	2.8	3.0	3.4	3.2	3.4	3.4
RX5D	q < 0.1	39.5	37.1	55.5	40.3	37.7	38.7	51.0	44.9
DD	q > 0.9	24.4	24.3	24.2	22.6	22.4	22.3	22.5	21.6
LDP	q > 0.9	16.0	13.8	14.2	15.9	11.6	11.0	13.5	13.2
SPI	-	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0

RESULTS

Climate models evaluation

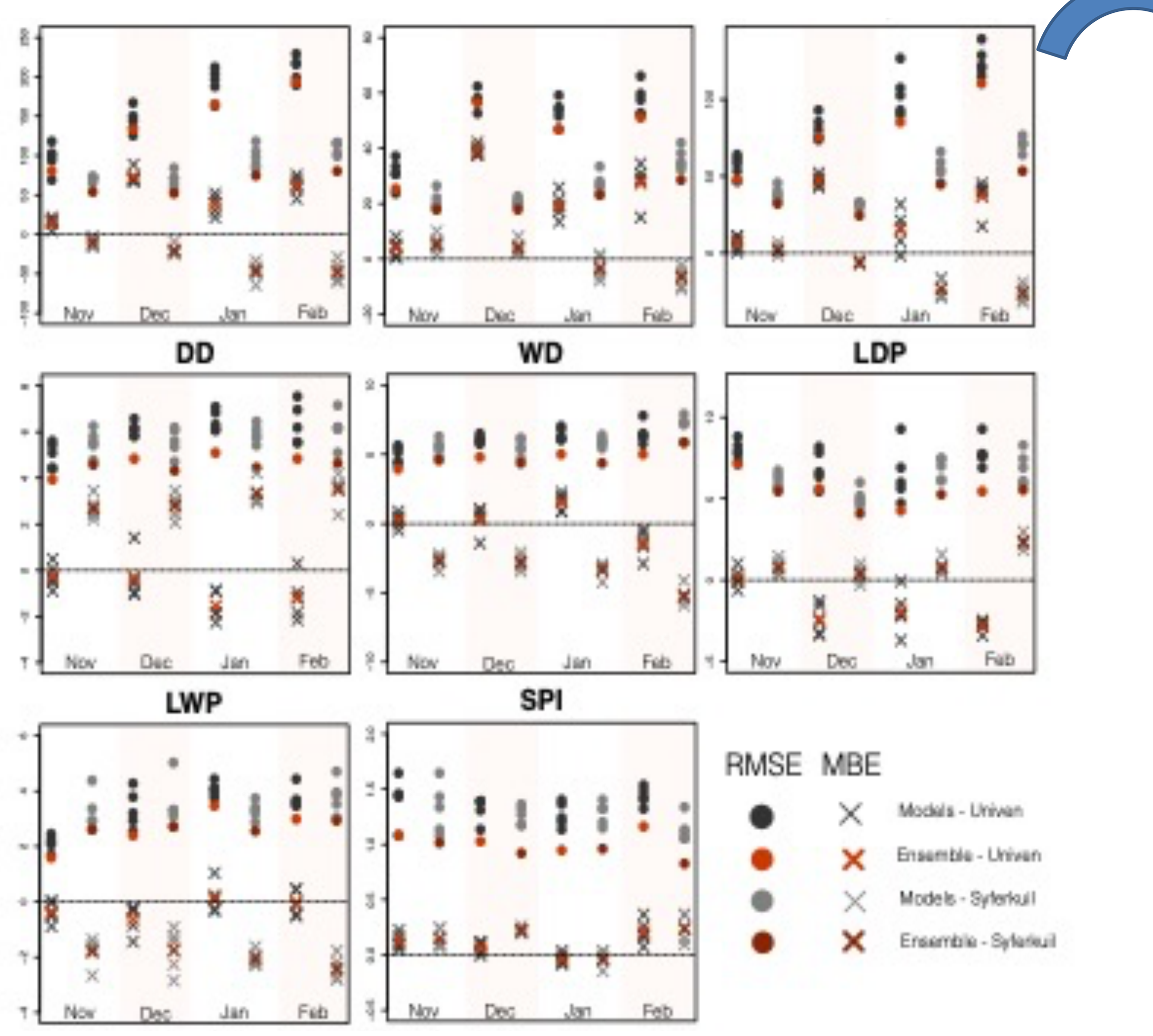

Fig 2. RMSE (circle) and MBE (cross) for Univen and Syferkuil. Shades of red indicate the errors of the ensemble, and shades of grey indicate the errors of the different models.

- The RMSE is lower in the ensemble compared to the models.
- The same pattern occurs in the MBE, which tends to approach zero when using the ensemble.
- In general, the patterns of underestimation or overestimation depend on the index, the model evaluated, and the region.

Historical and future precipitation in Limpopo

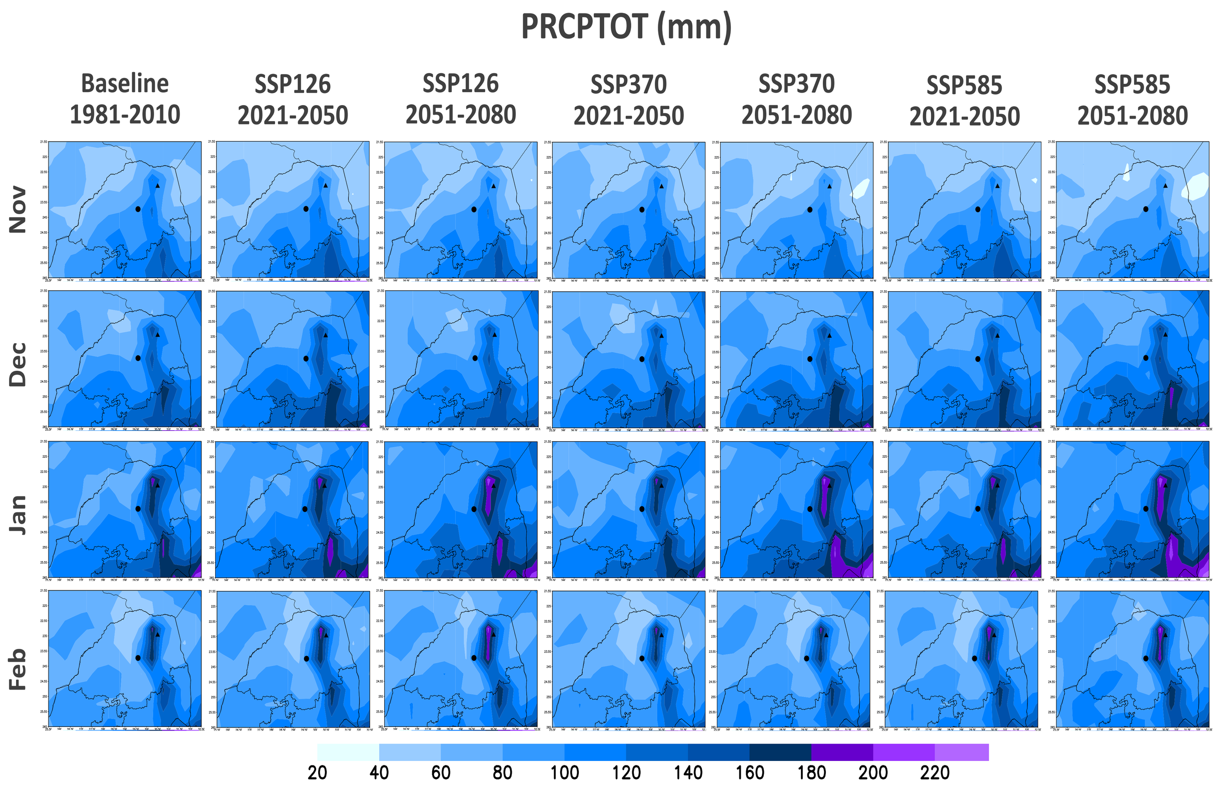

Fig 3. 30-year average PRCPTOT in Limpopo, using historical simulation and future scenarios. The circle indicates the Syferkuil site and the triangle the Univen site.

- Climate scenarios indicate small changes in accumulated precipitation
- The greatest changes occur in January (mostly in SSP5-8.5, 2051-2080), with increasing precipitation.
- There is no indication of decreasing precipitation in future scenarios for both sites, which highlights the importance of using drought indices.

Historical and future drought patterns

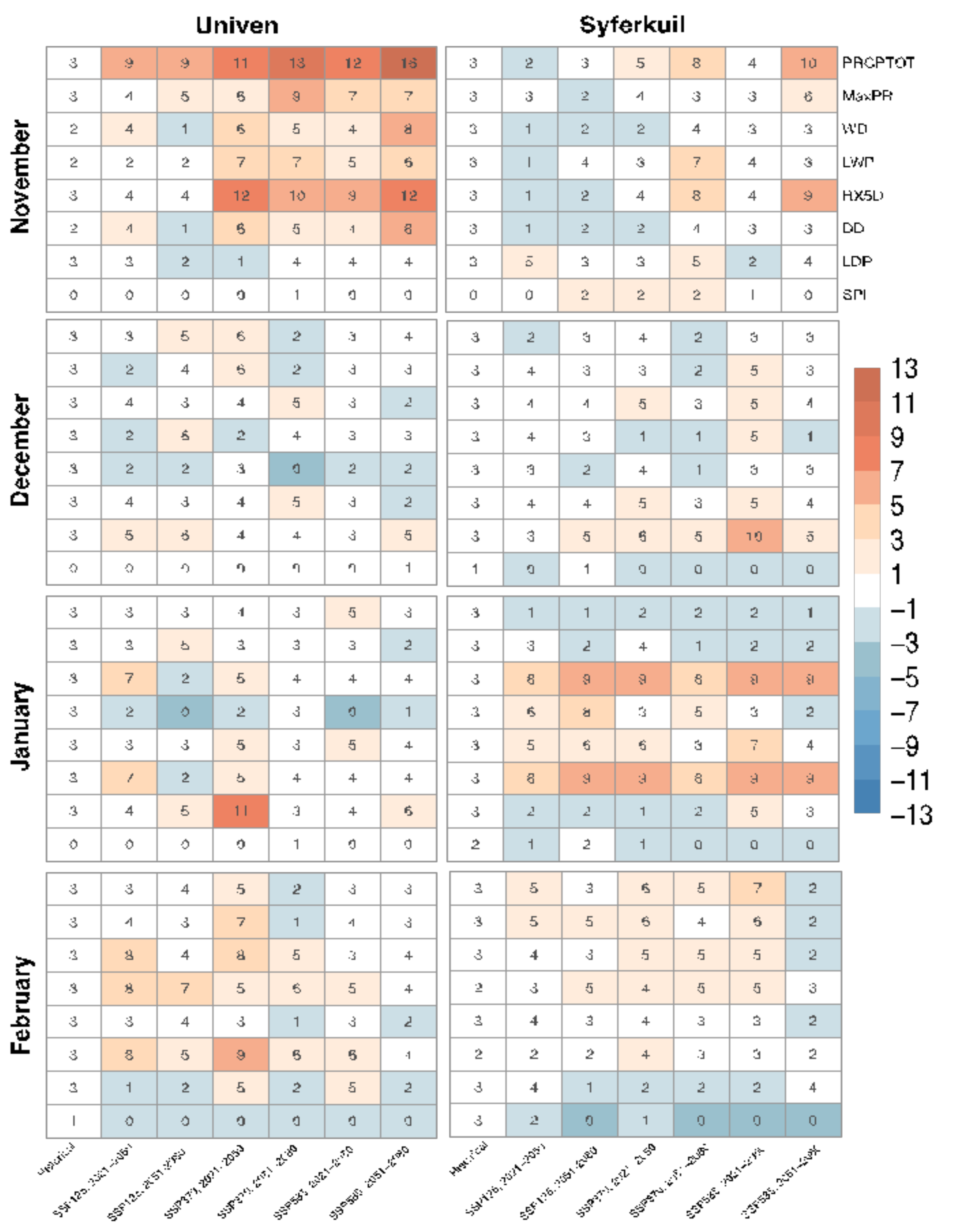

Fig 4. Number of years with DC (numbers) in Univen and Syferkuil. Colors indicate the difference between future scenarios and historical simulation. Shades of red show increasing of DC in the future, and blue shades show decreasing of DC in the future.

- Univen: worst future DC tends to occur in November, with decreasing of PRCPTOT, MaxPR, WD, LWP, and RX5D; and increasing of DD.
- Syferkuil: worst future DC tends to occur in January with decreasing of WD, LWP, RX5D; and increasing of DD.

KEY MESSAGES

1. Models have uncertainties that must be evaluated and can be reduced with the use of the ensemble.
2. Precipitation evaluation is not enough to study droughts in the region, which highlights the importance of using drought indices.
3. Droughts will affect the two sites differently and at different times. This requires different mitigation and adaptation measures in each region.

Now that we have an idea about the future droughts patterns in Limpopo, we still want to know...

- What are the impacts of droughts in maize production?
- What are the management options and mitigation measures to reduce these impacts?
- How can we support ideotyping?

REFERENCES

Adams, R. M., & Peck, D. E. (2009). Effects of climate change on drought frequency: Potential impacts and mitigation opportunities. In Managing Water Resources in a Time of Global Change (pp. 133-146). Routledge.

Drumond, A., Stojanovic, M., Nieto, R., Vicente-Serrano, S. M., & Gimeno, L. (2019). Linking anomalous moisture transport and drought episodes in the IPCC reference regions. Bulletin of the American Meteorological Society, 100(8), 1481-1498.

Intergovernmental Panel on Climate Change (IPCC). Climate Change 2014: Synthesis Report; Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

support

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

DLR Projektträger

project region

SPACES II
Science Partnerships for the Adaptation to Complex Earth System Processes in Southern Africa

partners

University of Limpopo
University of Venda
WITS UNIVERSITY
BiK^F
UNI BONN

SPACES II Midterm, Pretoria, South Africa
20 – 21 May 2020