Ecosystem and Livelihood Resilience in Botswana's Communal Rangelands: Investigation of ENSO cycle for the primary climate variables Across Botswana

El Niño–Southern Oscillation

The El Niño–Southern Oscillation (ENSO) is the natural phenomenon that results from the slowing and enhancing of the surface level trade winds in the Walker circulation and the resulting changes to ocean surface temperatures. The oscillation has significant ramifications for global climate.

- In the El Niño phase, the weakening of the surface level easterly trade winds associated with the low pressure at the equator results in the surface ocean water being pushed less towards the west and rather staying present longer at the equator near the western side of Ecuador and Peru. This warms the ocean surface resulting in a positive temperature anomaly.
- In the La Niña phase, the surface easterly winds of the Walker circulation are enhanced. This results in surface ocean water moving to the west faster than normal, with subsequent upwelling of cold waters along the west coast of South America. Surface temperatures are anomalously cols in this phase.
- The neutral phase is the average of these two states, or where the cohesive influence on or between the ocean and atmosphere is limited or non-existent.

The ENSO phases are shown below with positive Bivariate ENSO Timeseries index values representing the El Niño and negative representing the La Niña phases.

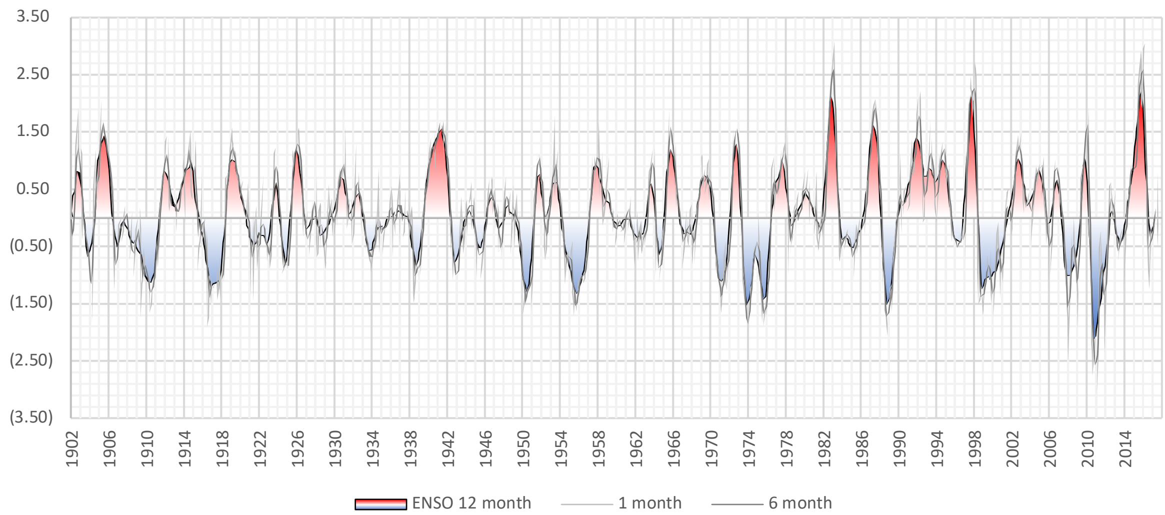

Figure 1. Bivariate ENSO Timeseries combining the SST of Nino 3.4 and the atmospheric Southern Oscillation Index. 1 month, 6 months and 12-month running averages[1]

Notable recent ENSO phases include El Niño years of 1992, 1995, 1998, 2003, 2007, 2010, 2015, and 2016; La Niña years of 1999, 2000, 2008, 2011, and 2012. Other recent years are considered Neutral years.

From a modelling perspective, the future trends in ENSO phase magnitude and frequency are uncertain[2]. The changes noted historically in El Niño phase increasing in strength and frequency have occurred under the significantly warming climate change scenario of the last 100 years, and it is not currently known if these changes to the ENSO phases are as a result of an equilibrium seeking adjustment in the Walker circulation, and therefore likely only to show increases in the initial stages

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[1] Prashant Sardeshmukh and Catherine Smith, Bivariate ENSO Timeseries, https://psl.noaa.gov/people/cathy.smith/best/

[2] Collins, M.; An, S-I; Cai, W.; Ganachaud, A.; Guilyardi, E.; Jin, F-F; Jochum, M.; Lengaigne, M.; Power, S.; Timmermann, A.; Vecchi, G.; Wittenberg, A. (2010). "The impact of global warming on the tropical Pacific Ocean and El Niño". Nature Geoscience. 3 (6): 391–7

of global warming before global temperature plateau, or if this trend will continue if/when this plateau is reached[3]. In the future, it is anticipated that climate change will result in increased sea surface temperature over the Nino 3.4 area. However, it is still unclear as to the future changes in the Walker circulation. As this phenomenon is atmospherically coupled, the changes the in frequency and magnitude of ENSO events remains uncertain[4].

ENSO effects over Botswana

The rainfall over Southern Africa is highly reliant on the moisture availability from the south Indian and Atlantic anticyclones inland towards the convectively driven low-pressure systems. The late summer convective rainfall over southern Africa is driven by the Indian Ocean dynamic anomalies as the source of much of this moisture. Studies[5] indicate the strong influence of the Walker circulation and associated with changes in the ENSO phase on the dynamics of the anticyclones in both the tropical Atlantic and Indian Oceans. there is a strong correlation between ENSO and rainfall variability over southern Africa with rainfall being so heavily dependent on these systems for moisture.

The influence of the Walker circulation during the El Niño phase of ENSO diminishes the advection[6] from the semipermanent anticyclone of southwestern Indian Ocean to Southern Africa resulting in a decrease in moisture availability. This moisture is rather advected to the north. The El Niño phase of ENSO is also noted to decrease the strength of South Atlantic and southern Indian Ocean highs reducing the pressure gradient between these anticyclones and the lower pressures over land created through convective action at the surface. The El Niño phase of ENSO, resulting in warming the Pacific Nino 3.4 area decreases the moisture transport from the oceans to Southern Africa and has been shown to correspond to drought response in Southern Africa. The El Niño phase of ENSO is generally drier in Botswana

The La Niña is generally considered a wet in Botswana thought the deepening of the south Indian and Atlantic anticyclones, increasing the pressure gradient towards the convectively driven low pressure over the heated landmass. The enhancement of advection brings additional moisture to the area resulting in anomalously high precipitation volumes.

The independent analysis undertaken as part of this assessment agrees with the conclusions above. The long-term precipitation anomalies are inversely correlated to the El Niño phase of ENSO. This is clearly evident in the 1990s where the multiple strong El Niño years resulted in decrease precipitation volumes of up to 50mm annually. The opposite is the case in the recent La Niña phase of 2008 – 2014 where there is an annual increase of 30 – 50mm noted.

Over the 116 years of data, 60 years are classified as + ENSO (El Niño), and 56 as – ENSO (La Niña)[7]. Of the El Niño years, ~61% more years show a decrease in precipitation than an increase (37:23). The years are ~27mm drier than normal years and ~21% drier than El Niño years that do show an increase in precipitation. The La Niña years saw ~7% more wet years than dry (29:27). However, these wetter years are ~33mm wetter than normal, and ~78% wetter than the La Niña that do have a decrease in the precipitation.

There is also a strong positive correlation between temperature[8] and ENSO phase. El Niño phase sees 47 out of 60 years showing anonymously (~0.28°C) high temperatures. Conversely La Niña years are cooler 41 of 56 years by ~0.32°C.

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[3] Meehl, G. A.; Teng, H.; Branstator, G. (2006). "Future changes of El Niño in two global coupled climate models". Climate Dynamics. 26 (6): 549–566.
[4] IPCC. 2018. Climate phenomena and their relevance for future regional climate change. Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter14_FINAL.pdf
[5] Nicholson 1997, An analysis of the ENSO signal in the tropical Atlantic and western Indian Oceans. Int. J. Climatol., 17, 345–375
[6] Transport by wind and pressure system
[7] The Neutral years are categories as either El Niño or La Niña to remove any selection bias
[8] When climate change signal is removed though removing the 20-year running average

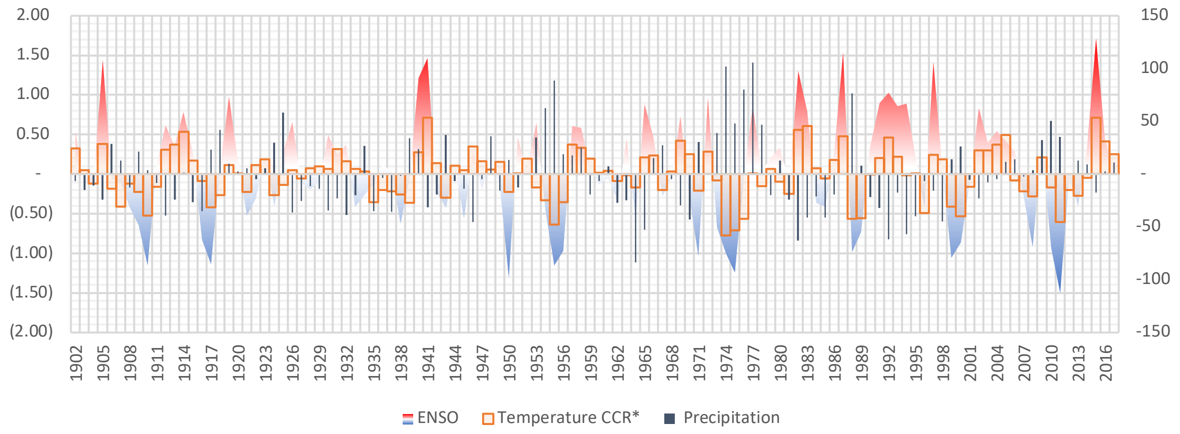
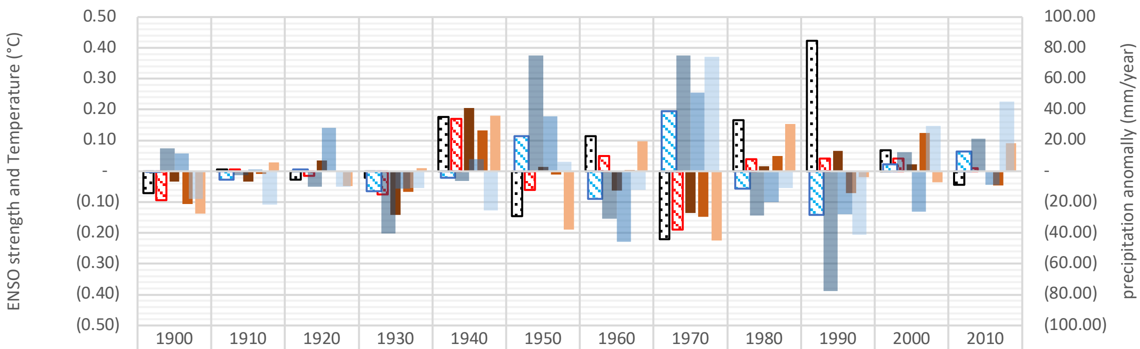


Figure 2. Long term average temperature and precipitation compared to the Bivariate ENSO Timeseries average for all the project sites*[9]

Between each of the study areas, there is little variation in the temperature anomalies in response to the ENSO phase, with the majority of the difference between each of the locations being <0.1°C (see 1970s temperature), with the exception to this being 1950 and 1980s. Precipitation anomalies are more varied. Ngamiland (Average of 703mm/year) has the highest sensitivity to the ENSO phase with the largest inverse correlations (~80mm per year) to ENSO in 1950, 1970, and 1990. Kgalagadi also shows a large inverse correlation to the ENSO phase (see 1970, 1980 and 2010), however, with the low precipitation climatology (Average of 474mm/year) this is likely more significant on the ground.

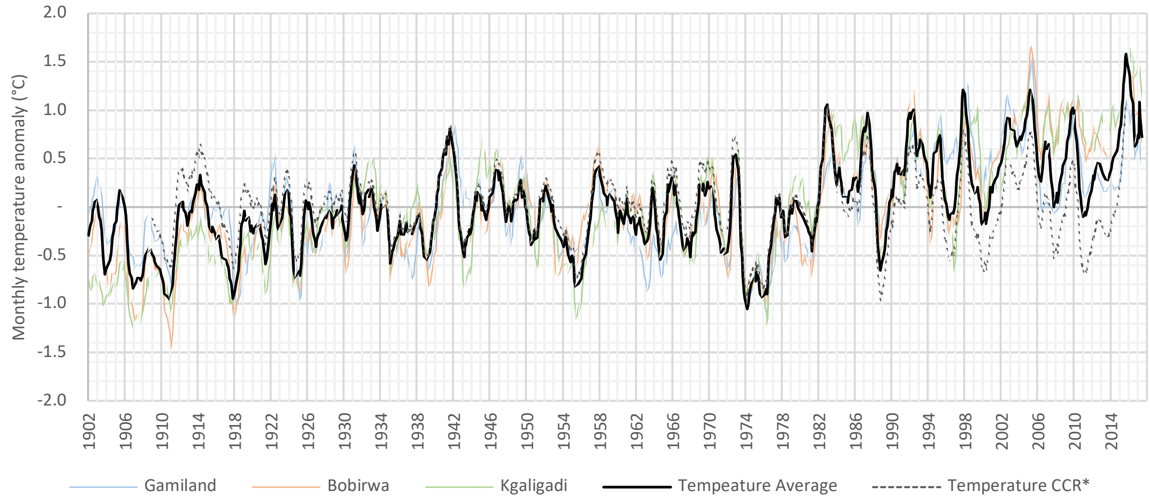


	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
ENSO phase	(0.07)	0.01	(0.03)	(0.02)	0.18	(0.15)	0.11	(0.22)	0.16	0.42	0.07	(0.04)
T all	(0.09)	0.01	(0.01)	(0.07)	0.17	(0.06)	0.05	(0.19)	0.04	0.04	0.04	0.01
T Ngamiland	(0.03)	(0.03)	0.04	(0.14)	0.21	0.01	(0.06)	(0.13)	0.02	0.07	0.02	0.00
T Bobirwa	(0.11)	(0.01)	0.00	(0.07)	0.13	(0.01)	0.00	(0.15)	0.05	(0.07)	0.12	(0.05)
T Kgalagadi	(0.14)	0.03	(0.05)	0.01	0.18	(0.19)	0.10	(0.22)	0.15	(0.02)	(0.04)	0.09
P all	(0.25)	(5.36)	1.11	(13.08)	(4.08)	22.80	(17.88)	38.96	(11.23)	(28.21)	4.58	12.82
P Ngamiland	14.81	(2.54)	(10.20)	(40.49)	(6.30)	75.01	(30.73)	75.01	(28.56)	(77.66)	12.48	21.03
P Bobirwa	11.39	1.06	28.18	(11.35)	7.70	35.69	(45.87)	51.18	(19.91)	(27.91)	(26.11)	(8.84)
P Kgalagadi	(17.72)	(21.66)	(9.90)	(11.04)	(25.23)	6.12	(11.92)	74.42	(10.78)	(41.32)	29.61	45.27

Figure 3. Decadal average temperature (T) and precipitation (P) compared to the Bivariate ENSO Timeseries average for each of the project sites*

[9] *Temperature (climate change single removed - 20-year average)

Further information if needed



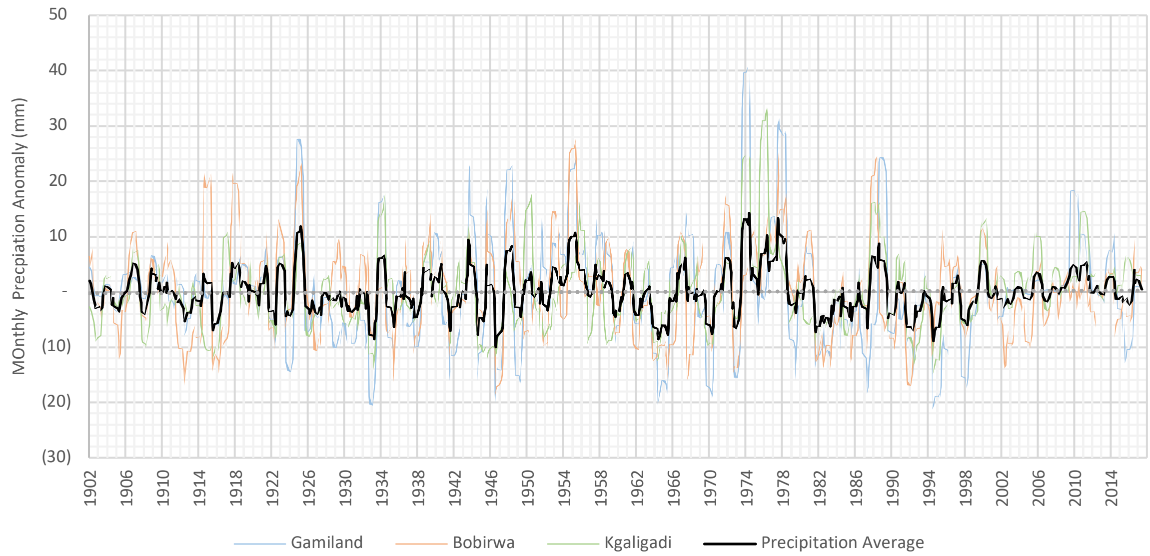


*Figure 4. Long term temperature signal for the three project sites and the average signal. *Temperature (climate change single removed (top). Long term precipitation signal for the three project sites and the average signal (bottom)*[10]

There is a clear long-term temperature trend with increases of ~0.08 per decade from 1902 to 2017. Projections indicate that this will likely be enhanced into the future. The climate change trend is removed from the temperature for analysis with ENSO variation. There is no clear trend in precipitation over time. More important is the inverse correlation with the El Niño.

Botswana study: Climate trends a key to public health plans- The results suggest that the cooler temperatures, increased rainfall, and flooding associated with La Niña years add up to about a 30 percent rise in the number of childhood diarrhoea cases between December and February.

[10] Climatic Research Unit, University of East Anglia. Climate data v4.01