Undergraduate

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Title: Spatio-Temporal Variability of Precipitation in the Limpopo River Basin (1984–2023)

Abstract: The rise in global temperatures driven by climate change is intensifying the hydrological cycle, leading to a dangerous loop of prolonged droughts and extreme precipitation. This study focuses on the Limpopo River hydrographic basin, a transboundary basin of approximately 415,000 km^2, shared by South Africa (45%), Botswana (20%), Mozambique (21%), and Zimbabwe (14%). The predominantly semi-arid region faces increasing climatic pressures that threaten the water and food security of its 14 million inhabitants, 90% of whom depend on rain-fed agriculture. The degradation of monitoring networks, such as the 68% reduction in South African rain gauges since the 1970s, hinders the prediction of extreme events and adaptive management. In the context of recurrent cyclones (Dineo-2017 and Eloise-2021) and droughts intensified by the 2023–2024 El Niño, analysing rainfall variability is crucial for developing effective resilience policies. This research used data from Mozambique's National Institute of Meteorology, the National Aeronautics and Space Administration, the Global Runoff Data Centre, and the HydroSHEDS system for the period from 1984 to 2023. All analyses were conducted in the R/RStudio environment (version 4.3.2) at a 5% significance level. Precipitation was estimated using ordinary kriging, validated by leave-one-out cross-validation. The seasonal autoregressive integrated moving average model was fitted to the time series and validated using (partial) autocorrelation plots, the Ljung–Box test, and the Akaike information criterion. The precipitation projections for 2024–2033, generated using the SARIMA model, included 95% confidence intervals. The results indicated a rainfall regime characterised by high variability, with a well-defined rainy season from October to April and a heterogeneous spatial distribution, where eastern areas consistently receive significantly higher precipitation. The most recent period (2019–2023) recorded the highest volume and greatest variability, suggesting an intensification of extreme events. Future projections indicate the continuation of this high volatility, without a clear trend of increasing or decreasing average precipitation. It is concluded that the basin operates under a cycle of climatic extremes, requiring resilient water and agricultural management strategies, enhanced early warning systems, and solid transboundary cooperation among the four sharing countries to ensure food and water security.

Keywords: Climate change; spatio-temporal rainfall variability; Limpopo River hydrographic basin; water security; SARIMA.