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Potential Impacts of Climate Change on Hydrological Droughts in the Limpopo River Basin

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Abstract : Climate change possibly intensifies hydrological droughts and reduces water availability in river basins. Despite this, most research on climate change effects in southern Africa has focused exclusively on meteorological droughts. This thesis projects the potential impact of climate change on the future characteristics of hydrological droughts in the Limpopo River Basin (LRB). The study uses regional climate model (RCM) measurements (from the Coordinated Regional Climate Downscaling Experiment, CORDEX) and a combination of hydrological simulations (using the Soil and Water Assessment Tool Plus model, SWAT+) to predict the impacts at four global warming levels (GWLs: 1.5℃, 2.0℃, 2.5℃, and 3.0℃) under the RCP8.5 future climate scenario. The SWAT+ model was calibrated and validated with a streamflow dataset observed over the basin, and the sensitivity of model parameters was investigated. The performance of the SWAT+LRB model was verified using the Nash-Sutcliffe efficiency (NSE), Percent Bias (PBIAS), Root Mean Square Error (RMSE), and coefficient of determination (R^2). The Standardized Precipitation Evapotranspiration Index (SPEI) and the Standardized Precipitation Index (SPI) have been used to detect meteorological droughts. The Soil Water Index (SSI) has been used to define agricultural drought, while the Water Yield Drought Index (WYLDI), the Surface Run-off Index (SRI), and the Streamflow Index (SFI) have been used to characterise hydrological drought. The performance of the SWAT+ model simulations over LRB is sensitive to the parameters CN2 (initial SCS runoff curve number for moisture condition II) and ESCO (soil evaporation compensation factor). The best simulation generally performed better during the calibration period than the validation period. In calibration and validation periods, NSE is ≤ 0.8, while PBIAS is ≥ □80.3%, RMSE ≥ 11.2 m^3/s, and R^2 ≤ 0.9. The simulations project a future increase in temperature and potential evapotranspiration over the basin, but they do not project a significant future trend in precipitation and hydrological variables. However, the spatial distribution of precipitation reveals a projected increase in precipitation in the southern part of the basin and a decline in the northern part of the basin, with the region of reduced precipitation projected to increase with GWLs. A decrease in all hydrological variables is projected over most parts of the basin, especially over the eastern part of the basin. The simulations predict meteorological droughts (i.e., SPEI and SPI), agricultural droughts (i.e., SSI), and hydrological droughts (i.e., WYLDI, SRI) would become more intense and severe across the basin. SPEI-drought has a greater magnitude of increase than SPI-drought, and agricultural and hydrological droughts have a magnitude of increase between the two. As a result, this research suggests that future hydrological droughts over the LRB could be more severe than the SPI-drought projection predicts but less severe than the SPEI-drought projection. This research can be used to mitigate the effects of potential climate change on basin hydrological drought.

Keywords : climate change, CORDEX, drought, hydrological modelling, Limpopo River Basin
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