Assessing Hydrological Extremes and Their Implications for Water Resources in the Gaborone Dam Catchment (Oral)

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ABSTRACT

Semi-arid regions in Southern Africa are increasingly characterized by amplified hydrological extremes, with climate variability driving more frequent transitions between severe droughts and intense flooding events. This poses significant challenges for sustainable water resource management. This study investigates hydro-climatic drivers of extremes and their implications for water security in the Gaborone Dam catchment, the primary water source for Botswana's capital city. The analysis utilized daily CHIRPS (Climate Hazards Group InfraRed Precipitation with Station) for the period 1981–2025. Key extreme rainfall indicators (RX1day, RX5day, R10mm, R20mm, R95pTOT, and PRCPTOT) were computed, while multi-timescale Standardized Precipitation Index (SPI-3, SPI-6 & SPI-12) values were calculated to characterize drought dynamics. Rainfall variability was quantified using the coefficient of variation (CV) at annual and seasonal scales. Trends were assessed using the non-parametric Mann-Kendall test and Sen's slope estimator. Catchment-averaged rainfall was then linked to historical Gaborone Dam Water level records to evaluate hydrological responses. The 45-year record captures pronounced drought-flood cycles, including the severe 2013–2016 meteorological drought when Gaborone dam levels fell below 2% capacity, triggering water rationing and supply disruptions for Greater Gaborone. This was followed by a dramatic recovery in the 2016/17 wet season associated with Tropical Cyclone *Dineo,* which raised dam levels to approximately 87-91% capacity within a short period. Results indicate no significant monotonic trend in annual rainfall totals (PRCPTOT), yet inter-annual variability has intensified, with the CV increasing by about 25%. Statistically significant increases in dry spell durations were observed during the wet season ($p < 0.05$), with more frequent and prolonged dry periods interspersed with intense wet events. Extreme rainfall indices (e.g., RX5day and R95pTOT) displayed sharp peaks during major flood events but no significant upward trends, suggesting increased hydrological unpredictability and volatility, rather than consistent intensification of extremes characterize the current hydro-climatic regime. Dam storage dynamics reveal that meaningful water level recoveries typically require multiple consecutive above rainfall years, while single extreme flood events, although effective for rapid replenishment, can mobilize contaminants from urban and agricultural runoff, raising water quality concerns during recession flows. Rapid urbanization and population growth further exacerbate vulnerabilities by increasing water demand and altering land cover within the catchment, reducing natural buffering capacity. The findings highlight that climate change in semi-arid Southern African hydrological systems primarily manifests through amplified hydrological volatility and frequent "drought-flood seesaws", rather than simple directional shifts in mean rainfall. This creates growing operational uncertainty for the Gaborone Dam system, as existing infrastructure was designed under assumptions of historical climatic stationarity. Key management implications include the adoption of adaptive, climate-resilient strategies such as enhanced early-warning systems, dynamic dam operating rules that incorporate uncertainty, conjunctive surface-groundwater use, nature-based solutions for catchment restoration, and proactive water quality protection during flood-driven recharge events. This research offers valuable long-term, catchment-specific empirical evidence to inform climate adaptation planning and Integrated Water Resources Management (IWRM) in semi-arid river systems facing escalating hydro-climatic risks.

Keywords: Hydrological extremes, Gaborone Dam, drought dynamics, rainfall variability, climate change adaptation.