

# Hydrological Resilience in River Systems: Rethinking Rainfall–Flood Linkages in the Zambezi Basin

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## ABSTRACT

River systems are increasingly exposed to hydrological variability under a changing climate, raising critical questions about the extent to which rainfall governs flood dynamics in river–floodplain systems. Hydrological variability is a defining characteristic of river–floodplain systems and plays a central role in regulating ecosystem processes, water availability, and flood risk. In large tropical basins such as the Zambezi, rainfall variability is often assumed to directly influence flood regimes; however, the extent to which precipitation variability translates into discharge variability remains uncertain. Recent studies have shown that streamflow sensitivity to precipitation varies significantly across basins and is strongly influenced by storage processes, basin size, and hydrogeomorphic characteristics. In floodplain systems, hydrological connectivity and groundwater interactions may dampen climatic signals, resulting in decoupled rainfall–discharge relationships. The Zambezi floodplain is one of Africa’s largest wetland systems, yet its hydrological response to long-term rainfall variability remains insufficiently quantified. This study investigates the hydrological resilience of the Zambezi River–floodplain by re-evaluating the strength of rainfall–flood linkages over a historical 50-year period (1965–2014) using observed hydro-meteorological data from the Chavuma gauge station on the Zambezi River. We hypothesise that floodplain discharge exhibits limited sensitivity to rainfall variability due to basin-scale buffering processes. A suite of statistical variability metrics, spectral analysis, flow duration curves, and precipitation elasticity of streamflow is used to characterise the flood dynamics. Results indicate substantial inter-annual variability in discharge (coefficient of variation = 0.21), presence of a dominant decadal periodicity (~10 years), a regulated flow regime with sustained moderate flows and attenuated extremes (from the shape of the flow duration curve), and a low precipitation elasticity of streamflow ( $\epsilon = 0.03$ ). The observed quasi-decadal periodicity further suggests that large-scale climate drivers may modulate hydrological behaviour. The flow duration curve indicates that high flows occur over relatively short durations, reflecting a propensity for seasonal flooding, while moderate flows are sustained over longer periods. Low flows exhibit a steep decline, indicating limited baseflow contributions during dry periods. Despite observable correspondence between rainfall and discharge fluctuations, the estimated precipitation elasticity of streamflow suggests weak sensitivity of floodplain hydrology to rainfall variability. These findings imply that basin-scale storage processes and hydrological buffering moderate the propagation of climatic signals into river discharge, indicating the hydrological resilience of the Zambezi river–floodplain system. Importantly, the findings also challenge the conventional assumption of direct rainfall–runoff relationship in large river systems. This has broader implications for hydrological understanding and water resources management across African river basins. Thus, hydrological models should incorporate basin-scale buffering processes rather than relying solely on rainfall–runoff relationships; and flood prediction frameworks need to account for delayed and non-linear system responses. Furthermore, climate adaptation strategies should consider the inherent resilience of floodplain systems while recognizing potential thresholds beyond which this resilience may be compromised. Therefore, river basin management approaches essential to sustaining ecosystem services and livelihoods should integrate catchment-scale controls in order to better inform adaptive water resources management, floodplain conservation, and climate resilience strategies across the continent.

**Keywords:** Hydrological resilience; Floodplains; Zambezi River