Vegetation Loss and Response to Hydrological Drought on the Islands of the Congo River (Oral)

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ABSTRACT

Floodplain vegetation in large tropical river systems is strongly regulated by hydrological connectivity, with seasonal fluctuations in river stage controlling soil moisture availability and ecological functioning. Despite the geomorphological stability of vegetated islands within the Congo River, the vulnerability of these systems to extreme hydroclimatic events remains poorly understood. This study investigates vegetation responses to a hydrological drought across approximately 800 islands (~1,000 km²) along a ~400 km reach of the middle Congo River.

Hydrometeorological conditions were characterised using CHIRPS precipitation data, ERA5-Land temperature and evaporation, and HydroWeb satellite altimetry-derived water surface elevation (WSE). Drought severity was assessed using the Standardised Precipitation Evapotranspiration Index (SPEI-3), consecutive dry days (CDD), and warm day frequency (WDF). Vegetation condition and change were quantified using Sentinel-2 Level-2A imagery through spectral indices (NDVI, NDMI) and supervised Random Forest land cover classification. Structural controls on vulnerability were evaluated using a 10 m canopy height dataset, stratifying vegetation into three classes (<1 m, 1–10 m, >10 m), and analysed along a longitudinal rainfall gradient.

Results show that the 2024 event originated as a meteorological drought, with persistent precipitation deficits (mean $z = -0.92$) and extreme temperatures (mean $z = 2.79$), before propagating into a hydrological drought as reduced upstream discharge caused river stage to fall below baseline from June onward. Peak dry-season WSE anomalies reached approximately −0.6 to −0.7 m across the study reach. Vegetation decline closely coincided with this reduction in river stage, indicating that drought impacts were mediated through diminished hydrological connectivity between the river and floodplain islands.

Spectral analysis revealed substantial vegetation stress, with NDMI medians declining from 0.28 (2020) to 0.13 (2024) and NDVI from 0.70 to 0.58, indicating widespread canopy drying and reduced photosynthetic activity. Land cover classification showed a marked reduction in vegetated extent from 92.74% to 65.23%, corresponding to a net loss of 27.51% of vegetated island area. Vegetation loss exhibited strong spatial heterogeneity, increasing downstream in association with declining rainfall. Mean vegetation cover declined by 10.9% upstream, 26.6% midstream, and 51.0% downstream, with the most severe losses (50–60%) confined to the driest reaches.

Vegetation structure strongly mediated drought vulnerability. Short-stature vegetation (<1 m) accounted for 93% of total vegetation loss and experienced substantially higher proportional decline (43.45%) compared to taller vegetation classes. Even under comparable rainfall conditions, shorter vegetation remained disproportionately vulnerable, consistent with shallow rooting depth and limited access to subsurface moisture. In contrast, tall vegetation (>10 m) exhibited minimal decline (<1%), indicating greater resistance to drought stress.

These findings demonstrate that drought impacts in the Congo River floodplain are governed by the interaction between hydroclimatic forcing and vegetation structure. While precipitation gradients control the spatial severity of drought, canopy height modulates ecosystem sensitivity to declining water availability. Repeated drought-driven vegetation loss may weaken eco-geomorphological feedbacks that stabilise river islands, increasing their susceptibility to future erosion.

Keywords: Hydrological Drought; Vegetation Dynamics; Remote Sensing