Sand Dams in Semi-Arid Regions: A Multi-Sensor Remote Sensing Perspective on Hydrological and Ecological Impacts (Oral)

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ABSTRACT

Sand dams are low-cost water harvesting structures increasingly recognized as a promising climate adaptation measure in semi-arid regions. Constructed in ephemeral riverbeds, they retain sediment and store subsurface water, improving local water security and landscape resilience. Despite their growing adoption across sub-Saharan Africa, the environmental impacts of sand dams remain incompletely understood, particularly at the landscape scale and across multiple Earth system components. This study presents a comprehensive, multi-sensor remote sensing assessment of sand dam impacts in the Kanthuni Valley, Makueni County, Kenya, a study area hosting 17 sand dams along 13 km of an ephemeral river.

Our research group has systematically investigated this site across five complementary dimensions. First, long-term vegetation dynamics were assessed using Landsat (5, 7, 8) NDVI time series (2000–2019) processed in Google Earth Engine, revealing a significant greening trend within 500 m of the river following dam maturation, confirmed by Mann-Kendall trend analysis. A large-scale extension of this approach covering 351 sand dams across Kenya, Tanzania, Zimbabwe, and Eswatini corroborated these findings, while also identifying regional contrasts and demonstrating that SAVI outperforms NDVI in sparse vegetation environments. Second, land surface temperature trends were derived from Landsat thermal imagery (2010–2024) using a statistical mono-window approach and decomposed with the DBEST algorithm, showing a general cooling signal of 1.5–3.5 K in vegetated areas, with latent heat flux identified as the dominant driver. Third, a semantic Earth observation workflow combining SIAM-classified Sentinel-2 and Landsat 8 data was evaluated for automated, reproducible land cover monitoring, demonstrating scalable vegetation dynamics analysis over a ten-year period. Fourth, surface deformation patterns were quantified using Sentinel-1 Small Baseline Subset (SBAS) InSAR analysis (2015–2025), providing novel insights into sediment dynamics and geomorphological stabilization effects along the dam cascade. Fifth, a SWAT+ hydrological model characterized the catchment water balance, identifying baseflow as the dominant streamflow component (70%) and highlighting the critical role of slow percolation pathways — the very mechanism sand dams are designed to enhance.

Together, these studies establish a multi-scale, multi-sensor monitoring framework that integrates optical, thermal, SAR, and process-based modelling approaches to comprehensively characterize the hydrological and ecological footprint of sand dams. Our findings confirm sand dams as effective landscape interventions, while identifying key site-specific dependencies and methodological pathways for large-scale transferability across African drylands.

Keywords: Sand Dams, Remote Sensing, Time Series Analysis, Semi-Arid Hydrology, Climate Adaptation