Integrating machine learning and traditional ecological knowledge to map wetland dynamics in wet-dry tropics of Australia

Abstract

Wetlands are critical ecosystems offering significant ecological, cultural, and socioeconomic services. In wet-dry tropical regions, particularly Northern Australia, wetlands face increasing pressures from climate change and anthropogenic activities. The Northern Territory contains largely pristine rainfed, river-fed, and groundwater-fed wetlands, yet they remain understudied due to their complexity, remoteness, and limited historical mapping, with the last major update in 2005. This study investigates wetland dynamics within the Daly River catchment, Northern Territory, integrating Random Forest classification with Traditional Ecological Knowledge (TEK). Time-series analysis from 2017 to 2024 was conducted using Sentinel-2 optical imagery and Sentinel-1 synthetic aperture radar (SAR) data at a 10 m spatial resolution. A range of water, soil, vegetation, and topographic indices (including HAND, slope, and elevation) were incorporated alongside TEK on seasonal wetland dynamics from Indigenous Rangers. The analysis identified seven primary wetland classes - Water, Grass sedge swamp, Forested swamp, Floodplains, Floodplains woodland, Mangroves, and Riparian vegetation - with a cumulative total wetland area increase of approximately 32% since 2017. Observed changes are likely associated with climatic variables such as rainfall variability, rising temperatures, and evaporation rates. Classification accuracy was high across all periods, with overall accuracies of 98% (Kappa 0.97) for 2017–2018, 97% (Kappa 0.96) for 2020–2021, and 98% (Kappa 0.98) for 2023–2024, validated using field observations and TEK. This research demonstrates the value of combining advanced remote sensing techniques with Indigenous Knowledge, providing a replicable model for wetland monitoring and management in tropical regions worldwide.