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Mapping groundwater-dependent ecosystems using a phenology matrix and fine-scale remote sensing data

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Abstract: A groundwater-dependent ecosystem (GDE) relies on groundwater for its persistence, condition or for some of its life history cycle. Such ecosystems, including vegetation communities and stygofauna are critically linked to crucial components of the hydrological cycle, and can also play a pivotal role in replenishing groundwater reserves and regulating surface water flows. Furthermore, GDEs can serve as natural water storage systems, thereby acting as a buffer against water-related stressors such as droughts or seasonal variability. However, locating and monitoring changes in GDEs poses significant challenges. Remote sensing is a key tool to map GDEs over large areas and provide a comprehensive view of their distribution, extent and condition, particularly for mapping groundwater dependent vegetation. Due to image spatial and temporal resolution, remote sensing techniques have difficulty in distinguishing between GDEs and non-GDEs, especially in areas with shallow groundwater where vegetation can be highly variable. Here we develop a GDE map of vegetation with 20 meters spatial resolution for the Victoria River catchment in Australia's Northern Territory. Vegetation exhibiting characteristics of prolonged greenness over the summer dry season with low inter-annual variability is interpreted as GDE by extracting and analyzing a phenology matrix of enhanced vegetation index (EVI) and normalized difference water index (NDWI) time-series (2016-present) from Sentinel-2. A data fusion method was implemented to optimize EVI and NDWI maps. Qualitative field surveys of GDEs were used to validate the outputs, revealing that all GDE and non-GDE sites were successfully classified. Additionally, an evapotranspiration (ET) dataset was applied to examine water transfers out of both identified GDE and non-GDE areas. Results indicated that more water was being transferred from the ground and vegetation to the atmosphere from GDE areas. Evapotranspiration in non-GDE areas varied by 55% over the past 20 years, while ET in GDE areas exhibited only a 15% variation, suggesting non-GDE areas demonstrate higher inter-annual variability of ET than GDE areas. This study provides a useful tool for GDE mapping, allowing further analysis of groundwater recharge, and provides tools to support biodiversity conservation, and groundwater management for regional scale.

Keywords: *GDE, Sentinel-2, EVI, NDWI, evapotranspiration, water management*