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Assessing sun-induced fluorescence capability for detecting water stress responses in arid vegetation groundwater dependent ecosystems

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Abstract: Arid vegetation groundwater dependent ecosystems (GDEs) rely heavily on groundwater for survival during dry periods and serve as buffer zones that help local environments withstand extreme events (Doody et al., 2017; Eamus & Froend, 2006). Under projected climate instability, understanding the ecological functions of arid GDEs and their physiological responses to water stress has become increasingly critical. Monitoring vegetation photosynthetic activity is fundamental to assessing GDE water stress responses. Traditional vegetation indices typically exhibit temporal lags in reflecting vegetation stress. With advances in remote sensing technology, sun-induced chlorophyll fluorescence (SIF) can now be monitored from space. SIF signals emitted during plant photosynthetic activity, particularly in the far-red band (720–760 nm), have demonstrated outstanding performance in detecting canopy stress in near real-time (Mohammed et al., 2019). Despite this potential, SIF applications for monitoring GDE responses to water scarcity in arid environments remain unexplored. This study focuses on the Victoria catchment in northern Australia, which exhibits a unique seasonal precipitation pattern with nearly no rainfall during the Austral dry season (June-August). This provides an ideal temporal window for studying GDE water use by isolating the effects of rainfall. Satellite-derived SIF data was used to monitor seasonal GDE responses to water availability in the Victoria catchment at monthly scale. Groundwater depth measurements and the Budyko framework were integrated to establish quantitative relationships between water stress indicators and GDE photosynthetic activity. Additionally, SIF's capability for revealing GDE water stress was compared with traditional vegetation indices to demonstrate SIF's superior performance in reflecting canopy stress. This research elucidates the relationships between arid GDE photosynthetic dynamics and groundwater availability, while demonstrating the potential of advanced remote sensing technologies for developing robust indicators of GDE water usage and ecosystem stress. Our results contribute to an improved understanding of dryland ecosystem responses to water availability and provide a foundation for enhanced GDE monitoring and management strategies.

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