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Identifying groundwater-dependent vegetation in arid zone Australia using imagery time series and singular value decomposition

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Abstract: Groundwater resources sustain life in Australia's Northern Territory providing over 90% of community water supply needs. In the Top End, terrestrial ecosystems have evolved to survive monsoonal wet conditions followed by 6-8 months of drought when aquatic ecosystems rely upon groundwater discharge for river and spring flows. In the Arid Zone, groundwater is the sole source of water for many terrestrial ecosystems and maintain waterholes and springs during extended periods of drought.

Terrestrial groundwater-dependent ecosystems (GDEs) are difficult to identify due to logistical challenges in accessing the vast area and remoteness of the Australian interior, and the expense of reaching areas for field surveys. Remotely sensed imagery provides cost effective and reasonably detailed vegetation cover information, but has mixed results in identifying GDEs in the Arid Zone. Most existing methods for identifying potential groundwater dependency involve direct comparison of selected vegetation imagery (NDVI or similar green vegetation indices) in conditions of high and low rainfall. While this approach is straightforward in areas that have distinct and predictable wet and dry seasons, applying this to the Arid Zone can be more challenging. Central Australian deserts typically vary between states of prolonged dry periods with most vegetation near dormancy, punctuated by brief pulses of high rainfall and intense vegetation growth. These wet periods occur at irregular intervals of months or years, and have highly variable magnitudes. In principle, vegetation using groundwater will stay green and active during periods when surrounding rain-fed vegetation would dry out, making it easily distinguishable. In practice, the variability in both timing and scale of these pulses can obscure signals and responses of wet vs. dry conditions, making patterns hard to detect.

We describe a technique which addresses this issue by considering a time series of all pixels in a set of imagery simultaneously. By subjecting a data cube to matrix decomposition (Singular Value Decomposition, SVD) we examine all sources of variation, and distinguish categories according to different kinds of variation. When the dominant source of variation in vegetation over time is driven by rainfall, as is overwhelmingly the case throughout arid central Australia, we can identify vegetation that deviates from that behaviour as vegetation using something besides rainwater. Field measurements or other independent validation is still required to ascertain whether groundwater is involved.

SVD is widely used in machine learning, and is a central calculation for Principal Component Analysis. It breaks an input matrix into two eigenvector matrices which isolate and describe the greatest sources of variation in the input matrix (one spatial and one temporal), and a diagonal eigenvalue matrix that describes the relative importance of each eigenvector set. The eigenvector values themselves can aid in mapping landscape characteristics and hypothesis generation; quantitative treatment of the values helps identify features. We present interpretations of these eigenvector values to determine vegetation characteristics that indicate groundwater dependency, including logistic regression of eigenvector values to known vegetation characteristics on the ground (preferable when sufficient field data exist) and cluster analysis and supervised classification when less field data are available.

Keywords: *Groundwater dependent vegetation, singular value decomposition, imagery time series*