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Performance of Sentinel-2 NDVI for assessing the relationship between vegetation and soil moisture under extreme drought conditions

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Initial indications are that the enhanced spatial and spectral resolution of Sentinel-2 would allow for better assessment of vegetation condition, and consequently improved application in conditions of moisture deficit/drought. Although NDVI and other indices are well established methods in drought monitoring, particularly at larger scales, little research has examined the suitability of Sentinel-2. While the utility of Landsat-8 NDVI in revealing local scale plant-soil dynamics has been explored, challenges around resolution have emerged. The principal aim of this study was to determine the extent to which NDVI time series reflects soil moisture conditions, and whether this offers an improvement over Landsat-8. On the basis of exposure to drought over the study period (Jul 2015-Mar 2017), availability of cloud-free imagery and measured soil moisture, five sites in South-Western United States were selected. These sites, normally dry to arid, were classified as being in various states of drought, but in general this represented extension and recession of a significant drought event. A secondary focus of the paper therefore was the performance of Sentinel-2 NDVI under extreme conditions. As far as we are aware, this represents the first study of this kind using Sentinel-2.

Following supervised classification, NDVI time series for areas of 1km radius around the monitoring stations were calculated. Sentinel-2 NDVI variants were calculated using Bands 8 (10m), 5, 6, 7, and 8A (20m). Landsat-8 NDVI was calculated at 30m resolution. Pearson correlation analysis was undertaken of all NDVI time series against soil moisture at all measured soil depths. In order to assess the difference in correlation strength produced from using the Sentinel-2 red-edge bands, compared to the standard NIR band, a principal component analysis (PCA) was conducted. This was performed on the combination of all Sentinel-2 bands and the combination of the red-edge bands. Performance of the Sentinel-2 red-edge NDVI time series against the standard NIR band was also evaluated using a Steiger comparison test.

While no significant correlations between Landsat-8 NDVI and measured soil moisture were found, high significant correlations were present between moisture at depths of <30cm and Sentinel-2 NDVI at three sites. No significant positive correlations were found at two sites, despite similar conditions to the others. These sites were characterised by much lower vegetation cover, suggesting a minimum cover threshold of ≈30-40% is required. The PCA shows that at all sites of significant positive moisture-NDVI correlations, the linear combination of the red-edge bands produced stronger correlations than the poorer spectral, but higher spatial resolution band. NDVI calculated using the higher spectral resolution bands may therefore be of greater use in this context than the higher spatial resolution option. However, each site/measurement with a relationship present also had an individual component which out-performed the PCA combination, most likely related to the spectral characteristics of local vegetation. These results suggest high potential for the application of Sentinel-2 NDVI in drought monitoring, even in extreme environments, thus allowing us to further our understanding of local scale plant-soil dynamics under such conditions.