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Multi-scale phenology from digital time-lapse camera to Sentinel-2 and MODIS over Australian pastures

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As a natural ecosystem dominated by grasses, phenological studies of pastures have attracted increased attention for their important roles in global carbon cycling, ecosystem biodiversity, and public health. To better understand pasture phenology from in-situ to regional scales, accurate monitoring of pasture greenness variations across different scales is critical. As an alternative approach to labor-intensive field surveys, digital time-lapse cameras (termed phenocams) can provide diurnal and long-term vegetation greenness observation at in-situ scale with less impact from atmospheric effects. Even so, monitoring of phenology at regional to global scales only can be obtained by satellite remote sensing. The data from satellite sensors whether medium-resolution (i.e. Moderate Resolution Imaging Spectrodiometer, MODIS, 250 m) or fine spatial resolution (i.e. Sentinel-2 mission, 10 m) is widely used for vegetation phenology monitoring. However, achieving accurate pasture greenness dynamics using satellite data remains challenging due to limitations resulting from heterogeneity in Australian pastures.

Combining phenocam, Sentinel-2 data and MODIS land surface products, this study aimed to (1) compare differences in temporal profiles of pasture greenness derived from ground-based phenocam and satellite sensors with fine- and medium-spatial resolutions, respectively; (2) assess the capacity of Sentinel-2 pixels for representing the phenocam footprint for monitoring greenness dynamics; and (3) evaluate the potential of improving greenness upscaling from phenocam to MODIS by masking non-grass areas via Sentinel-2 data.

A set of RGB phenocams was deployed over sites located over eastern Australian pastures. Green chromatic coordinate (GCC) was calculated from phenocam images. Six spatial footprints centered at phenocam sites were defined (i.e. 10 m, 30 m, 90 m, 250 m, 750 m and 1250 m), in which the Enhanced Vegetation Index (EVI) was calculated from Sentinel-2 and MODIS. The correlations between phenocam GCC and Sentinel-2 EVI were analyzed at single and multiple sites within the phenocam footprint (< 100 m) across all phenophases. Similarly, the correlations between GCC and EVI derived from Sentinel-2 and MODIS were analyzed for larger scales (> 100 m). Finally, we analyzed the relationships between GCC and MODIS EVI derived after applying a Sentinel-2 grass mask.

First, generally consistent temporal patterns of GCC and EVI were found at all spatial scales and phenophases, though there were differences at larger scales. Second, relationships between GCC and Sentinel-2 EVI within the phenocam footprint (< 100 m) kept nearly consistent regression trends and significant correlations whether from single or multiple sites, but decreasing at scales beyond 100 m. Third, correlations between GCC and MODIS EVI were similar to Sentinel-2 EVI at the same scales (< 100 m). However, at > 250 m scale, EVI derived from Sentinel-2 non-grass filtered data improved the correlation with GCC compared with EVI from all Sentinel-2 pixels and MODIS pixels. Our results indicate that Sentinel-2 can enable retrieval of grass pasture phenology in heterogeneous landscapes with higher accuracy compared with MODIS, and demonstrated the potential of Sentinel-2 data as a land cover filter to improve phenocam upscaling to MODIS.