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Using high-resolution UAV spectral images to disentangle soil, shade, and tree contributions to satellite vegetation indices in sparse dry forests

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Remote sensing (RS) techniques have great potentials for earth surface monitoring. Nevertheless, for most low to moderate resolution satellites, the problem of mixed pixels with information from the vegetation of interest and the background surfaces can cause large biases in signals and also in their interpretations. This is especially so in low-density forests and semi-arid ecosystems. Ground-level multispectral instruments reduce these effects by measuring at close range to the canopy. However, little work has been published on partitioning the contributions from vegetation and the background elements for both approaches.

This work was motivated by the observed mismatch between data for the same ecosystem from Landsat 8 satellite and Skye radiometer installed on a flux tower in a low-density semi-arid pine forest from 2013-2019. Data from both sources showed similar seasonal patterns in NDVI, but large differences in the reflectance bands. This was most prominent in the NIR reflectance, which showed an opposite seasonal cycle in the two sensors. Thus, similar changes in NDVI were produced by different signals. We hypothesized that the different contributions of the surface components (canopy, shaded areas, and exposed soil) in the footprint areas of the two sensors can explain, and can help correct, these differences.

Multispectral images with a spatial resolution of 5 cm were captured monthly using an Unmanned Aerial Vehicle (UAV) from April 2018 to November 2019. Reflectance-based algorithms were developed to identify and estimate the fraction and reflectance from the canopy, shaded areas, and open soil. This information was, in turn, applied in the equivalent nadir-viewing satellite pixel. For the tower-based Skye footprint, the same quantities were calculated from its 90° angle of view and the 3D canopy data.

The results showed a canopy fraction of 45% and 95% in the Landsat 8 and Skye footprints. The remaining soil fraction showed a similar seasonal cycle in NDVI as the canopy, but different in the NIR reflectance. The partition between exposed and shaded soil was related to the sun angle, with the exposed soil having a NIR seasonal cycle opposite to that of the vegetation (correlating with soil moisture), and shaded soil having a weak NIR signal variably diluting the overall pixel NIR signal. Differences in the red reflectance were smaller with less effects on the seasonal NDVI cycles.

The results demonstrated firstly, that accounting for the fractional contributions of the surface components can reconcile differences between satellite and ground-based RS. Secondly, vegetation indices such as NDVI obtained by satellite RS in low-density forests can provide misleading information, despite its apparent correlation with certain vegetation variables.