Improving Irrigation Management with Remotely Sensed Images from Satellite and Drones

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Irrigation accounts for 80% of human freshwater consumption, and most of it returns to the atmosphere through evapotranspiration (ET). Given the challenges of already-stressed water resources and groundwater regulation in California, timely information on evapotranspiration (ET), a dominant component of crop consumptive water use, with known uncertainty is critical for growers to tailor irrigation management based on in-field spatial variability and in-season variation. We developed a semi-empirical Priestley-Taylor (PT) approach to estimate daily ET at a 30m resolution in California's agricultural lands. Daily net radiation was estimated mostly from Landsat satellite multispectral and thermal observations. MODIS Terra and Aqua land surface temperature (LST) products were combined to improve the outgoing longwave radiation estimate. The partitioning of available energy to latent heat, represented by the PT coefficient, was parameterized as a function of leaf area index and normalized moisture index derived from Landsat imagery. We optimized the PT coefficients for each crop type with available ET measurements from eddy covariance towers or surface renewal stations for seven crop types (alfalfa, almond, citrus, corn, pasture, pistachio, and rice) in California. A generalized PT optimization was also done for the rest of crops where no field data was available.

Good agreement was found between satellite-based estimates and field measurements of net radiation with a R^2 of 0.83 and RMSE of 26.2 Wm^{-2}. Daily ET estimates from the PT approach optimized with 70% of the field data agreed well with the measured ET ($R^2 = 0.84$), and the RMSE of the estimated daily ET was less than 1.3 mm/day during Landsat overpassing dates and 1.5 mm/day when comparing with the 30% of field data. We applied the calibrated algorithm to the Sacramento-San Joaquin Delta region to map ET for the 2015 and 2016 water year. It captured the seasonal dynamics and spatial distribution of ET well in the region. Our study demonstrated that the semi-empirical PT approach, calibrated with ground measurements and driven by satellite observations, shows great promise for consistent ET mapping across diverse crop types. This continuous monitoring of crop consumptive water will help growers to tailor irrigation management at the field scale and inform decision makers to adaptively manage water at a larger scale.

We also tested the capability of UAV-based multispectral and thermal aerial imaging in crop ET mapping at 1meter resolution. Five flights were deployed to match Landsat 8 satellite overpasses during the 2016 irrigation season in ~3.5 hectares blocks of alfalfa, pasture and corn in Staten Island in the Sacramento-San Joaquin Delta. Aerial imagery from both Micasense RedEdge 5-band camera and ICI 9640 thermal camera were collected. We used another ET approach, Mapping EvapoTranspiration using high Resolution and Internalized Calibration (METRIC) to estimate instantaneous and daily ET. Our results showed that, when aggregated to the Landsat scale, mean daily ET estimates from UAV observations are similar to those derived from Landsat-8 satellite observations. However, in all three crops, given its higher spatial resolution (1 and 0.05 m pixel), UAV estimates captured a significant higher spatial variability and wider range of values for fractions of reference ET (ETrF), and consequently ET. The UAV-based imaging proved to be another important emerging technology for crop consumptive water use monitoring, due to its easy deployment and high spatial and potentially temporal resolution.