Estimating Crop Coefficients using multitemporal Sentinel-2 remote sensing data to estimate actual evapotranspiration of a citrus orchard

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Estimation of evapotranspiration using the crop coefficient method is one of the most common approaches for irrigation water management. The crop coefficient, $K_c$, can be estimated as the ratio between maximum crop evapotranspiration, $ET_{max}$, and reference evapotranspiration, $ET_0$. However, in the last few decades, many correction factors have been proposed to split $K_c$ into separate coefficients to account for water stress conditions, as well as to estimate separately crop transpiration and soil evaporation. Furthermore, the remote sensing data collected from various satellite platforms have shown their full potential in mapping various vegetation indices (VI), which can be directly related to the spatio-temporal variability of $K_c$ values. Despite various VI-$K_c$ relationships have been proposed in the past years, only recently, thanks to the availability of new sensors with higher temporal and spatial resolutions, it is possible to retrieve new relationships able to follow the variability of the crop coefficient during the different crop phenological stages.

This study aimed at identifying a VI-$K_c$ relationship suitable to map actual evapotranspiration of a citrus orchard based on an extended time-series of NDVI images retrieved by Sentinel-2 platform and combined with a set of field micro-meteorological measurements.

The experiments were carried out during 2019 and 2020 in a commercial citrus orchard (C. reticulata cv. Tardivo di Ciaculli) with tree spacing of 5 x 5 m, located near the city of Palermo, Italy, in which different irrigation systems and management strategies were applied in three different portions of the orchard. In particular, the first portion was irrigated with a traditional micro-sprinkler system (TI) whereas the other two with a subsurface drip system maintained under full irrigation (FI) and deficit irrigation (DI) applied during the phase II of fruit growth (from 1-July to 20-August). The orchard was equipped with a standard weather station (WS) and an Eddy Covariance (EC) tower to acquire, every half-an-hour, precipitation, air temperature and relative humidity, wind speed and direction, global and net solar radiation and, finally, sensible and latent heat fluxes. During the entire period, a weekly dataset of Sentinel-2 images characterized by a spatial resolution of 10 m was acquired and processed in a GIS environment to obtain the spatial and temporal distribution of NDVI. Using the data acquired in 2019, a functional relationship
between $K_c$ and NDVI was calibrated accounting only for those periods in which the crop was maintained in the absence of water stress. The values of $K_c$ were determined as the ratio between actual daily ET measured by the EC tower and reference Penman-Monteith ET$_0$ obtained as indicated by the Food and Agriculture Organization of the United Nations. The procedure was then validated with the data recorded in 2020, by comparing estimated crop ET and the corresponding measured by the EC tower. The comparative analysis indicated root-mean-square-error and mean-bias-error associated with estimated ET of about 0.5 mm/d and 0.2 mm/d, respectively. Finally, based on the NDVI maps it was possible to derive the spatial variability of $K_c$ and actual ET, under the different irrigation systems and management strategies.