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Assessment of spatially distributed values of Kc using vegetation indices derived from medium resolution satellite data

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In the last years, the theme of suitable assessment of irrigation water supply has been raised relevant interest for both general principles of sustainable development and optimization of water resources techniques and management. About 99% of the water used in agriculture is lost by crops as evapotranspiration (ET). Thus, it becomes crucial to drive direct or indirect measurement in order to perform a suitable evaluation of water loss by evapotranspiration (i.e. actual evapotranspiration) as well as crop water status and its effect on the production.

The main methods used to measure evapotranspiration are available only at field scale (Bowen ratio, eddy correlation system, soil water balance) confined to a small pilot area, generally due to expense and logistical constraints. This led over the last 50 years to the development of a large number of empirical methods to estimate evapotranspiration through different climatic and meteorological variables as well as combining models, based on aerodynamic theory and energy balance, taking into account both canopy properties and meteorological conditions. Among these, the Penman-Monteith equation seems to give the best results providing a robust and consistent method world wide accepted.

Such conventional methods only provide accurate evapotranspiration assessment for a homogeneous region nearby the meteorological gauge station and cannot be extrapolated to other different sites; whereas remote sensing techniques allow for filling up such a gap. Some of these satellite techniques are based on the use of thermal band signals as inputs for energy balance equations. Another common approach is mainly based on the FAO method for estimating crop evapotranspiration, in which evapotranspiration data are multiplied by crop coefficients, Kc, derived from satellite multispectral vegetation indices obtained. The rationale behind such a link considers that Kc and vegetation indices are sensitive to both leaf area index and fractional ground cover.

Thermal-based energy balance models are more suitable than the FAO-Kc model for estimating crop ET, especially under moisture stress conditions, but they require many inputs and detailed theoretical background knowledge; so they can be only used in regions where high quality, hourly agricultural weather data are readily available providing instantaneous values of heat fluxes corresponding to the time of the satellite overpass. Thus, FAO-Kc approach is widely used in research activities and real-time irrigation scheduling for several water applications since it does not require temporal upscaling for obtaining daily values and satellite imagery in the reflective bands used for vegetation index computation are more readily available at higher spatial resolution than thermal band data.

There is no simple way to compute crop coefficients because they depend on climate, soil type, crop and its varieties, irrigation method, soil water, nutrient content and plant phenology. Consequently, specific calibrations of crop coefficient are required in various climatic regions. Many authors suggested a linear relationship between Kc and vegetation indices, but non-linear relationships have been proposed too. However, according to the radiative transfer theory, the nature of such relationships depends on the crop architecture and the definition of the adopted vegetation index, but the linear assumption can be adopted as first. Such studies, mainly investigated the possibility to use high resolution satellite data, such as Quickbird, Ikonos, TM, which are not suitable for operational purposes since in spite of the high spatial sampling they have an inadequate revisiting time over a given area. To obtain adequate temporal sampling, some authors proposed the use of a virtual constellation made by all currently available high-resolution satellites (e.g., DEMETER project). However the joint use of data from different satellites requires a carefully inter-satellite cross-calibration and co-registration.

In order to avoid such problems and to generate spatially distributed values of Kc capturing field-specific crop development, the employment of vegetation indices derived from medium resolution MODIS data having a higher temporal sampling has been investigated. The spatial and temporal correlation between NDVI (Normalized Difference Vegetation Index) and crop coefficients for different herbaceous and arboreal cultivations has been investigated to define their relationships. Through this approach site-specific crop coefficients were derived taking into account the effective ground coverage and status. The analysis has been applied on the 2005-2008 time series for the Basilicata region, Southern Italy.