Crop Water Requirements estimation from open satellite and agro-meteorological data

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An efficient and sustainable management of water resources is a crucial topic for arid and semi-arid areas, like the Mediterranean area, to ensure the environmental sustainability of the agricultural activity. Water Balance (WB) assessment is an essential Decision Support Tool (DST) in irrigation systems both on management strategies (e.g. water pricing policies) and on the implementation of infrastructural actions, to take wise decision and achieve a rational and sustainable resources management. Literature shows the importance of remote sensing technologies to retrieve the necessary biophysical vegetation's parameters useful for estimating the WB's components over large areas, with relative low cost and in near real time. This is true especially for satellite data, thanks to recent widespread of new open dataset (e.g. Sentinel) with higher temporal and spatial resolutions. In the last decades, many different methods to estimate the principal terms of the agricultural WB (in particular the evapotranspiration and soil moisture) from remote sensing data have been proposed. Nowadays, a great number of initiatives, spreading worldwide, are implementing satellite-based irrigation advisory services in order to improve irrigation water management at different scales (from field to regional scale).

The main scope of the present study was to assess the capability of Sentinel-2 data, in combination of *in-situ* agrometeorological measurements, to estimate the crop parameters (e.g. Leaf Area Index) useful to estimate the actual evapotranspiration and thus the irrigation requirements at large scale. Focusing on the "Sinistra Ofanto" irrigation district, the present study performs WB and IWR evaluations for the 2016 irrigation season at sub-district scale. The study area is located in the South of Italy (Apulia Region) and is characterized by a semi-arid climate and an extremely fragmented and heterogeneous landscape with the presence of the most significant Mediterranean crops (mainly vineyards, olive trees, orchards, and cereals). It has an extension of 55.000 hectares, cultivated by almost 27.000 farmers organised in the "Capitanata" Irrigation Consortium which manage the irrigation and land reclamation activities.

The evaluation of the WB allows to estimate the IWR, that is defined as the quantity of water needed in addition to the effective rainfall (Pe) in order to compensate the Crop Water Requirement (CWR), represented by the actual evapotranspiration (ETc):

$$IWR = CWR – Pe = ETc - Pe$$

The estimation of the Crop Water Requirements was carried out using the "Analytical Approach" proposed by D'Urso *et al*. This method follows the standard single crop coefficient (Kc) approach proposed by the Food and Agriculture Organization (FAO) and requires the knowledge of agrometeorological data measured in-situ (temperature and relative humidity of the air, wind speed, and the solar radiation) and satellite-derived vegetation parameters, i.e. the crop height (h_c), albedo (α) of the crop-soil surface, Leaf Area Index (*LAI*), and the canopy resistance acquired by remote sensing. Using these data, for each satellite acquisition, the crop coefficient (Kc) map for cloud free pixels of the entire study area was calculated. The meteorological data were retrieved from the 4 agrometeorological stations available on the study area and spatially distributed using the Thiessen polygons techniques. The agrometeorological data are recorded by the Consortium and daily published on its website (www.consorzio.fg.it) where the parameters of each station (i.e. position, elevation) are present. Vegetation parameters were retrieved from 14 cloud free Sentinel-2 Top of Atmosphere reflectance (Level-1C) images acquired during the irrigation season and available free of charge

from the Copernicus Open Access Hub (https://scihub.copernicus.eu/dhus/#/home). The images were atmospherically corrected using the European Space Agency's *Sen2Cor processor*. In the present study the LAI was derived using the Biophysical Processor tool; the h_c was fixed at 0.50 meters, due to the lack of land cover classification datasets, and the albedo was calculated for each satellite data under the hypothesis of Lambertian surfaces using the approach proposed by *Menenti and Bastiaanssen* (adapted for the Sentinel-2 dataset) as a weighted sum of the surface reflectance. From the Kc maps were retrieved, by linear interpolation, the Kc patterns for each pixel and for the entire irrigation season in order to estimate the ETc at daily scale.

Due to the scarce rate of precipitations and the low soil humidity during the crops season, which made feasible the assumption that almost all the rainfall is available for crops, the effective rainfall was estimated by subtracting 4 mm to each registered event.

The comparison of the estimated IWR with the water volumes provides by the Irrigation Consortium allows a first assessment about the SWB's performance and show a general good performance of the proposed method. The difference between the IWR estimated and the Irrigation Water provided by the Consortium shows a good performance of the proposed study. Moreover, these results can indicate the existence of an additional water supply resources (e.g. the groundwater resource largely utilised in the study area but not completely assessed).

Future developments and more detailed results could be achieved with the improvement of the Water-Soil Balance model and of the vegetation's parameters estimation (especially h_c and the stomatal resistance) using a detailed crop type classification, useful also for the detection of the irrigated areas.

Keywords. Water management – Decision support systems – Crop water use - Remote sensing - Open data.