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Development and assessment of Transpirative Deficit Index (D-TDI) for agricultural drought monitoring

Anna Borghi, Michele Rienzner, Claudio Gandolfi, and Arianna Facchi
Department of Agricultural and Environmental Sciences (DiSAA), University of Milan

Drought is a major cause of crop yield loss, both in rainfed and irrigated agroecosystems. In past decades, many approaches have been developed to assess agricultural drought, usually based on the monitoring or modelling of the soil water content condition. All these indices show weaknesses when applied for a real time drought monitoring and management at the local scale, since they do not consider explicitly crops and soil properties at an adequate spatial resolution.

This work describes a newly developed agricultural drought index, called Transpirative Deficit Index (D-TDI), and assesses the results of its application over a study area of about 210 km2 within the Po River Plain (northern Italy). The index is based on transforming the interannual distribution of the transpirative deficit (potential crop transpiration minus actual transpiration), calculated daily by means of a spatially distributed conceptual hydrological model and cumulated over user-selected time-steps, to a standard normal distribution (following the approach proposed by the meteorological index SPI - Standard Precipitation Index). For the application to the study area a uniform maize crop cover (maize is the most widespread crop in the area) and 22-year (1993-2014) meteorological data series were considered. Simulation results consist in maps of the index cumulated over 10-day time steps over a mesh with cells of 250 m. A correlation analysis was carried out (1) to study the characteristics and the memory of D-TDI and to assess its intra- and inter-annual variability, (2) to assess the response of the agricultural drought (i.e. the information provided by D-TDI) to the meteorological drought computed through the SPI over different temporal steps.

The D-TDI is positively auto-correlated with a persistence of 30 days, and positively cross-correlated to the SPI with a persistence of 40 days, demonstrating that D-TDI responds to meteorological forcing. Correlation analyses demonstrate that soils characterized by high available water content (AWC) can more easily compensate for a short-term variability in the precipitation pattern, while soils with low AWC are more strictly linked to the SPI variability.

Since D-TDI relies both on climate and fine-resolution soil and land cover data, it provides a reliable measure of the evolution of agricultural drought over the territory with respect to that achieved through meteorological drought indices. The accumulation of the index over a 10-day period considering a mesh with cells of 250 m allows to capture the response of the territory to drought at time and spatial scales of interest for stakeholders. Modelling efforts utilizing the D-TDI have potential to shed light on the vulnerability of agricultural areas to drought; future work using the D-TDI as a tool to map drought prone areas could therefore improve the ability of farmers and irrigation district managers to cope with agricultural droughts and set up adaptation actions. Despite D-TDI was used in this study on historical data series, the index has the potential to be applied for real-time or provisional monitoring by incorporating real time or provisional meteorological data, giving the opportunity to stakeholders to promptly cope with droughts.