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Proper modelling of the hydrological behaviour of facultative phreatophytes at plot scale using additional in-situ transpiration measurements

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Semi-arid areas are characterized by limited water availability, shallow soils and deep aquifers; therefore, some species in these environments have developed deep groundwater tapping roots. Quercus ilex is one of the main Mediterranean evergreen oaks in the Iberian Peninsula and in semi-arid conditions can become a facultative phreatophyte. Most of these Q. ilex forests grow at the upper part of the catchments and their actual evapotranspiration can heavily influence downstream water availability, especially in water-limited environments, where evapotranspiration can be greater than 85% of mean annual precipitation. Hence, groundwater transpiration in these ecosystems cannot be neglected. However, it is often not considered when using conventional hydrological models, leading to an underestimation of actual evapotranspiration and an overestimation of net recharge.
Hence, groundwater transpiration is a critical aspect, which should be included in the hydrological models used in semi-arid conditions in order to make precise predictions. Within this framework, two models of different complexity were calibrated using the experimental data recorded in an 1800 m2 Q. ilex experimental plot under a semi-arid climate. The first model is the broadly used LEACHM model, which already has a non-free drainage option. Nevertheless, this model has a high number of parameters that should be estimated and consequently, it can be challenging to use it at catchment scale or in operational hydrology applications. Consequently, the second model is based on the parsimonious and conceptual eco-hydrological model TETIS, adapted in order to incorporate groundwater transpiration. The plot was highly monitored during the observational period (01/10/2012-26/04/2016). Soil water content (SWC) was measured by means of a Decagon Devices EC-5. A total of 15 probes were installed at 5, 15, and 30 cm depth. Sap flow velocity was measured through the heat ratio method in 14 trees, divided into 4 different diametrical distributions. The measurements were upscaled to stand transpiration accounting for the density of trees and their diameter frequency distribution.
A multi-variable calibration with a multi-objective approach was carried out and the performance of the models in reproducing the SWC and the transpiration was compared to that obtained with the single-variable and single-objective solutions placed at the extremes of the Pareto front. The results showed that when using the single-objective optimums, the calibrated state variable can be reproduced with accuracy, but the other state variable or even the water balance can reach unrealistic results. This is especially true when using SWC, however better results were obtained using only transpiration because some parameters are not related to SWC but they do are to transpiration.
Consequently, transpiration measurements are essential in these ecosystems in order to make precise predictions, and if only SWC is observed, these results suggest that the problem must be carefully approached, because information transfer is not possible in this case and good results may be obtained for the “wrong reasons”. Finally, it should be highlighted that TETIS, although simpler is able to reproduce the water dynamics of Q. ilex and this bolsters its capacity of being used at catchment scale with remote sensing evapotranspiration measurements.