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Evaluation of a simple method for crop evapotranspiration partitioning and comparison of different water use efficiency approaches

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In the current context of climate change, intra- and inter-annual variability of precipitation can lead to major modifications of water budgets and water use efficiencies (WUE). Obtaining greater insight into how climatic variability and agricultural practices affect water budgets and their components in croplands is, thus, important for adapting crop management and limiting water losses. The principal aims of this study were 1) to assess the contribution of different components to the agro-ecosystem water budget and 2) to analyze and compare the WUE calculated from ecophysiological (WUEplt), environmental (WUEeco) and agronomical (WUEagro) points of view for various crops during the growing season and for the annual time scale.

Eddy covariance (EC) measurements of CO_2 and water flux were performed on winter wheat, maize and sunflower crops at two sites in southwest France: Auradé and Lamasquère. To infer WUEplt, an estimation of plant transpiration (TR) is needed. We then tested a new method for partitioning evapotranspiration (ETR), measured by means of the EC method, into soil evaporation (E) and plant transpiration (TR) based on marginal distribution sampling (MDS). We compared these estimations with calibrated simulations of the ICARE-SVAT double source mechanistic model.

The two partitioning methods showed good agreement, demonstrating that MDS is a convenient, simple and robust tool for estimating E with reasonable associated uncertainties. During the growing season, the proportion of E in ETR was approximately one-third and varied mainly with crop leaf area. When calculated on an annual time scale, the proportion of E in ETR reached more than 50%, depending on crop leaf area and the duration and distribution of bare soil within the year.

WUEplt values ranged between -4.1 and -5.6 g C kg-1 H_2O for maize and winter wheat, respectively, and were strongly dependent on meteorological conditions at the half-hourly, daily and seasonal time scales. When normalized by the vapor pressure deficit to reduce the effect of seasonal climatic variability on WUEplt, maize had the highest efficiency. Absolute WUEeco values on the ecosystem level, including water loss through evaporation and carbon release through ecosystem respiration, were consequently lower than on the stand level. This observation was even more pronounced on an annual time scale than on the growing-season time scale because of bare soil periods. Winter wheat showed the highest absolute values of WUEeco, and sunflower showed the lowest. To account for carbon input into WUE through organic fertilization and output through biomass exportation during harvest, net biome production (NBP) was considered in the calculation of an ecosystem-level WUE (WUENBP). Considering WUENBP instead of WUEeco markedly decreased the efficiency of the ecosystem, especially for crops with important carbon exports, as observed for the maize used for silaging and pointed out the profits of organic C input. From an agronomic perspective, maize showed the best WUE, with exported (marketable) carbon per unit of water used exceeding that of other crops. Thus, the environmental and agronomical WUE approaches should be considered together in the context of global climate change and sustainable development.