Geophysical Research Abstracts
Vol. 12, EGU2010-3394, 2010
EGU General Assembly 2010

Crop evapotranspiration partitioning and comparison of different water use efficiency approaches

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In the context of climate change and water resource limitations for agriculture, agro-ecosystems water use efficiency (WUE) assessment and improvement is essential. The principal aims of this study are 1) to assess the different components of the agro-ecosystem water budget and 2) to analyse and compare the WUE calculated for plants (WUE_{plt}), for the ecosystem (WUE_{eco}) and from an agronomical point of view (WUE_{agro}) for several crops during the growing season and at the annual time scale, as well as to evaluate the environmental impact of crop rotations and intercrop on WUE_{eco} and WUE_{agro}.

To achieve this goal, EC measurements of CO_2 and water fluxes were performed above winter wheat, maize and sunflower at Auradé and Lamasquère sites in south west France. To infer WUE_{plt}, an estimation of plant transpiration (TR) is needed, therefore a new methodology of ETR partitioning between soil evaporation (E) and TR based on marginal distribution sampling (MDS) was tested and evaluated against the ICARE-SVAT double source mechanistic model.

Results showed good agreement between both partitioning methods and MDS proved to be a convenient and robust tool with reasonable associated uncertainties for estimating E. During the growing season, the proportion of E in ETR was around one third, varying mainly with crop leaf area. When calculated at the annual time scale, the proportion of E in ETR reached more than 50 %, depending on both crop leaf area and bare soil duration and distribution within the year. WUE_{plt} values ranged between -4.3 g C kg^{-1} H_2O for maize and -5.8 g C kg^{-1} H_2O for winter wheat. It was strongly dependant on meteorological conditions (mainly vapour pressure deficit) at both daily and seasonal time scale. When normalised by vapour pressure deficit to reduce the effect of climatic variability on WUE_{plt}, maize (C4 photosynthesis crop) had the highest efficiency. WUE values were lower at the ecosystem level than at the plant level because of water loss through E and carbon release through ecosystem respiration. This observation was even more pronounced at the annual time scale because bare soil periods were included in the calculation. To account for carbon input through organic fertilisation and output through biomass exportation during harvest, net biome production (NBP) was considered in the calculation of ecosystem WUE (WUE_{NBP}). This environmental WUE consideration markedly decreased the efficiency of the ecosystem, especially for crops with important carbon exports as observed for the maize used for silaging at Lamasquère during the year 2005-2006. Finally, the environmental and the agronomical WUE approaches were compared and discussed considering the different processes accounted for by both considerations.