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Comparison between the evapotranspiration of alfalfa measured by eddy covariance and estimated by FAO 56 method in Central Italy

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The objective of this study is the comparison between crop evapotranspiration measurements by eddy covariance (ET_{EC}) and estimates by FAO-56 method (ET_C). An open patch eddy covariance (EC) system has been installed in the middle of an alfalfa farmland in Central Italy. The EC system consisted of a 3D sonic anemometer/thermometer (model CSAT3) and a gas-analyzer (model Li-7500). CSAT3 and Li-7500 measured three-directions fluctuations of wind, sonic temperature, and concentrations of H_2O and CO_2 at 20Hz. These instruments allowed to measure independently latent heat flux (LE) and sensible heat flux (H). Soil heat flux (G) and net radiation (Rn) were measured using soil heat flux plates (model HFP01) and a net radiometer respectively, in order to check energy balance closure. All the sensors were connected to a datalogger (model CR3000) and the 10-min statistics (average, variance and covariance) were computed. Daily precipitation and air temperature were also recorded. The sensors were placed at 1.8m height over the soil surface.

Available energy (Rn-G) systematically exceeds the measured fluxes (LE+H), being the underestimation of LE+H between 10 and 30%. Therefore, in accordance to the literature, the energy balance closure was considered to provide evidence for the validity of the results on LE.

The evapotranspiration was measured by the EC system between days of the year 2009 (DOY) 130 (10^{th} May) and 153 (2^{nd} June), corresponding to the first 24 days of the 2^{nd} cutting cycle of the growing season and between DOY 190 (9^{th} July) and 240 (21^{st} August), the whole 3^{rd} cutting cycle of the growing season.

For the same periods crop evapotranspiration was also calculated as the product between reference evapotranspiration (ET_0) estimated by the FAO Penman-Monteith equation and the factor Kc·Ks (where Kc, crop coefficient; Ks, water stress coefficient, FAO-56 method). Tabulated Kc values, adjusted for the specific air humidity and wind speed conditions measured at the experimental site, were used. Kc values are 0.4, 1.14, 1.07 (immediately following cutting, at full cover, and immediately before cutting respectively) for the 2^{nd} cutting cycle and 0.4, 1.15, 1.08 for the 3^{rd} cutting cycle. Ks values were computed simulating the daily soil water balance.

The comparison between the ET_{EC} and ET_C shows an high correlation for both the cutting cycles being the correlation coefficients r=0.93 and r=0.92 respectively. For the 2^{nd} cutting cycle the cumulated ET_{EC} is 60mm (2.50mm·day^{-1}), ET_C is 71mm (2.95mm·day^{-1}) and RMSE=0.69. During this cycle the Ks is always equal to 1.

For the 3^{rd} cutting cycle the cumulated ET_{EC} is 145mm corresponding to 3.55mm·day^{-1} (7.2mm, 59.5mm, 41.4mm, 37.3mm for initial, development, mid and late season stages respectively) and the ET_C is 143.1mm corresponding to 3.49mm·day^{-1} (12.1mm, 59.8mm, 38.5mm, 32.6mm for initial, development, mid and late season stages respectively) with RMSE=0.70. During this cutting cycle a water stress condition was detected by a Ks lower than 1 almost every day. Infact, with Ks=1 (no stress) the ETc estimation would be overestimated, i.e. 234mm corresponding to 5.70mm·day^{-1} (12.5mm, 87.9mm, 69.8mm, 63.7mm for initial, development, mid and late season stages respectively) and RMSE=2.39.

Concluding it was observed that EC system provides measures of evapotranspiration that can be considered aligned with the corresponding FAO-56 estimates, but particularly during the initial stage, the FAO-56 method overestimates the actual crop evapotranspiration. An opposite behavior is present during mid and late season stages while a good agreement is present for the development stage. The observed differences could lead to the adjustment of the tabulated alfalfa Kc values, but a further investigation is necessary in order to perform the analysis under standard conditions.