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Evapotranspiration of alfalfa: comparison between eddy covariance measurements and the FAO-56 approach estimates in Central Italy

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The objective of this study was the comparison between evapotranspiration measured by eddy covariance (ET_{ec}) and evapotranspiration estimated by the FAO-56 approach (ET_c). In particular the tabulated alfalfa crop coefficients (K_c) have been compared with K_c computed as the ratio of ET_{ec} to reference evapotranspiration (ET_0) during the growing stages characterized by standard conditions (no water stress). 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 (CSAT3) and a gas-analyzer (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 (HFP01) and a net radiometer respectively, in order to check energy balance closure. All the sensors were connected to a datalogger (CR3000) and the 10-min statistics were computed. Daily precipitation and air temperature were also recorded. The sensors were placed at 1.8m height over the soil surface.

The available energy (Rn-G) was balanced by the measured fluxes (LE+H) on a daily time scale.

The evapotranspiration was measured by the EC system during different growing stages of the years 2009 and 2010. For some days data are missing due to the EC system malfunctioning.

For the same periods ET_c was also calculated as the product between ET_0 estimated by the FAO Penman-Monteith equation and the factor $K_c \cdot K_s$ (where K_s is a water stress coefficient). Tabulated K_c values, adjusted for the local climatic conditions, were 0.4 (K_{c-ini}), 1.14 (K_{c-mid}), 1.08 (K_{c-end}), immediately following cutting, at full cover, and immediately before cutting respectively. The lengths of the growing stages were calibrated according to local conditions. K_s values were computed simulating the daily soil water balance. K_s varied between 0 (full stress condition) and 1 (no stress).

Two cutting cycles (2^{nd} and 3^{rd}) were analyzed in the year 2009. For the 2^{nd} cutting cycle the cumulated ET_{ec} is 60mm, ET_c is 71mm and RMSE=0.69. During this cycle, being K_s always equal to 1, it has been possible to estimate the crop coefficients K_c. K_{c-ini} and K_{c-mid} were about 0.25 and 0.93 respectively, whereas K_{c-end} was not evaluated due to the presence of missing data. For the 3^{rd} cutting cycle the cumulated ET_{ec} is 145mm and the $ET_c$is 143.1mm with RMSE=0.70. The presence of water stress conditions didn't allow the evaluation of K_c.

Three cutting cycles were analyzed in the year 2010. For the 1^{st} cutting cycle the cumulated ET_{ec} is 76.31mm, ET_c is 99.3mm and RMSE=1.13. The K_s is always equal to 1 and the K_{c-mid} value was about 0.99, K_{c-ini} and K_{c-end} were not evaluated for missing data.

For the 2^{nd} cutting cycle the cumulated ET_{ec} is 87.8mm, ET_C is 101.88mm and RMSE=1.22. K_{c-ini} and K_{c-mid} were 0.29, 1.10 whereas K_{c-end} was not computed due the presence of water stress conditions.

For the 3^{rd} cutting cycle the cumulated ET_{ec} is 62.53mm and the $ET_C$is 43.23mm with RMSE=0.82. K_c were not quantified due to the presence of water stress conditions.

The comparison between ET_{ec} and ET_c showed that the performance of FAO-56 approach can be improved with the determination of appropriate K_c values. In particular it was observed that the FAO-56 method overestimates the actual crop evapotranspiration. The computed K_c values were lower (by about 10%) than the corresponding tabulated values. This difference could reflect the local climate and cropping conditions that are included implicitly in the single crop coefficient.