Geophysical Research Abstracts, Vol. 7, 03181, 2005
SRef-ID: 1607-7962/gra/EGU05-A-03181

Estimating bare soil evaporation using experimental soil moisture data

F. Ventura (1), R.L. Snyder (2), K. M. Bali (3)

(1) Dept. of Agro-environmental Sci. and Tech., University of Bologna, Bologna, Italy. fventura@agrsci.unibo.it

(2) Dept. of Land Air and Water Res., University of California, Davis, California, USA.

(3) University of California Cooperative Extension, Imperial County, California, USA.

It is well known that soil evaporation rates follow a three-stage process (Feddes 1971; Idso et al. 1974). During stage-1 evaporation, the evaporation rate is only limited by the amount of energy available to vaporize soil moisture in the upper layer of the soil, and it is similar to evaporation from a surface of free water. This phase ends when the soil moisture content in the upper layer decreases and the soil matric potential reaches a critic value. During stage-2, evaporation rates are limited by the lack of water in the upper soil layer and by soil hydraulic properties that determine the transfer of liquid and vaporized water to the surface. In this stage, the flux of water moves in the liquid and vapor forms. Stage-2 ends when there is minimal liquid water movement with only vapor flux through the soil pores. Stage-3 is determined mainly by soil physical and adsorbing characteristics. In stage-3, the evaporation rate is negligible.

Ritchie (1972) reported that in stage-2 the evaporation rate decreases as a function of the square root of time after wetting. However, both Stroonsnjider (1987) and Gallardo et al. (1996) found a good relationship between cumulative bare soil evaporation and cumulative reference evapotranspiration (CET_o), where CET_o is the sum of daily reference evapotranspiration (ET_o) rates for short canopies (ASCE-EWRI 2004). Like in the model of Ritchie (1972), soil evaporation is described as a two-stage process where a soil hydraulic factor (β) determines the point where the evaporation rate changes from stage-1 to stage-2. The hydraulic factor is determined using the soil evaporation (E_s) by plotting cumulative soil evaporation (CE_s) versus the square root of the maximum possible cumulative soil evaporation (CE_x). When E_s is not limited by soil

hydraulic factors (i.e., stage-1), the cumulative soil evaporation is calculated as:

$$CE_s = CE_x = K_x \times CET_o$$

This equation is used when $\sqrt{CE_x} < \beta$. During stage 2, when$\sqrt{CE_x} \geq \beta$, the cumulative soil evaporation is calculated as:

$$CE_s = \beta\sqrt{CE_x}$$

to estimate soil evaporation rates with time after wetting. Using field CE_s measurements and CE_x estimates, a regression of CE_s versus $\sqrt{CE_x}$ is used to determine βu For x-axis values of $\sqrt{CE_x} \geq \beta$, a plot of CEs versus $\sqrt{CE_x}$ gives a linear relationship through the origin with slope equal to β. Therefore, using hourly data, the minimum value for $\sqrt{CE_x}$ is increased until the slope of the regression line first exceeds the selected minimum value for $\sqrt{CE_x}$. The change in slope from before and after$\sqrt{CE_x} = \beta$ is clearly evident from a plot of CE_s versus$\sqrt{CE_x}$.

Here a method is presented that uses continuous soil moisture measurements and hourly reference evapotranspiration data to estimate the soil hydraulic factor (βp) for modeling soil evaporation. A previously developed and tested method to determine β (Snyder et al., 2000) uses an energy balance approach with sensible heat flux density estimated using the surface renewal method to obtain the continuous soil evaporation. A new method is presented, which uses a hydroprobe soil moisture measuring device to estimate the continuous soil evaporation. The estimation of evaporation with soil moisture sensors was simpler and less expensive when compared to the energy balance technique. The methods, evaluated in two field experiments, showed good agreement with evaporation data. The soil evaporation model was used with β from both methods and the results were similar for experiments conducted in two locations (i.e. a difference of 0.4 % and 2.6 % for the two sites). A comparison between modeled and measured daily soil evaporation using the β hydraulic factor from either the energy balance or soil moisture monitoring methods gave a RMSE = 0.6 mm d^{-1}. Comparing the measured daily soil moisture and energy balance estimates of soil evaporation gave a RMSE = 1.3 mm d^{-1}. The error in the soil moisture method was higher, but the greater error was offset by the relatively simple and less expensive soil-moisture method.

0.1 References

ASCE-EWRI (2004). The ASCE Standardized Reference Evapotranspiation Equation. Technical Committee report to the Environmental and Water Resources Institute of the American Society of Civil Engineers from the Task Committee on Standardization of Reference Evapotranspiration. 173 p.

Feddes, R.A. (1971). "Water, heat and crop growth" PhD thesis, Comm. Agric. Univ., Institute of Land and Water Management Research, Wageningen, 184 pages.

Gallardo, M., Snyder, R.L., Schulbach, K., and Jackson, L.E. (1996). "Crop growth and water use model for lettuce." *J. of Irrig. and Drain. Engng.*, ASCE, 122 (6), 354-359.

Idso, S.B., Reginato, R.J., Jackson, R.D., Kimball, K.B. and Nakayama, F.S. (1974). "The three stages of drying in a field soil." *Soil Sci. Soc. Am. Proc.*, 38, 831-837.

Ritchie, J.T. (1972). "Model for predicting evaporation from a crop with incomplete cover." *Water Resour. Res.*, 8 (5), 1204-1213.

Snyder, R.L., Bali, K.M., Ventura, F. and Gomez-MacPherson, H. (2000). "Estimating evaporation from bare or nearly bare soil." *J. of Irrig. and Drain. Engng.*, ASCE, 126 (6), 399-403.

Stroosnijder, L. (1987). "Soil evaporation: test of a practical approach under semi-arid conditions." *Netherlands Journal of Agricultural Science*, 35, 417-426.