Comparison of two different models for estimating soil evaporation under the conditions of Çukurova Region

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1. Introduction

In general, the models of soil water evaporation have expressed the loss rates from cropped areas rather than just those from bare soils. However, in semi-arid regions, evaporation from the soil surface constitutes a large fraction of the total water loss not only from cropped fields but also from bare soils (Hanks, 1992; Hillel, 1980). Parameterization of evaporation from a non-plant-covered surface is also very important in the hierarchy strategy of modeling land surface processes (Mihailovic et al., 1995). The evaporation from soils depends not only on the atmospheric conditions but also on soil properties. Many simple models (Alvenas and Jansson, 1997; Black et al., 1969; Brisson and Perrier, 1991; Gardner, 1959; Gardner and Hillel, 1962; Hanks and Gardner, 1965; Hillel, 1975; Jackson et al., 1976; Katul and Parlange, 1992; Liu et al. 1998; Malik et al., 1992; Staple, 1974) are available which give the reasonable prediction of evaporation from bare soils. In the present study, Ritchie (1972) and Aydin (1998) models were compared with measured evaporation.

2. Materials and Methods

In order to compare the performance of the models, a field experiment was carried out on a heavy clay soil in the Cukurova Region, Southern Turkey. The soil at site has no water table and salinity problem. During the experimental period, the test plot and the surrounding field were kept bare and several times watered. Soil evaporation was measured with micro-lysimeters (Boast and Robertson, 1982; Evett et al., 1995).

Daily potential evaporation from bare soil was calculated using the Penman-Monteith equation with a surface resistance of zero (Allen et al., 1994; Aydin et al., 2005; Brisson et al., 1998; Monteith, 1965; Radersma and de Ridder, 1996; Saunders et al., 1997; Wallace and Holwill, 1997; Wallace et al. 1999; van Dam et al., 1997).

$$Ep = \frac{\Delta(Rn - G) + 86.4\rho C_p \delta / ra}{\lambda(\Delta + \gamma)} \qquad (1)$$

where E_p is potential soil evaporation (kg m^{-2} d^{-1}≈mm d^{-1}), Δ is the slope of saturated vapor pressure-temperature curve (kPa °C^{-1}), R_n is the net radiation (MJ m^{-2} d^{-1}), G_s is the soil heat flux (MJ m^{-2} d^{-1}), ρ is the air density (kg m^{-3}), c_p is the specific heat of air (kJ kg^{-1} °C^{-1}=1.013), δ is the vapor pressure deficit of the air (kPa), r_a is the aerodynamic resistance (s m^{-1}), λ is the latent heat of vaporization (MJ kg^{-1}), γ is the psychrometric constant (kPa °C^{-1}), and 86.4 is the factor for conversion from kJ s^{-1} to MJ d^{-1}.

The most commonly used model to predict evaporation of water from bare soils is based on Ritchie's (1972) approach, which considers evaporation to occur in two distinct phases. During the first stage, surface resistance is zero, and the evaporation from the soil proceeds at the potential rate. During the falling rate stage, with a dry layer at the surface, the evaporation rate is reduced. Phase I lasts for a number of days (t_I) until the total amount of water evaporated is U (mm), after which Phase II begins. Soil evaporation in second phase is proportional to the square root of time (Radersma and de Ridder, 1996; van Dam et al., 1997; Wallace and Holwill, 1997).

$$\sum E_{s1} = \sum_{t0}^{t1} E_p = U \qquad t<t_1 \qquad (2)$$

$$\sum E_{s2} = \alpha (t - t_1)^{1/2} \qquad t>t_1 \qquad (3)$$

where $\sum E_{s1}$ and $\sum E_{s2}$ are the cumulative amounts of soil evaporation (mm) in the first and second drying phases, respectively. α (mm $d^{-0.5}$) is assumed constant for any particular soil and is a function of soil diffusivity.

Aydin (1998) model is based on the relations among potential and actual soil evaporation and soil water potential at the top surface layer of the soil, with some simplifying assumptions.

$$E = \frac{Log|\varphi| - Log|\varphi_{ad}|}{Log|\varphi_{tp}| - Log|\varphi_{ad}|} Ep \qquad (4)$$

where *E*a and *E*p are actual and potential evaporation rates (mm d^{-1}), respectively, Ψtp is the absolute values of soil water potential (matric potential) at which actual evaporation starts to drop below potential one, Ψad is the absolute values of soil water potential at air-dryness, and Ψ is the absolute value of soil water potential to be determined in situ between Ψtp and Ψad. Assuming that the water potential at dry soil surface is at equilibrium with the atmosphere, the minimum water potential (Ψad) can be derived from the Kelvin equation ((Aydin et al., 2005; Brown and Oosterhuis, 1992; Feddes et al., 1978; Kirby and Ringrose-Voase, 2000).The values of all Ψ are in cm of water.

3.Results and Conclusions

A comparison of evaporation rates estimated by Ritchie (1972) and Aydin (1998) models, and measured evaporation is shown in Fig.1. Ritchie model was unable to predict daily soil evaporation accurately, but was capable of providing good estimates of cumulative soil evaporation over hydrologically significant periods. Aydin model was successful in estimating evaporation on daily basis for a range of soil types with only simple parameter requirements such as matric potential measured only near soil surface, and easily obtainable climatic data.

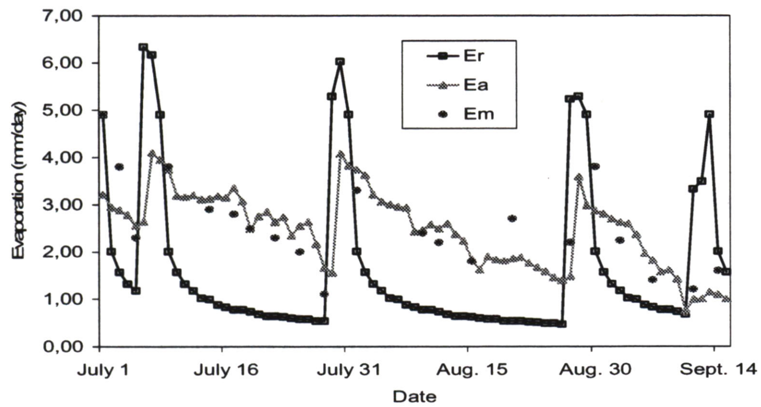

Fig.1. Comparison of evaporation rates estimated by Ritchie (Er) and Aydin (Ea) models, and measured evaporation (Em).

It can be concluded that as a result of its simple and practical nature, Aydin approach can be used in Soil-Water-Atmosphere-Plant environment to estimate evaporation from bare soils as well as soil evaporation from row crop plots, if matric potential measurements are available. However, the objective measurement of soil water potential near the surface of the profile is difficult especially for drier upper layer. Thus, in further studies, it will be useful to find a way for predicting matric potential near soil surface.

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