P2.14 SOIL WATER CONTENT SIMULATIONS USING A SIMPLE BALANCE MODEL IN THE WET PAMPAS

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1. INTRODUCTION

In studies of the energy balance in the soil – atmosphere interface, one of the term which presents some difficulty for drawing up parameters is the ground heat flux. To the complexity of estimating thermal conductivity adequately, due to the physical composition of the soil, is added the fact that this parameter depends on the water content of the soil thickness considered and the type and characteristics of plant cover. Taking into account that the soil – plant – atmosphere system may be seen as a continuum in which water flows and is redistributed according to its availability in the system, the temporal variations of this variable produce temporal changes in soil thermal conductivity and will therefore affect the estimate of heat flux in the ground. A very important aspect for the determination of soil water content is its usefulness for an efficient and rational use of water in an appropriate management of crops for higher productivity.

There are two main methods to model the soil water content: the volumetric balance model (Rao, 1987; Rao et al., 1988, 1990; George, 1997; Hajilal et al., 1998) and the dynamic model. The former is better known as it is simpler, requires few entry data and may be used on a local scale. Volumetric balance models are based on the principle of mass conservation within the thickness of the soil, whose lower limit is the maximum depth the roots of the crop under consideration reach. The thickness of the soil, which acts as a water reservoir, is divided into two layers: the active roots zone, the area where the roots have already developed and the second the so-called passive root zone which is determined by the previous depth and the maximum depth which the roots are expected to reach. The first layer is where the water balance will be estimated taking into consideration the supply (rainfall and irrigation) and loss (runoff, evapotranspiration and percolation) in the system. For the second layer, only percolation is considered as a supply and loss mechanism.

The simple soil water balance conceptual model suggested by Panigrahi and Panda (2003) was adapted for the Balcarce (37º45'S, 50º18'W) area in the Province of Buenos Aires, in an experimental corn (Zea mays) area to make a daily estimate of the soil water content from the time of sowing to physiological maturity. The results obtained were validated with the information obtained during the 1998-1999 field campaign, during which the crop was always growing under near potential conditions.

2. METHODOLOGY AND MATERIALS

Fig.1 shows the components of the system and the estimated variables. The balance for one day is:

$$CAS_i \, ra_i = CAS_{i-1} ra_{i-1} + P_i + R_i + \Delta ra_i \, CAS0_{i-1} - Pe_i - EVTr_i - Es_i \qquad (1)$$

where *i* is the number of days after the sowing, *CAS* is the soil water content in the active root layer (mm/cm), *CAS0* is the soil water content in the passive root layer (mm/cm), *ra* is the depth of the active roots (cm), *P* is the rainfall (mm), *R* is irrigation (mm), Δ*ra* the variation in the depth of the active roots (cm), *Pe* is percolation in the active root layer (mm), *EVTr* is the real evapotranspiration of the crop (mm) and *Es* is the runoff (mm).

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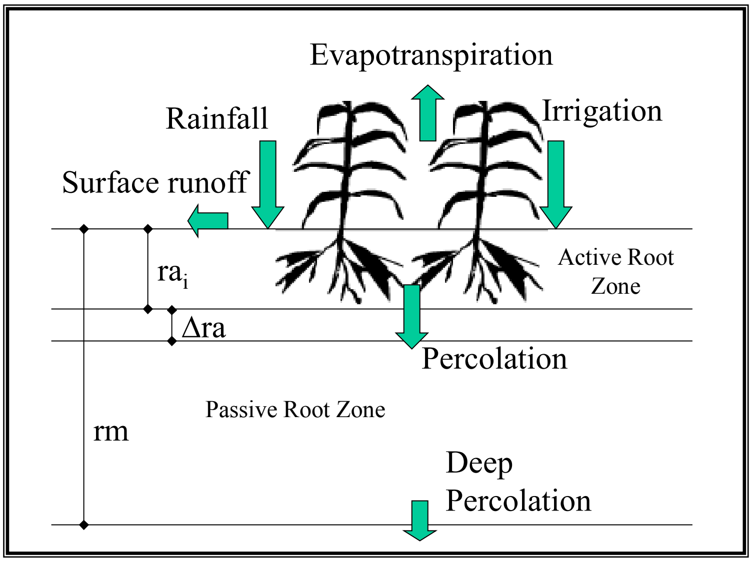

Fig. 1: Diagram of the soil – plant – atmosphere system and balance components.

2.1 Active root thickness estimate

The expression suggested by Panigrahi and Panda (2003) was used for root growth, where the root growth is represented as a sinusoidal function:

$$ra(i)=rm\left(0.5+0.5\sin\left(3.03\left(t/_{tm}\right)-1.47\right)\right) \tag{2}$$

where *rm* is the maximum depth that the roots may reach, *t* is the time from sowing and *tm* is the duration of the complete root development in days after sowing. In this case, it was considered that *tm* = 75 days, coinciding with bloom.

2.2 Percolation and deep percolation estimate

Percolation is estimated as the difference between the water entering the layer under study and the excess of water with respect to the field capacity. So, it can be estimated as:

$$Pe_i=\left(P_i+R_i-Es_i\right)-\left[\left(CC-CAS_{i-1}\right)ra_{i-1}+\left(CC-CAS0_{i-1}\right)\Delta ra_i\right] \tag{3}$$

where *CC* is the field capacity (mm/cm).

If the percolation value estimated with (3) is negative, it is considered that there will be no percolation and the soil water content in the passive root layer (*CAS0*) will therefore remain the same as of previous day:

$$CAS0_i=CAS0_{i-1} \qquad Pe_i\le 0 \tag{4}$$

If the percolation value is positive, the *CAS0* increase compared to the previous day's value will be given by the quotient between the percolation and the passive root zone thickness:

$$CAS0_i=CAS0_{i-1}+\frac{Pe_i}{rm-ra_i} \qquad Pe_i>0 \tag{5}$$

If the soil water content condition in the passive root layer is more than the field capacity, deep percolation will occur. It is not necessary to make the calculation for the purposes of this paper. However, for these cases, the *CAS0* value is corrected, taking it to field capacity conditions.

2.3 Surface runoff estimate

The Curve Number technique of the Soil Conservation Service of the United States (USDA_SCS National Engineering Handbook, 1972) provides an approximate methodology to estimate the rainfall volume lost in surface runoffs, taking into consideration the type of soil and land use, the management and crop hydrologic conditions. The runoff estimate is:

$$Es_i=\frac{\left(P_i-0.2s\right)^2}{P_i+0.8s} \tag{6}$$

where *s* is the maximum soil retention potential (mm) and is related to the curve number (*NC*) in the following expression:

$$s = 254\left(\frac{100}{NC} - 1\right) \tag{7}$$

The curve numbers are selected from tabulated values for fallow or appropriate land use, treatment, and hydrologic conditions (crop condition) plus an antecedent moisture adjustment. Runoff and infiltration volumes can be calibrated by entering override curve numbers for a field. The *NC* value used in this paper was selected for straight row practice in row crops land use and considering good hydrologic conditions and hydrologic soil group "B" (*NC* = 78). The soils of group "B" are those which have a moderate infiltration rate as water moves relatively quickly through the soil. The corrections proposed by Sharpley and Williams (1990) were taken into account according to the percentage of available water. When rainfall was under 0.2**s*, it was considered there was no runoff.

2.4 Real crop evapotranspiration estimate

Real evapotranspiration was estimated on the basis of the maximum evapotranspiration of the crop. The model suggested by Gardiol *et al* (2003) was used to calculate soil evaporation and plant transpiration separately. This is a double-layer model based on the resistance theory, proposing a parallel resistance arrangement to represent the latent heat flux from both the soil surface and the crop leaves in the canopy. The real evapotranspiration of the crop is obtained from the maximum evapotranspiration *(ETM)* with the following equation:

$$ETV_i = \frac{(CAS_i - PM)}{(1-p)(CC - PM)} EVM_i \tag{8}$$

$$if \quad PM < CAS_i < (1-p)(CC - PM)$$

$$ETV_i = EVM_i \tag{9}$$

$$if \quad (CAS_i - PM) \geq (1-p)(CC - PM)$$

where *PM* is the welting point and coefficient *p* being the soil water reduction factor which depends on the type of crop and the maximum evapotranspiration during the time under consideration. Factor *(1-p)* is the most difficult to estimate for the different stages of the crop: what is the minimum proportion of useful water *(CC – PM)* for the crop to continue growing under potential conditions. Some authors propose constant values for the whole period of the crop. Others suggest exponential functions. Here a box-type function was proposed as shown in Fig.2 in which the upper limit of the function represents 65% of available water and the lower limit 50%.

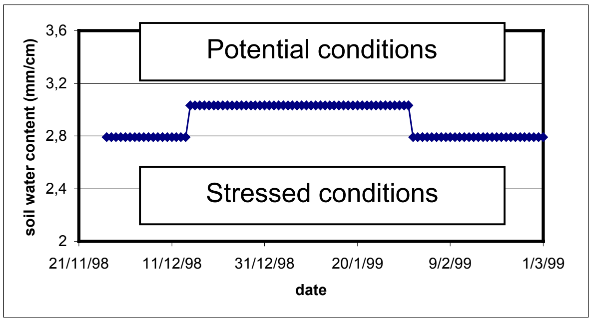

Fig. 2: Limit of potential conditions using a box-type function

The relation between real and maximum evapotranspiration according to the availability of soil water content is shown in Fig.3.

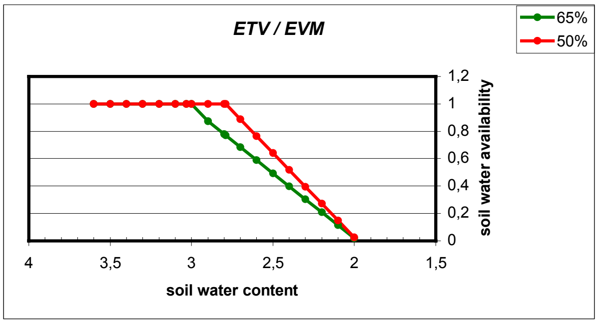

Fig. 3: Relation between real and maximum evapotranspiration as a function of soil water content.

3. DESCRIPTION OF THE EXPERIMENT

The simple balance model was applied to simulate soil water content during the development of maize cops (*Zea mays L.*) in the area of Balcarce, Buenos Aires province (Argentina). Data were collected during a field experiment at the Unidad Integrada Facultad de Ciencias Agrarias UNMdP-EEA INTA, during the 1998-99 growing season. Maize (Dekalb 639) was planted on October 16 with a density of 85,714 pl/ha on a 0.7 m row spacing. The maize plot was split into two different water regimes. In one the soil was covered with a black polyethylene of 100-μm thickness in order to prevent evaporation from the soil (RRRC). In the other the soil was left uncovered (RRRD). Both plots were irrigated by sprinkling to maintain an available water level for potential growth, and were pest and disease free. The maize plot was fertilized with 150 kg/ha nitrogen when plants were in the V6 phenological stage (Ritchie and Hanway classification, 1982). During the experimental period RRRD received 93.1 mm of rainwater and 225.3 mm of irrigated water. RRRC received 320.0 mm of irrigated water during the same period.

Soil water content was measured at 2-5 day intervals by the gravimetric method in the 0-0.1 m layer and by the neutron scattering method (Troxler 4300 Neutron Probe, Troxler E.L. Inc., Res. Triangle Park, NC) in the layers of 0.1-1.40 m for RRRC and 0.1-1.00 m for RRRD. Meteorological data were collected at the INTA Balcarce agro meteorological station, located 300-m away from the plots. Also, aerial biomass of plants was sampled six times during the growing season on some particular phenological stages. The total green leaf area of the sample was estimated from the green leaf area of a subsample measured with an area meter (model LI-3000, Li-Cor Inc., Lincoln, NE), multiplying the measured leaf area by the ratio between the dry weight of leaves of the sub- and total-samples. The green leaf area index *(L)* was obtained by multiplying the mean green leaf area per plant by the number of plants per square meter.

Field studies were conducted on a Balcarce loam (illitic thermic loam petrocalcic Paleudoll) and 130 m above sea level. Annual average precipitation in Balcarce is 910 mm. The simulation was performed from 11/27/1998 to 03/01/1999.

4. DISCUSSION AND RESULTS

The daily soil water content in a column 100 cm. deep was calculated using the irrigation and rainfall data.

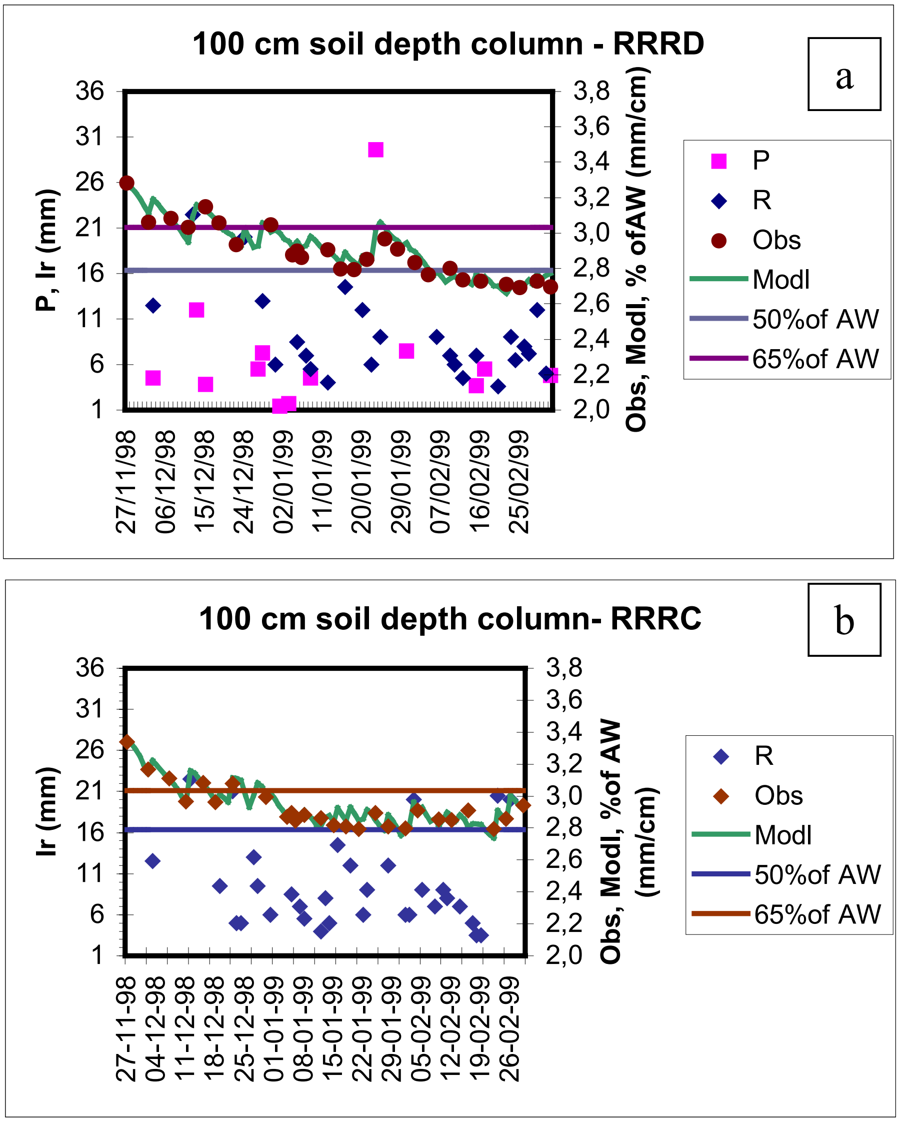

Fig. 4: Simulation of daily soil water content in a 100 cm deep column, a. uncovered plot (RRRD), b. covered plot (RRRC).

Although the crop was sown in the middle of October, the simulations began at the end of November. Observed data of soil water content was used as initial information for the first day of simulation.

Both simulations represented adequately the data observed (Fig.4a and b) with a good response to irrigation and rainfall in the case of RRRD for the data observed averaging the whole soil column. As from the first week of February the water content in the whole of the RRRD 100-cm column indicated that the crop was slightly below potential conditions. The representation of the soil evaporation and plant transpiration was adequate, according to the behavior observed in both RRRD and RRRC.

A statistical evaluation was made to quantify the differences between observed and modeled values. The statistics used were the mean square error (MSE), the normalized mean square error (NMSE) and the mean fractional bias (FB). Table 1 shows the results obtained.

Table 1: Summary of the statistical model evaluation

Plot	**MSE**	**NMSE**	**FB**
RRRD	0.0060	0.0007	0.022
RRRC	0.0009	0.0001	0.007

It can be seen that the model worked well as indicated by the low MSE and NMSE values and the mean fractional bias although there was a slight tendency to overestimate, indicated by the sign of this statistical indicator.

5. CONCLUSIONS

Estimation of the soil water content is one of the more complicated parameters but it is necessary for evaluation of heat transference through the soil in estimation of energy balances in crop covered surfaces. In this case, a simple soil water content evaluation model was used in a 100-cm deep column for maize. The model was compared to data from two different cultivation conditions. Uncovered (RRRD) and covered (RRRC) soil was used. During the simulated period the rainfall was 93.1 mm and the plots were irrigated with 225.3 mm (RRRD) and 320 mm (RRRC) of water. The volume of water entering the system allowed the crop to develop under practically potential conditions. The model adequately predicted the evolution of the daily water content in the column studied with low errors in the estimation. The parameterizations used for each of the different terms considered proved to be adequate for the configuration of the system studied in the experiment. The behavior of the model with different crops will be studied under the same soil conditions and an attempt will be made to forecast the water content in different layers and for different crops.

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