

## ASSESSING FAO-56 MODEL TO ESTIMATE TABLE OLIVE WATER CONSUME UNDER SOIL WATER DEFICIT CONDITIONS

Giovanni Rallo<sup>1</sup>, Mario Minacapilli<sup>1</sup>, Giuseppe Provenzano<sup>1</sup>

<sup>1</sup> Department of Agro-Environmental Systems (SAGa), Università degli Studi di Palermo, Viale delle Scienze Ed. 4 - 90128, Palermo, Italy.  
\* rallo.giovanni@gmail.com

### Abstracts

Agro-hydrological models can be considered an economic and simple tool to quantify crop water requirements. In the last two decades, agro-hydrological physically based models have been developed to simulate mass and energy exchange processes in the soil-plant-atmosphere system. Although very reliable, due to the high number of required variables, simplified models have been proposed as simple tools to quantify crop water consumes. The main aim of the paper is to assess, for a Sicilian orchard of table olive, the suitability of FAO-56 agro-hydrological model to estimate the crop transpiration under soil water deficit conditions. The model validation is carried out by means of measurements of sap-flow and soil water contents, acquired during three years of field observations. An amendment of the model is suggested in order to take into account the water stress function and the soil water uptake ability as experimentally evaluated. The results show that the modified model improves the estimation of crop transpiration and soil water content, considered that the associated RMSEs resulted higher than the corresponding values obtained with the original version of the model.

**Keywords:** FAO-56 Agro-hydrological model, Water stress Function, Table Olive

### Introduction

The quantification of crop water requirements of irrigated land is crucial in the Mediterranean regions, characterized by semi-arid conditions. The knowledge of the actual transpiration fluxes allows to correctly estimate the crop water requirements and to dispose of irrigation management strategies aimed to increase the water use efficiency. Physically based agro-hydrological models, although very reliable, in relation to the high number of variables and the complex computational analysis, cannot often be used. The use of simplified agro-hydrological models may therefore represent a useful and simple tool for irrigation scheduling.

FAO Irrigation and Drainage Paper 56 (Allen *et al.*, 1998) is a standard reference to estimate crop evapotranspiration.

It provides a comprehensive description of the widely accepted Penman-Monteith method to estimate reference evapotranspiration from standard weather data and procedures to compute actual crop evapotranspiration under standard and non-standard (stressed) conditions. The original publication also includes a spreadsheet (Idaho University, [www.kimberly.uidaho.edu/water/fao56/index.html](http://www.kimberly.uidaho.edu/water/fao56/index.html)) for irrigation scheduling under standard conditions. In this spreadsheet program the root zone is treated as a single layer from which water is depleted by the crop. The spreadsheet was developed for full irrigation and cannot be directly used for scheduling irrigation under water stress conditions. For this reason, a first amendment of the algorithm was proposed by Rallo *et al.* (2011). Another limit of the model is related to the water stress function controlling the kinetic of the crop water uptake from the bucket. The model describes the water stress by means of a coefficient  $K_s$  linearly depending on the soil water content ( $SWC$ ), in the range of  $SWCs$  between a critical value and the wilting point.

The shape of the transpiration reduction function depends on several factors and particularly on eco-physiological processes, like plant resistance/tolerance/avoidance to water stress, as well as on soil water availability in the root zone. In xerophytes like olive groves, a convex shape of the  $K_s(SWC)$  has been recognized (Rallo *et al.*, 2011) and the reduction of actual transpiration becomes severe only under extreme water stress conditions.

The main objective of the work is to assess the suitability of FAO-56 spreadsheet program to simulate table olive water requirements

under soil water deficit conditions and to propose an amendment of the model aimed to consider a more realistic shape of the water stress function, as obtained by Rallo *et al.* (2011).

### Materials and Methods

The experimental layout used for the research has been previously illustrated (Cammalleri *et al.*, 2011). Here the suggested model amendment and the approach followed to estimate the critical values for the soil water status introduced in the water stress function are briefly presented. In particular the original linear water stress function  $K_s(SWC)$  is replaced with a convex shape, as experimentally obtained by Rallo *et al.* (2011) for olive orchards planted in the same experimental site. The values of  $K_s$  are expressed as a function of the relative depletion in the range of soil water contents between a value,  $SWC^*$ , below which water stress occurs and the minimum value,  $SWC_{min}$ , corresponding to the highest stress recognized in the field. Under the investigated conditions,  $SWC^*$  is equal to 16% whereas, as suggested from Trambouze and Voltz (2000), the  $SWC_{min}$  was assumed as the minimum  $SWC$  measured at the end of the cropping season, in place of the wilting point; the latter is in fact often subject to measurement errors and that does not take into account the real ability of the crop to extract water from the soil. Therefore, for the investigated site,  $SWC_{min}$  is assumed equal to 8%, lower than the measured wilting point, equal to 13.0%. The simulations were run for the irrigation seasons 2009, 2010 and 2011 (from April 15, DOY 105, to September 30, DOY 273).

The average seasonal value of basal crop coefficient of olive orchards used for the simulation was 0.65, as recommended from Allen *et al.* (1998). For all the investigated years,  $SWC$  equal to the field capacity ( $0.33 \text{ cm}^3 \text{ cm}^{-3}$ ) was assumed as initial condition, according to the previous abundant rainfall occurred in the site.

### Results and Discussions

Fig. 1 shows the temporal dynamic of observed and simulated  $SWC$  (1a, 1b, 1c), of potential evapotranspiration,  $ET_0$ , and of crop transpiration (1d, 1e, 1f), obtained using FAO-56 dual crop coefficient approach, during all the investigated irrigation seasons.

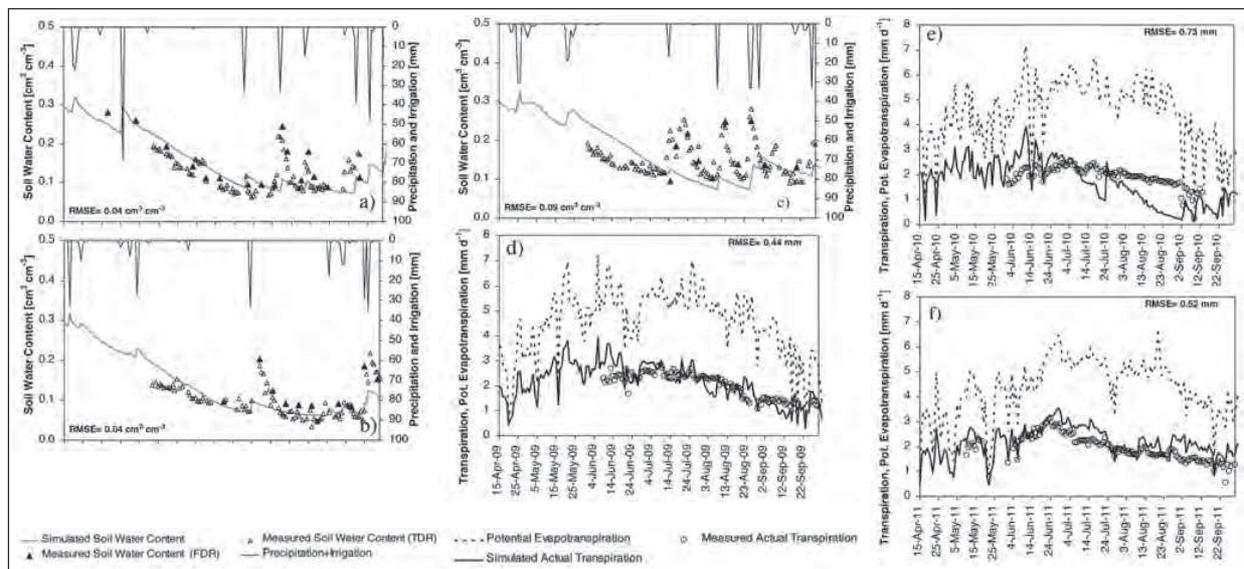


Fig. 1. Temporal dynamic of observed and simulated soil water content and actual transpiration fluxes during 2009, 2010 and 2011.  $ET_0$  and total water supply are also shown.

In the same figures, the water supply (precipitation plus irrigation) is shown.

A substantial agreement between measured and estimated average soil water contents is observed. For all the seasons, average RMSE is in fact about  $0.05 \text{ cm}^3 \text{ cm}^{-3}$ . The differences observed immediately after each water supply could be consequent to an inaccurate computation of the average SWC. In fact, irrigation practiced by trickle irrigation plant, determines a quite high horizontal and vertical gradients of SWC in the root zone. For this reason, for trickle irrigation systems and sparse vegetation, it is crucial to choose the correct position of the SWC sensors.

As can be observed in Fig. 1d-f, even the seasonal trends of simulated transpiration fluxes in all the investigated periods, resulted quite similar to those observed on daily integrated sap flow measurements, with RMSE values of about  $0.58 \text{ mm d}^{-1}$ . Despite the reasonable global agreement between simulated and measured transpiration trends, some local discrepancies can be observed after each water supply and the consequent drying process.

In particular after any input of water in the soil, actual estimated transpiration shows a peak value due the quick decrease of the depletion. This result occurs because the model does not take into account the water redistribution process in the soil and the effect of tree capacitance related to the increasing stored water in the leaves, branch and trunk of the tree.

Moreover, during drying periods of the soil, the local underestimation of transpiration fluxes can be also due to the neglected contribute to transpiration of the water stored in the leaves, branch and trunk of the tree.

In order to improve the FAO-56 model framework and its parameterization, further researches are however necessary to investigate on the effect of tree capacitance on actual transpiration.

## Conclusions

In the paper, the suitability of FAO-56 agro-hydrological model to estimate table olive transpiration under soil water deficit conditions was investigated. The model validation was carried out by means of

sap-flow and soil water contents measurements, acquired during three years of field observations. On the basis of the differences between measured and estimated soil water contents and actual transpirations simulated with the original version of the model, an amendment was suggested in order to introduce a more realistic shape of the water stress function and the minimum soil water content corresponding to the highest crop water stress level recognized in the field. In this way it was possible to take into account the roots uptake ability, as experimentally evaluated.

The modified model allowed to improve the estimation of crop transpiration and soil water content, according to the evaluated RMSEs, that resulted higher than the corresponding values obtained with the original version of the model.

## Bibliography

- Allen, R.G., Periera, L.S., Raes, D., Smith, M., 1998. Crop Evapotranspiration: Guidelines for Computing Crop Requirements, Irrigation and Drainage Paper No. 56. FAO, Rome, Italy, pp. 300.
- Rallo G., Agnese C., Minacapilli M., Provenzano G. 2011. Comparison of SWAP and FAO agro-hydrological models to schedule irrigation of wine grape. Accepted for publication (July 2012) on Journal Irrigation and Drainage. DOI: 10.1061/(ASCE)IR.1943-4774.0000435.
- Rallo, G., Agnese, C., Minicapilli, M. and Provenzano, G. 2011. Modelling eco-physiological response of table olive trees (*Olea Europaea L.*) to water stress. Submitted for publication on Agricultural Water Management. Nov. 2011.
- Cammalleri C., Rallo G., Agnese C., Ciralo G., Minacapilli M., Provenzano G. 2011. Combined use of eddy covariance and sap flow techniques for partition of ET fluxes and water stress assessment in an irrigated olive orchard. Submitted for publication on Agricultural Water Management. Dec. 2011.
- Trambouze W., Voltz M., 2000. Measurement and modelling of the transpiration of a mediterranean vineyard. Agric. For. Meteorol. 2913, 1–14.