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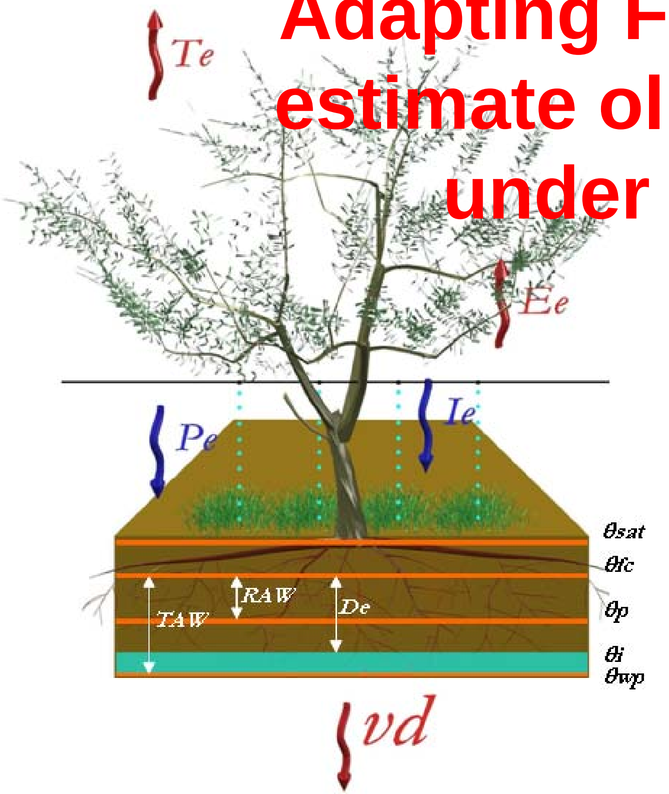
EUROPEAN GEOSCIENCES UNION

Adapting FAO-56 Spreadsheet Program to estimate olive orchard transpiration fluxes under soil water stress condition



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Wien, April 22 – 27, 2012

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 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.

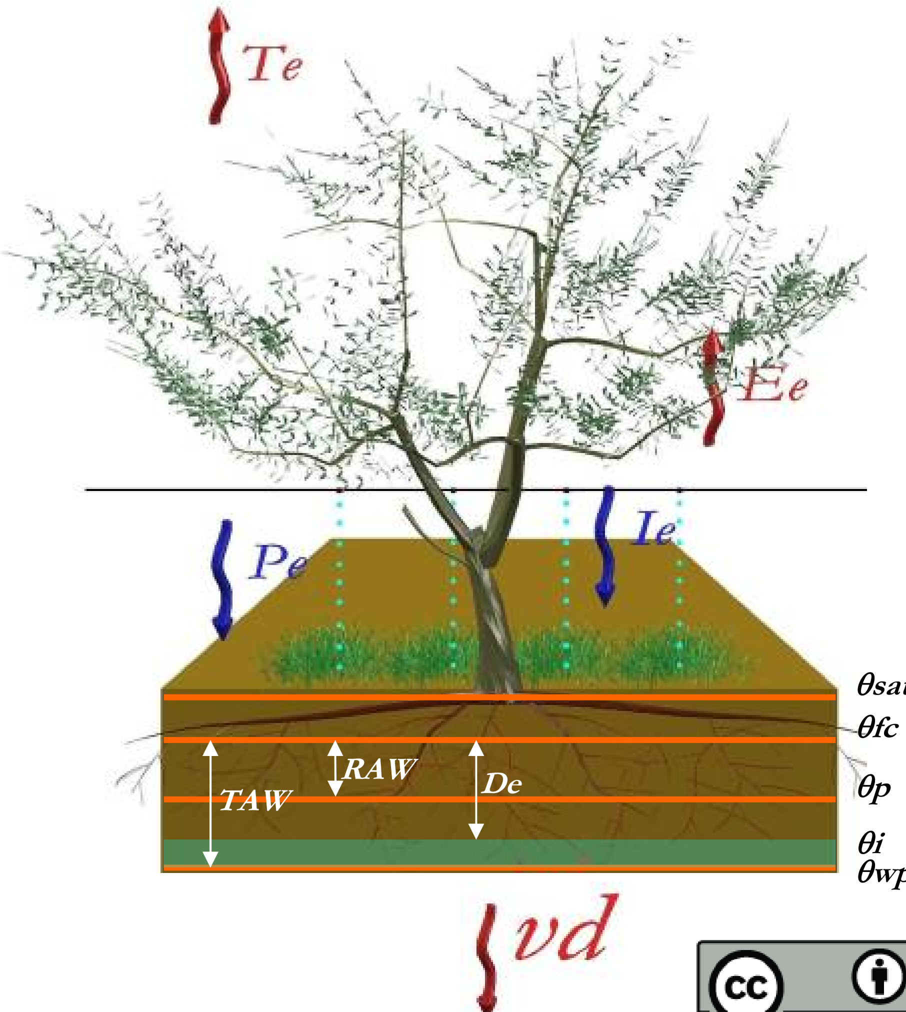
The use of simplified agro-hydrological models may therefore represent a useful and simple tools for irrigation scheduling.

FAO-56 Agro-hydrological Model (Allen et al., 1998)

$$D_{r,i} = D_{r,i-1} - P_i - RO_i - I_i - CR_i + ET_{c,i} + DP_i$$

FAO Irrigation and Drainage Paper 56 (Allen et al., 1998) is a standard procedures to compute actual crop evapotranspiration under standard and non-standard (stressed) conditions.

In this spreadsheet program, the root zone is treated as a single layer from which water is depleted by the crop.



FAO-56 Agro-hydrological Model

$$D_{r,i} = D_{r,i-1} - P_i - RO_i - I_i - CR_i + ET_{c,i} + DP_i$$

INPUT

Weather
(Temp, Prec., Rad, UR, Wind)

Crop
K_{cb}, K_e, Height, Root depth
Irrigation (only for calibration)

Soil
Hydrological property

CORE

Penman-Monteith mod. FAO

$$ET_{ref}$$

$$E_p = K_e * ET_{ref}$$

$$T_p = K_{cb} * ET_{ref}$$

Crop Evapotranspiration

$$TAW = 1000 * (\theta_{fc} - \theta_{wp}) * Z_r$$

$$p = \frac{1}{\alpha_p + \beta_p ET_c} - 0,1(5 - No_{cg})$$

$$RAW = p * TAW$$

Scheduling Irrigation

$$E_a = K_r * E_p$$

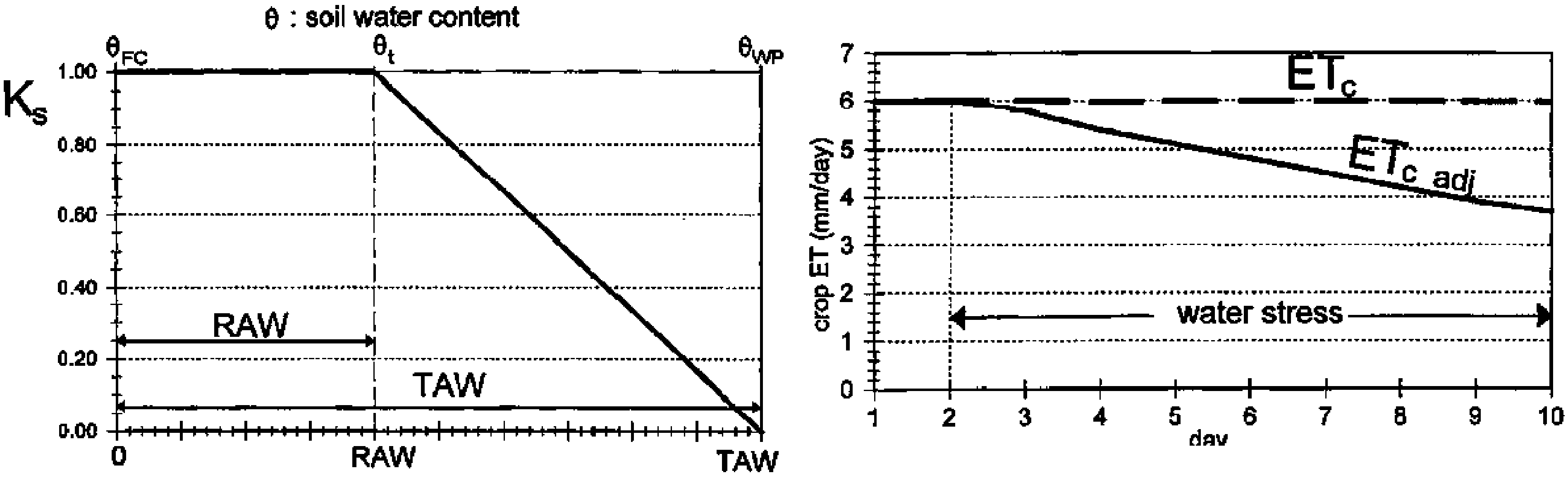
$$T_a = K_s * T_p$$

OUTPUT

Real ET Irrigation amount

Soil Water Depletion

FAO-56: Water Stress Function



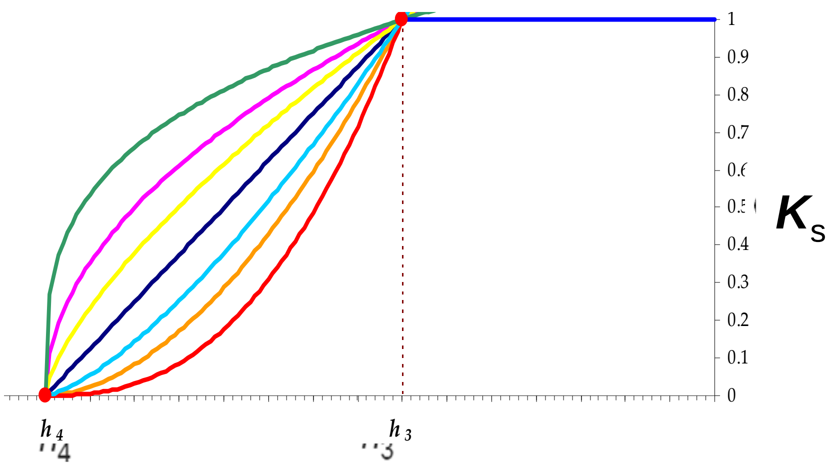
The water stress coefficient K_s is used to reduce K_{cb} under conditions of water or salinity stress.
For the i-th depletion value $D_i > RAW$:

$$K_s = \frac{TAW - D_i}{(1 - p)\,TAW}$$

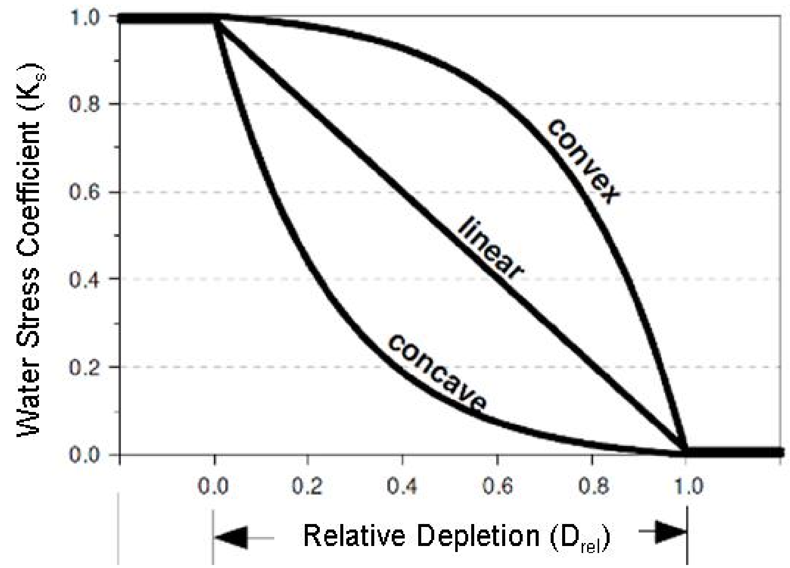
TAW=total available soil water in the root zone (mm)
p=fraction of *TAW* that a crop can extract from the root zone in absence of water stress.

Crop water stress models

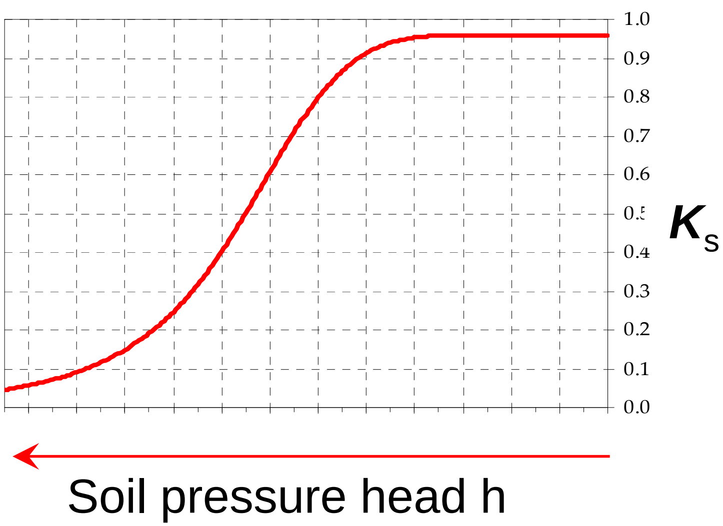
Modified Feddes



Steduto et al., 2009



Homaee (1999)



$$K_s = 1 - \frac{e^{D_{rel}\ f_{shape}} - 1}{e^{f_{shape}} - 1} \qquad D_{rel} = \frac{\theta^* - \theta}{\theta^* - \theta_{\min}}$$

θ^* = threshold value of the SWC below which water stress occurs

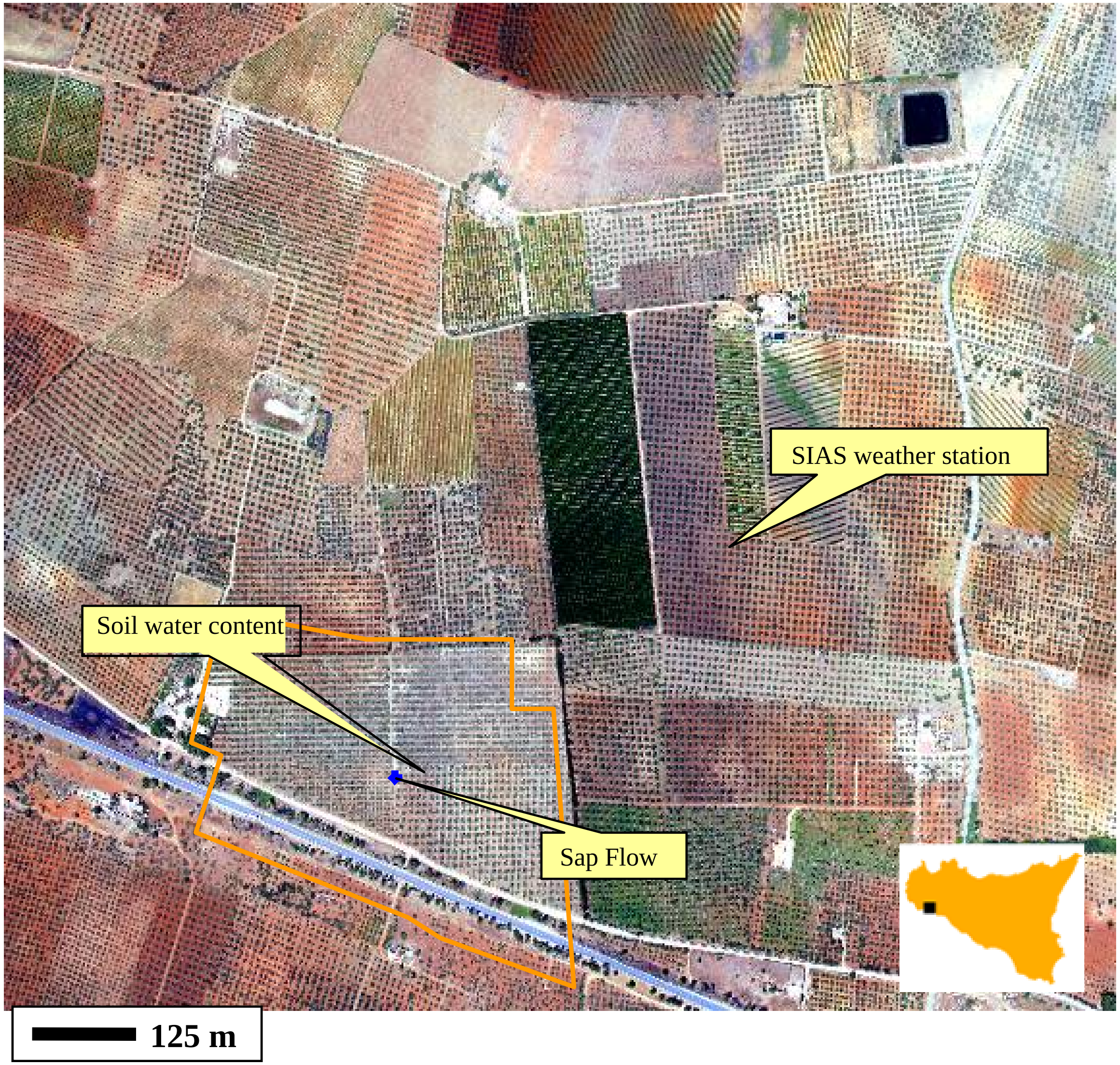
$\theta_{\min}$ = SWC for which the stress is at its full strength.

Objectives

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.

On the basis of the differences between measured values of soil water contents and actual transpirations with the corresponding simulated by the original version of the model, an amendment is suggested to consider a more realistic shape of the water stress function, as obtained by Rallo et al. (2011).

Experimental layout



Farm “Tenuta Rocchetta”

Lat. 37 ° 38’ 36,8”

Long. 12° 50’ 49,8”

Extension: 30 Ha

Crop: Table Olives

8 x 5 m (250 plant/Ha)

Fraction coverage: 0.35

Soil: Clay-Loam (USDA)

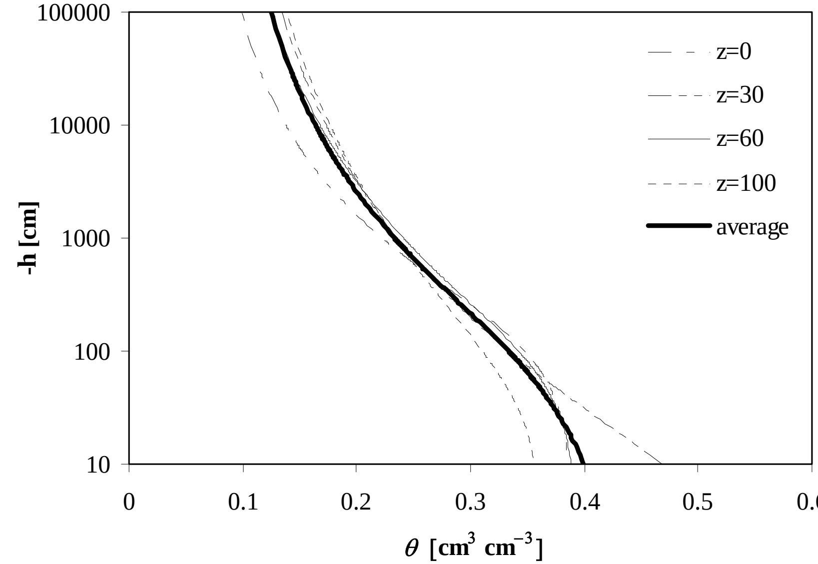
Irrigation: four 8 l/h drip/plant

Years of monitoring: 2009, 2010 and 2011

Preliminary analysis

Evaluation of van Genuchten parameters of the SWRC

Z [cm]	ρ_b [Mg m^{-3}]	van Genuchten parameters: θ_r [cm^3 cm^{-3}]	θ_s [cm^3 cm^{-3}]	α [cm^{-1}]	n [-]	m [-]
0	1.36	0.05	0.39	0.008	1.32	0.24
30	1.31	0.05	0.56	0.0147	1.19	0.16
60	1.38	0.06	0.39	0.0138	1.23	0.18
100	1.61	0.06	0.36	0.0223	1.18	0.15

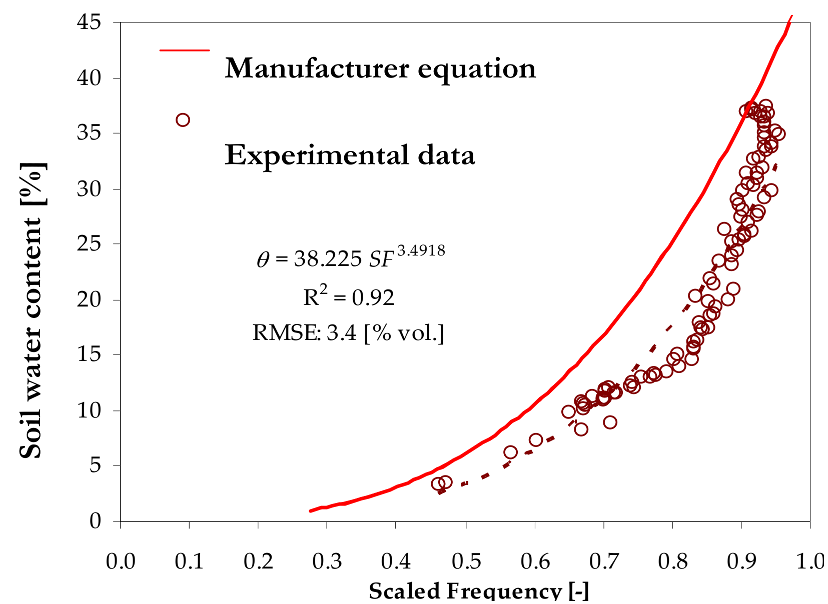


Calibration of FDR sensor

$\theta = 38.225\ SF^{3.4918}$

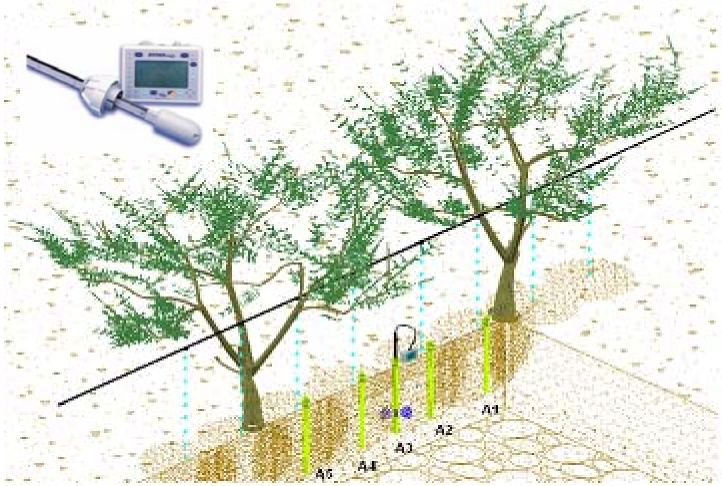
$R^2 = 0.92$

RMSE: 3.4 [% vol.]



Soil water content measurements

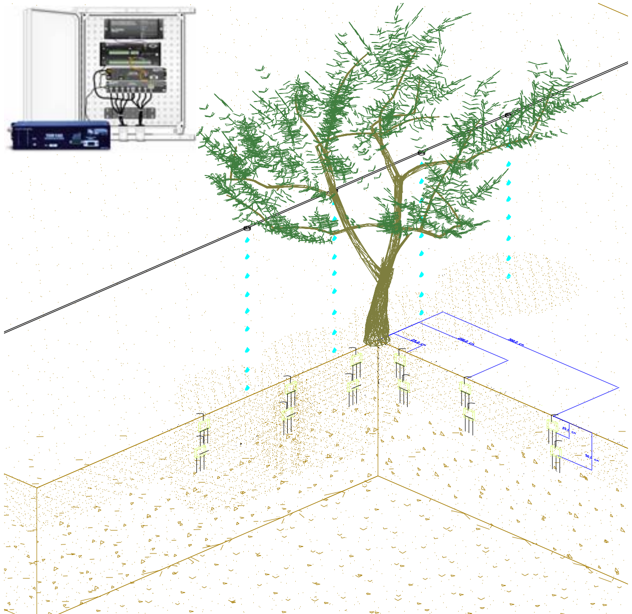
FDR (Frequency Domain Reflectometry)



Five 1.0 m access tubes were installed where the maximum root water uptake occurs after irrigation.

Measurements were manually carried out every 10 cm, weekly, before and after irrigation.

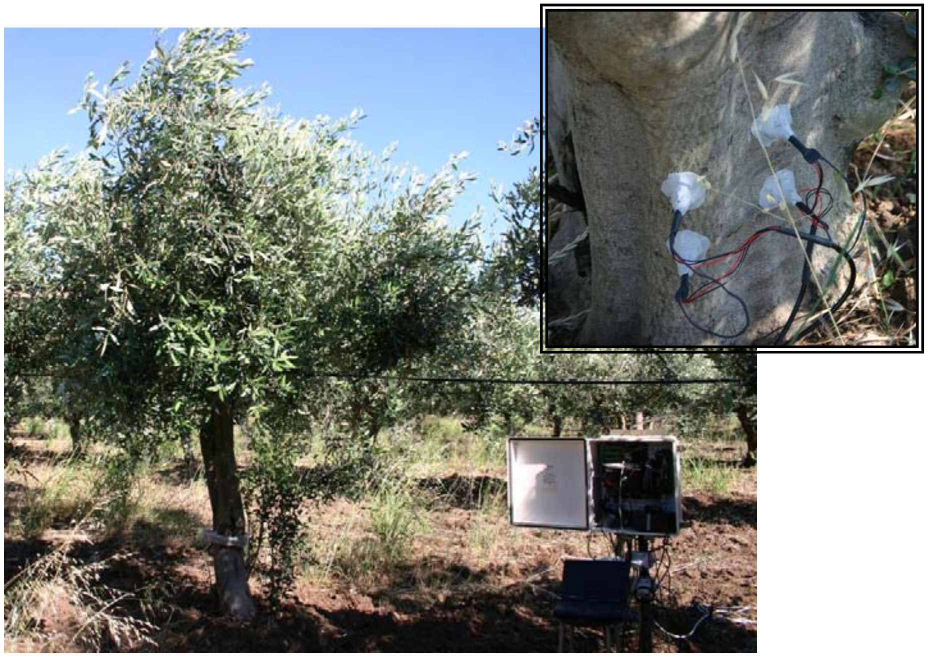
TDR (Time Domain Reflectometry)

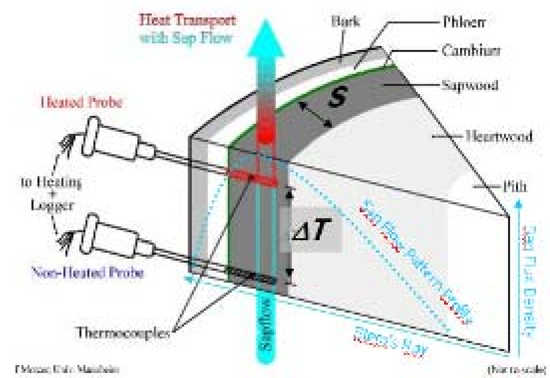


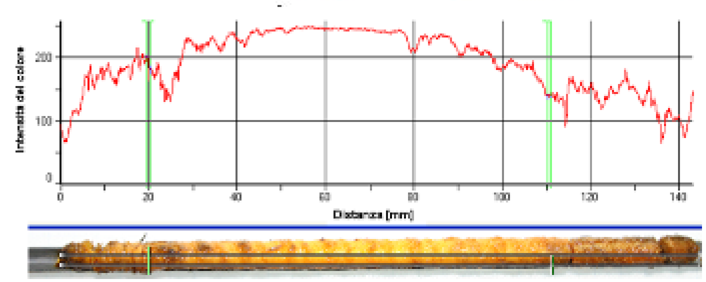
Nine TDR probes were horizontally installed along three profiles at 15, 45 and 70 cm depth. A Campbell TDR100 was used and measurements of SWC were stored into a CR1000 datalogger every 3 hours.

Sap flow measurements

Thermal Dissipation Probe



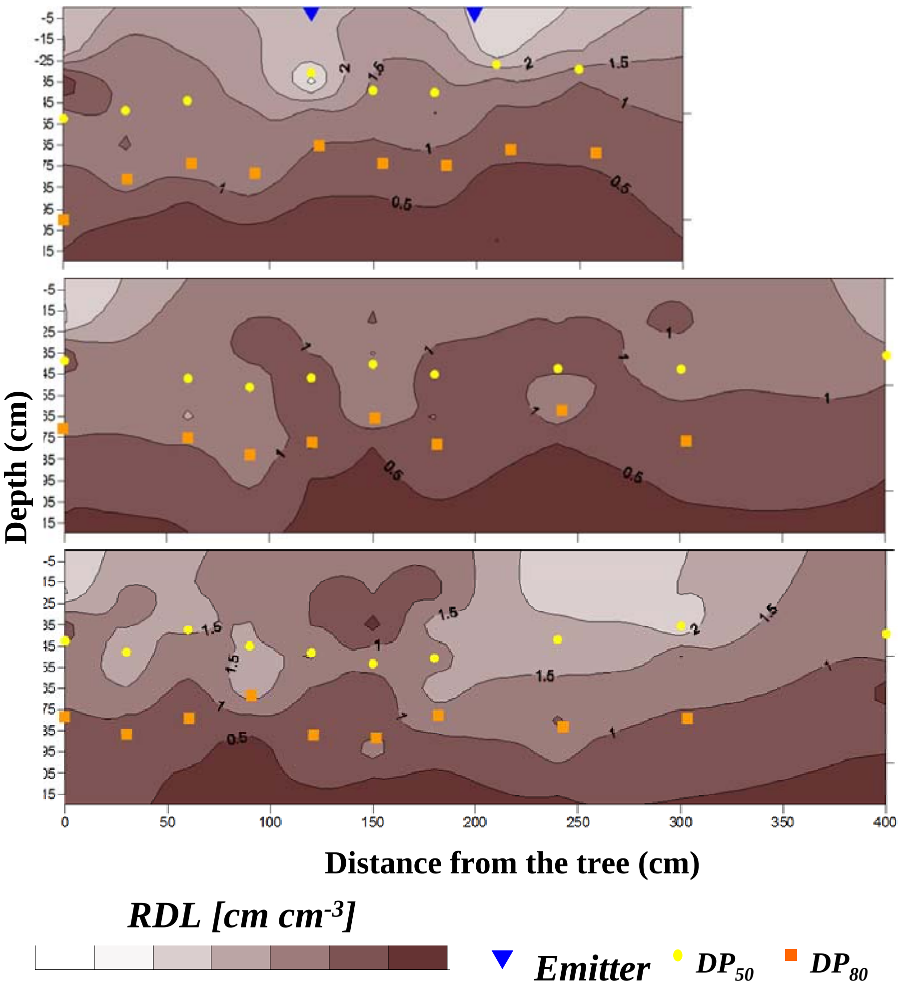


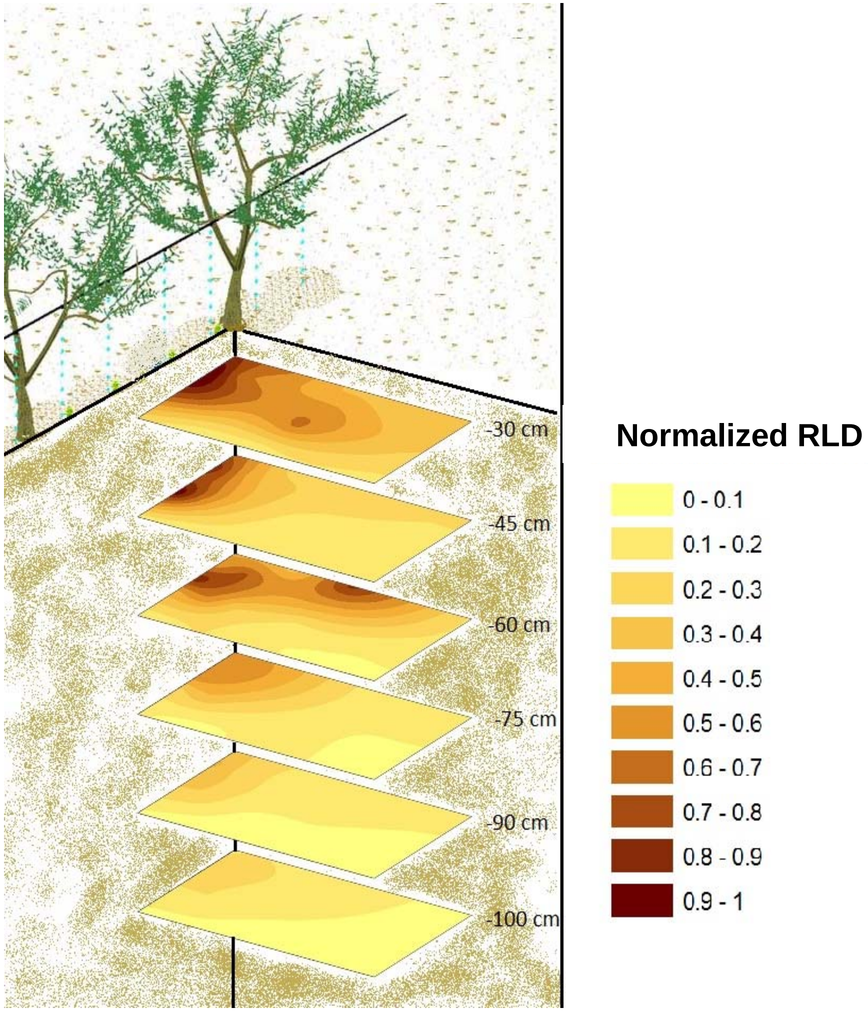


Integration of sap fluxes at a daily scale, allowed to determine actual transpiration as the volume of water consumed by a single plant, assuming negligible the effect of the tree capacitance related to the increasing/decreasing water stored in the leaves, branches and trunk.

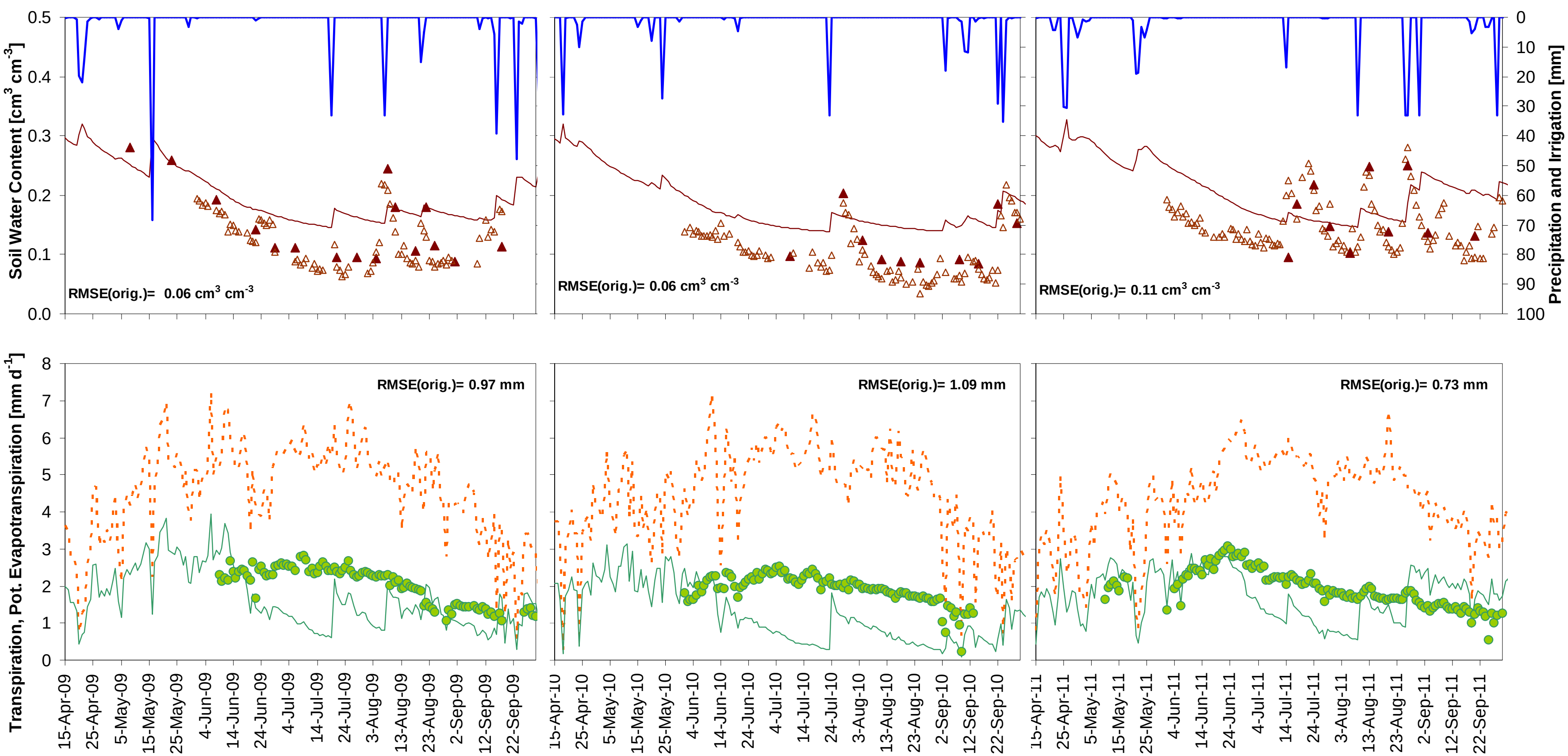
Root spatial distribution

Evaluation of the maximum root depth (*Zr*) where 80% of the roots are localized (*DP_{80}*)





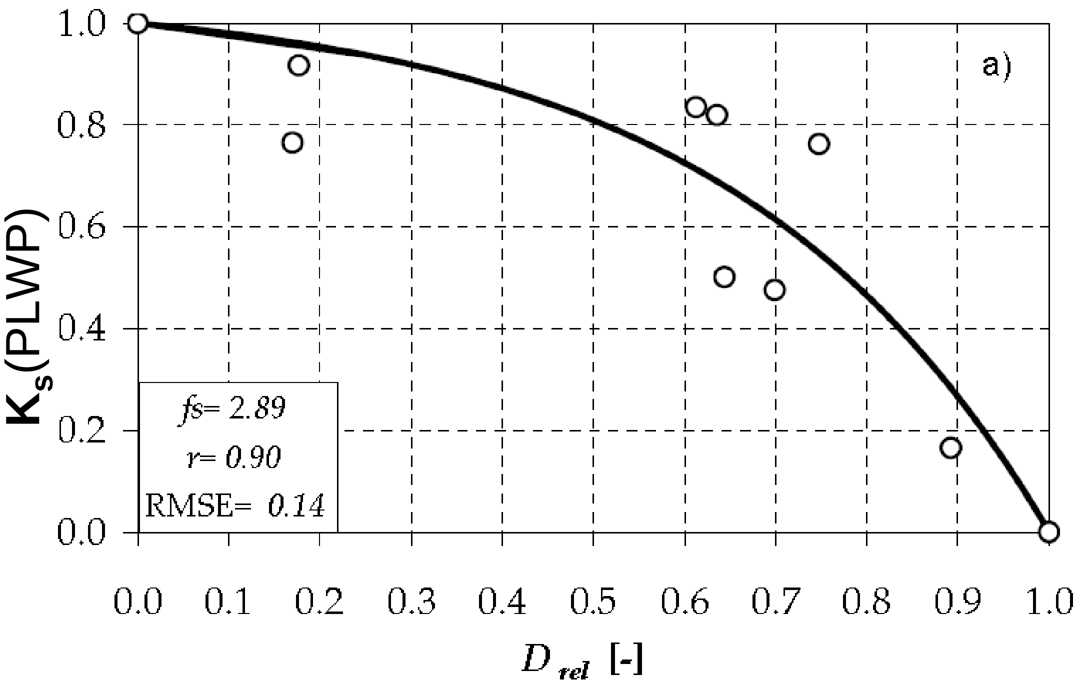
Results: Simulations with original FAO-56



The original model overestimates SWC because the linear water stress function does not reproduce correctly the root water uptake ability. In fact, for each fixed SWC the actual value of Ks coefficient results higher than the corresponding simulated value, and therefore, during stress periods, despite the higher simulated SWC, the model underestimates T_a.

Water Stress Function

Steduto et al., 2009



$$K_s = 1 - \frac{e^{D_{rel}\ f_{shape}} - 1}{e^{f_{shape}} - 1}$$

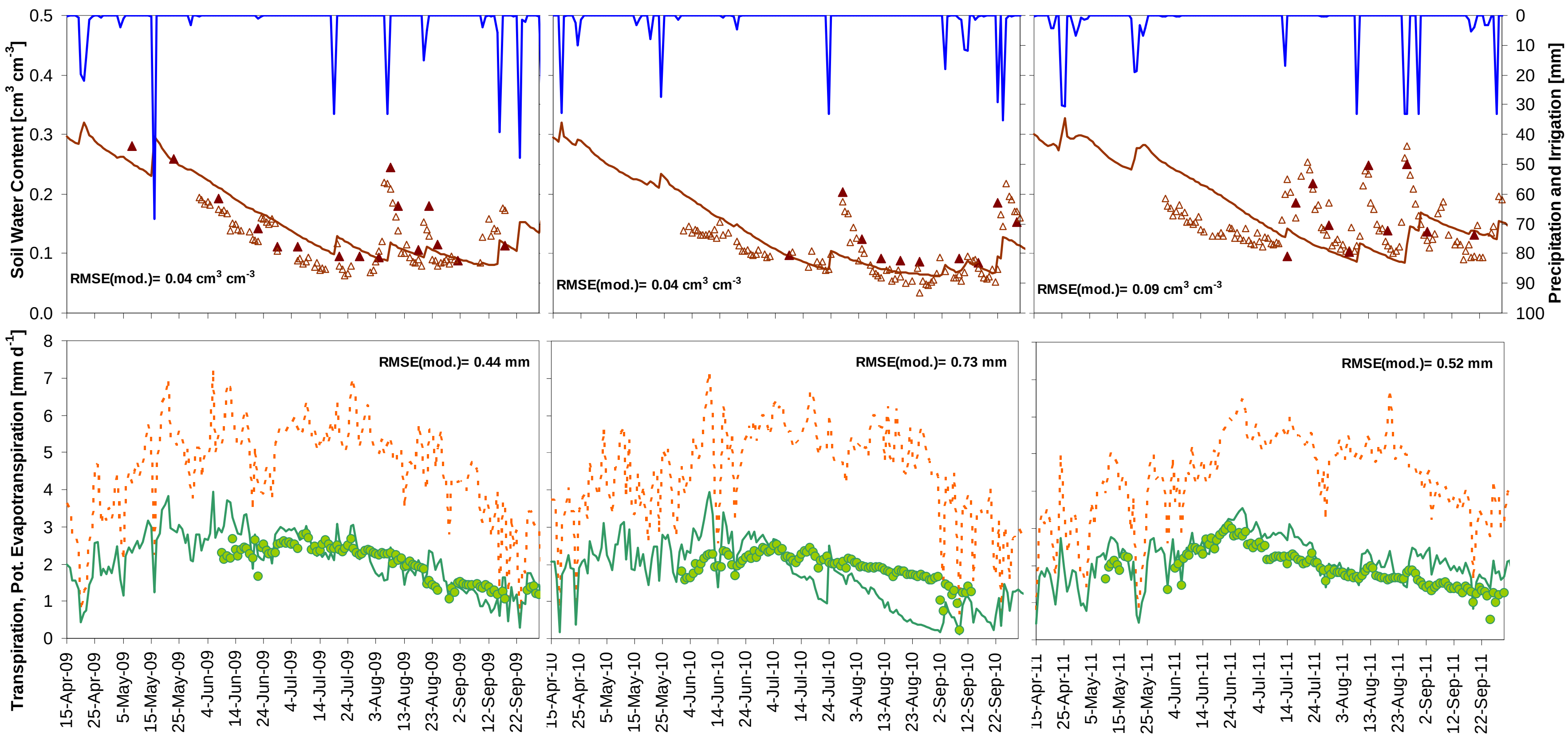
$$D_{rel} = \frac{\theta^* - \theta}{\theta^* - \theta_{\min}}$$

θ^* = 0.16 cm^3 cm^{-3}
$\theta_{\min}$ =0.08 cm^3 cm^{-3}

$\theta_{\min}$ was assumed as the minimum θ measured at the end of the cropping season, in place of the wilting point, as suggested from Trambouze and Voltz (2000), to take into account the real ability of the crop to extract water from the soil.

Rallo, G., Agnese, C., Minacapilli, 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.

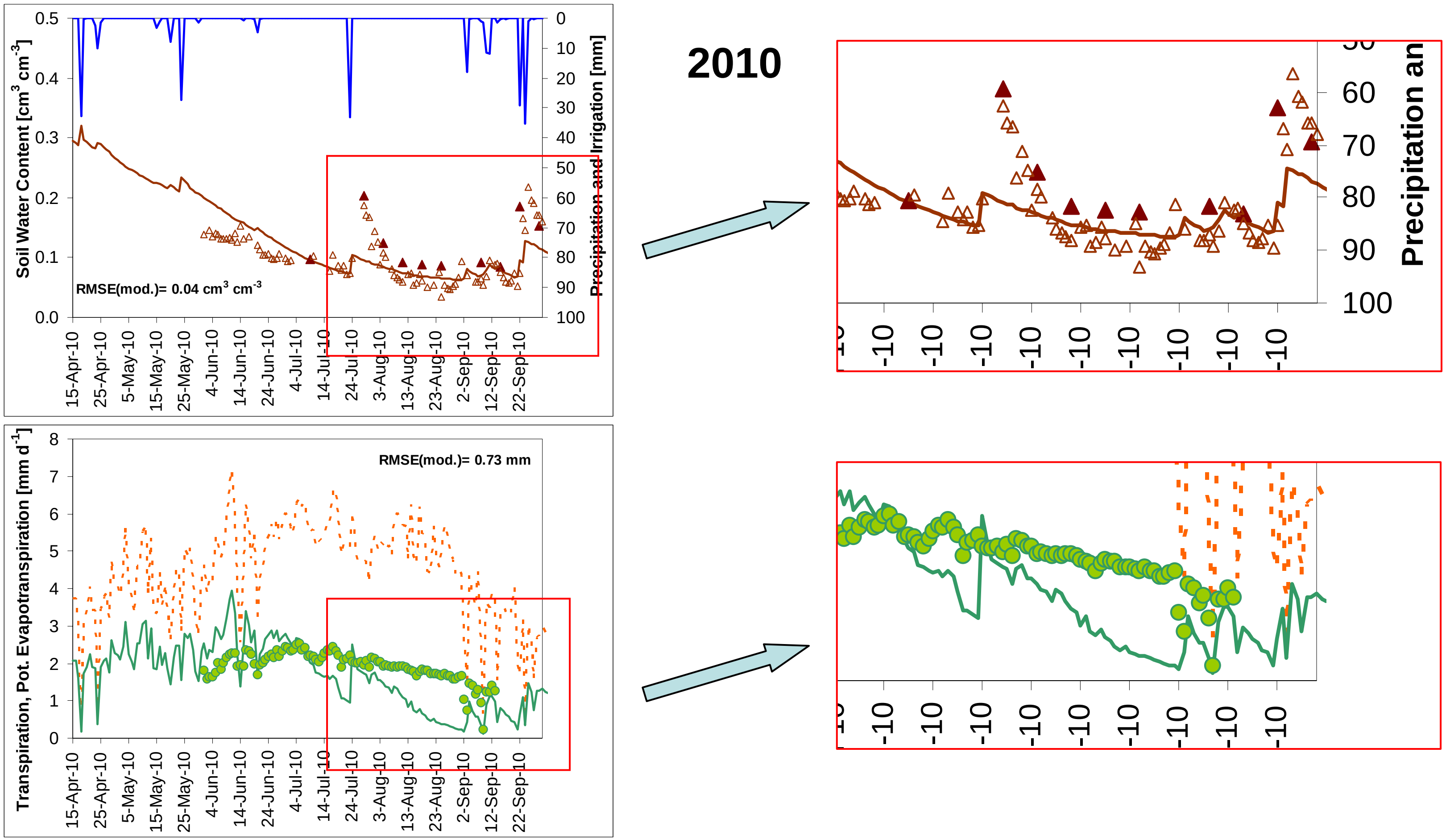
Simulations with modified FAO-56



RMSE	Ta [mm d^{-1}]	SWC [cm^3 cm^{-3}]
ORIGINAL		
all investigated seasons	0.92	0.08
2009	0.97	0.06
2010	1.09	0.06
2011	0.73	0.11
MODIFIED		
all investigated seasons	0.58	0.07
2009	0.44	0.04
2010	0.73	0.04
2011	0.52	0.09

A better performance can be obtained when a more realistic stress function is implemented in the model. In fact, SWCs in dry periods tend to decrease more than in the original version, becoming similar to the measured values. The enhanced root water uptake ability also determines a significant improvement of actual transpiration estimation.

Simulation with modified FAO-56



Local discrepancies between simulated and measured T_a observed at the end of the dry period 2010 could be due to the persistence of SWC near to $\theta_{min.}$ These differences can be consequent to the neglected contribute of tree capacitance on actual transpiration. Further investigation are necessary in order to improve the stress function under the most extreme water stress conditions.

Conclusions

•The suitability of FAO-56 agro-hydrological model to estimate table olive transpiration under soil water deficit conditions was investigated.

•The performance of the model, in its original version, was verified 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 simulated soil water contents and actual transpirations, 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 level of crop water stress 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 a general improvement of crop transpiration and soil water content estimation, even if further investigation are necessary to consider the role of tree capacitance on the water stress function.


Thank you!
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