Modeling of citrus evapotranspiration under different water supply conditions: case study of Beni Khalled

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Introduction

Tunisia, with its Mediterranean climate, has good potential for citrus production, with 240,000 tonnes for the 2021-2022 season (the national citrus federation). However, in this region, where climate change is increasingly felt, water resources are becoming increasingly scarce. Therefore, as the citrus sector is a large consumer of water, it is important to accurately determine its water requirements (evapotranspiration) to fight against the water deficit and therefore to ensure a rational management of water resources.

At present, different methods are available for determining evapotranspiration. Some methods are based on direct measurements such as sap flow (Er. Raki et al.,2011; Peddinti et al.,2019), lysimeter (Tanner et al., 1967 ; Petillo and Castel, 2007) and the Eddy Covariance (Rana et al.,2005 ; Er. Raki et al.,2009; Pedditni et al.,2019). The last one the most suitable and precise but it is difficult to apply because of its costs and its need to a regular technical maintenance (Villalobos et al.,2000; Wullschleger et al.,2000). Often it is necessary to predict ET, so it must be modelled.

The Penman-Monteith evapotranspiration model (PM) is the most recommended among actual evapotranspiration (ET) models (Allen et al.,1998). The success of ET estimates depends on the calibration of PM model by modelling of two parametric data : aerodynamic (ra) and bulk canopy resistances (rc). In the past, such papers have been use and calibrate this model to estimate evapotranspiration in hourly scale (Rana et al.,2005; Consoli et al.,2013). However, there works was limited to obtain coefficients calibration for 10 days of data representative all climatic conditions (Rana et al.,2005) and three months of data during good water status (Consoli et al.,2013). The aim objective of this study is to understand the behaviour of model for citrus in contrasting water status (well irrigated and under different stress levels). To calibrate the PM model for a total period from January 2014 to December 2018 which is characterised by interannual variability of climatic conditions, the Bowen ratio (H/LE) was used as a stress index to classify periods stress from the lowest to the most severe level of stress.

study site and crop description

The study site is a citrus orchard managed by the Citrus Technical Center (CTA) located in the north-east of Tunisia, on the Cap-Bon peninsula. It has a total area of 4080 m^2. With a length of 68 m and a width of 60 m. The experimental field is planted with four naval orange cultivars "Navel Naveline", "New Hall", "Washington Navel" and "Lane Late" at a planting density of 4 × 5 m. It is surrounded by evergreen Cupressus windbreak trees, the orchard is drip irrigated with two ramps on the line spaced 1.5 m apart [4]. This area has a typical Mediterranean climate (average annual temperature of 17.7 ° C, total annual precipitation of 400 mm). The trees are 3 m high and cover the ground about 70%.

Used data : Eddy Covariance data

An Eddy Covariance station has been installed in the middle of the orchard since 2013 allowing the measurements of the three wind speed components and sonic temperature, the fluctuation of the humidity, the incident and reflected short and long waves radiations and the three-soil heat flux. All the sensors were linked to a datalogger (CR3000, Campbell Sc, USA). The power is assured by a battery and solar panel. The first four parameters were acquired and stored at a frequency of 20Hz. The other variables were measured each second and were recorded after an average of 15 minutes.

These hourly data was subject to quality control so that only good quality data was kept, and there was used in this study without going throught the gap filling stage. Beside there use in comparaison with the estimates of PM model, the Eddy Covariance data was used to calculate the Bowen ratio as the ratio between the sensible and latent heat fluxes to be used as a stress index.

Modelling citrus evapotranspiration

Citrus orchard evapotranspiration (ET) was analysed using the Penman-Monteith model. ET was calculated at hourly scale using :

$$\lambda E = \frac{\Delta A + (\rho C_p D / r_a)}{\Delta + \gamma(1 + r_c / r_a)} \quad (1)$$

where A = Rn - G (W m-2), ρ is the air density in kg m-3 , Δ is the slope of the saturation pressure deficit versus temperature function in kPa C-1 , γ is the psychrometric constant in kPa C-1 , Cp is the specific heat of moist air in J kg-1 C-1 , D is the vapour pressure deficit of the air in kPa, rc is the bulk canopy resistance in s m-1(it is not constant for irrigated crops (Rana et al.2005), so, in our study, it is calculated from equation (1) by introducing the E values calculated by Eddy Covarianc, and ra is the aerodynamic resistance in s m-1 (more details in Rana et al.2005) .

- Calibration of the model

The calibration of the PM model was done by the analysis of the relationship between rc/ra and r*/a (where r* is a climatic resistance (more details in Rana et al.2005)) and after incorporation of this relation in equation (1). Where : $\frac{r_c}{r_a} = a\frac{r^*}{r_a} + b$

Calibration was done for different conditions: well irrigated and under stress conditions (four levels of stress according to Bowen ratio : level 1 (weak stress: 1<bowen<2); level 2 (moderate stress: 2<bowen<3); level 3 (severe stress: <3<bowen<4) and level 4 : very severe stress: bowen>4)

Results

- Coefficient calibration

Table1 :

Coefficient	All conditions	Well-watered	Level1 of stress	Level 2 of stress	Level3 of stress	Level4 of stress
a	**2.83**	**0.46**	**1.21**	**2.01**	**3.81**	**6.63**
b	**50.5**	**20.6**	**19.3**	**21.7**	**54.7**	**49.1**

From table 1, the slope value (a) increases gradually from well-irrigated conditions to the most severe stress levels. To properly verify the behaviour of « a », we set the value of b to that found for the conditions of no stress, and this verifies that it is the slope that bears the sign of stress (a= 1.12 ; 1.93 ; 4.38 and 6.9) respectively from level 1 to level 4 of stress.

- Comparison between the evapotranspiration measured by Eddy Covariance and estimated by PM model

a- well-watered conditions

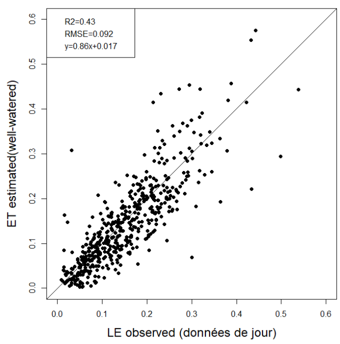

Figure 1: Comparison of ET estimated by PM model (ET) with ET measured by Eddy Covariance (LE), will-waterd periods (2014-2018)

b-stress conditions

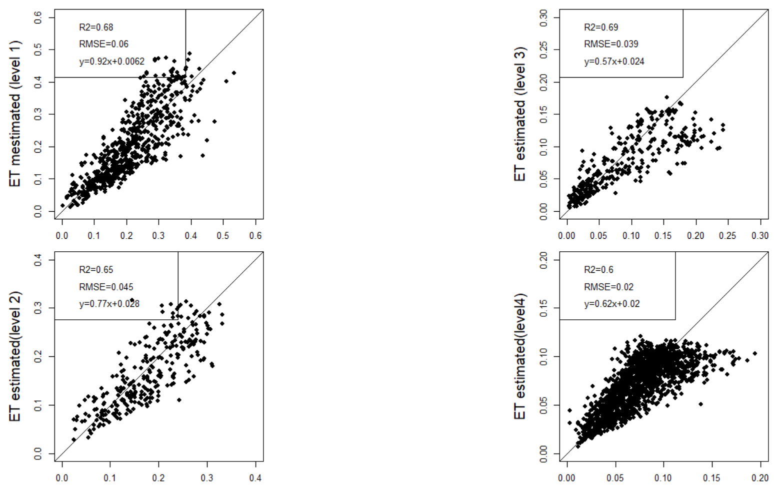

Figure 2: comparison of ET estimated (ET) by PM with ET measured by Eddy Covariance (LE) for all levels of stress (2014-2018)

The graph 1 showed the comparison between evapotranspiration estimated by PM model with that observed in well-watered periods, the results showed a good correlation with R2=0.68 and RMSE=0.092.

The graph 2 present the comparison between estimations and observations for all levels of stress. The results showed that model simulated well the evapotranspiration and had a good correlation for all level. The RMSE decrease from level 1 to level 4 from 0.045 to 0.02.

Conclusion

Model calibration according to stress levels improved the results and showed a good correlation between estimated and measured evapotranspiration so that the RMSE decreases from 0.092 for the no-stress conditions down to 0.02 for the most severe stress level

For the comparison of the estimated evapotranspiration with that measured by Eddy Covariance, using the calibration coefficients proposed by Rana et al. (a=0.226 and b=0.0042), we found an RMSE equal to 1.14 and for those proposed by Consoli et al.2013 (a=0.364 and b=0.0422), the RMSE is equal to 0.83. So, these coefficients are not coherent for our conditions. For the entire period from 2014 to 2018, the established calibration coefficients were (a=2.83 and b=50.5), for this coefficient, R2 was 0.12 and RMSE was 0.09.

For the calibration coefficients, the results show that one of these coefficients varies according to the stress levels (the more the level increases, the steeper the slope) which allows us to conclude that this coefficient is not empirical as expected in the literature.

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