REFERENCE EVAPOTRANSPIRATION: CHOICE OF METHOD

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INTRODUCTION

During the last fifty years, a large number of empirical methods have been developed and used to estimate ET_0 (reference evapotranspiration). Testing the accuracy of these methods, under a new environment, has proved to be costly, time consuming and to have a limited global validity. In addition, this requires lysimeters and well-trained personnel.

In 1990, an expert panel has analysed various ET_0 estimation methods under diverse climatic conditions. This study has revealed a widely varying performance of the different equations and, acknowledging that Penman and all methods require local calibration, has reached the following conclusions:

- Radiation methods show good results in humid climates where the aerodynamic term is relatively small.
- Temperature methods require local calibration but Hargreaves method usually gives more reasonable ET_0 results than other temperature driven equations.
- Pan evapotranspiration method proved to be erratic depending on microclimate conditions and on the rigour of the weather station maintenance.
- Relatively accurate and consistent performance of the Penmam-Monteith approach in both arid and humid climates has been indicated.

One of he consequences of these large studies is that the **FAO IRRIGATION AND DRAINAGE PAPER 56** recommends Penman-Monteith method as the sole standard method.

Nevertheless, even in places provided with the required devices and where a large number of accurate crop water balance experiments have been conducted, as in Córdoba (southern Spain; 38º N), large interanual weather differences can make difficult the choice of the best fitted ET_0 calculation method. In this area, during summer, Penman-Monteith usually underestimates ET_0 and Hargreaves, a more empirical method, seems to give better results (Villalobos & Orgáz; personal communication). In addition, a previous study, realised at the

European Union level, found Original Penman equation more reliable than Penman-Monteith approach (Choisnel et al., 1992).

No universal solution may be found. However, it is clear that if we want to use a complex crop model to help growers in establishing the schedule and amount of their irrigation, we must make sure that the main equations of the water balance are adequate for the area and period of the year. In addition, in places where Penman-Monteith cannot be calculated due to a lack of data (vapour pressure deficit (VPD), wind speed or solar radiation) we should consider that empirical methods, such as a calibrated Hargreaves, can be more reliable than Penman-Monteith calculated with estimations of VPD or any other variable.

Finally, we consider that a simple model, based on ET_0, a time step for climatic data input of 5-10 days, and crop coefficients can be enough when the main objective is to help growers in decision making. Highly/Very mechanistic models should be reserved for research purposes due to the difficulty in obtaining all the parameters required without a guarantee that the greater complexity would give a better prediction.

In order to highlight the above comments, we have used different methods for ETo estimation, at two Spanish locations: Córdoba (38ºN, 90 m altitude; semiarid climate) and Lugo (43ºN, 480 m altitude; humid area).

METHODS

- Penman-Monteith: (P-M) (Monteith, 1965 & 1981). Equations are that recommended by FAO Irrigation and drainage paper 56 (Allen et al., 1998).
- FAO-Modified Penman Method. As described by Doorembos and Pruitt (1976). The equations are that presented by Smith (1988) for a grass reference.
- Penman. Using the version of the Penman equation (1948) for grass presented by Maff (1967) and modified by Mason (1978).
- Penman Open Water Method (P. Open Water). Using the version of the Penman equation (1948) for open water presented by Penman (1963)
- Priestley-Taylor (P-T): as calculated by the DSSAT3.5 model with a coefficient & of 1.1(htpp://www.icasanet.org).
- Penman-FAO: as calculated by the DSSAT3.5 model (htpp://www.icasanet.org).
- Hargreaves: Hargreaves equation presented in FAO Irrigation and drainage paper 56 (Allen et al., 1998).
- Evaporation method (A pan). As described by FAO Irrigation and drainage paper 56 (Allen et al., 1999).

RESULTS

Table 1. Daily reference evapotranspiration calculated through different equations at Córdoba, southern Spain, from December 1986 to July 1987 and from December 1987 to July 1988.

Córdoba (38ºN, 90 m altitude)

Monthly ET	Penman-Monteith*	Penman*	Penman-FAO*	P. Open Water*	Priestley-T (DSSAT)	P-FAO (DSSAT)	Hargreaves
	mm/d	mm/d	mm/d	mm/d	mm/d	mm/d	mm/d
Dec 86	1.0	0.7	1.2	1.3	1.5	1.6	1.8
Jan 87	0.9	0.8	1.2	1.3	1.5	1.4	1.5
Feb 87	1.5	1.4	1.8	2.1	2.2	2.3	1.7
Mar 87	2.6	2.6	3.2	3.5	3.4	4.0	2.0
Apr 87	3.5	3.7	4.4	4.8	4.5	5.3	2.9
May 87	5.1	5.2	6.2	6.7	6.1	7.6	6.2
Jun 87	6.5	6.6	7.8	8.3	7.1	9.0	7.4
Jul 87	6.3	6.4	7.5	8.0	7.0	8.6	
Dec.-Feb. Average	1.1	1.0	1.4	1.6	1.7	1.8	1.7
Mar.-May Average	3.7	3.8	4.6	5.0	4.7	5.6	3.7
June-July Average	6.4	6.5	7.7	8.2	7.1	8.8	7.4
Global Average	3.4	3.4	4.2	4.5	4.2	5.0	3.4

	Penman-Monteith*	Penman*	Penman-FAO*	P. Open Water*	Priestley-T (DSSAT)	P-FAO (DSSAT)	Hargreaves
	mm/d	mm/d	mm/d	mm/d	mm/d	mm/d	mm/d
Dec 86	0.8	0.7	1.0	1.2	1.3	1.2	2.2
Jan 87	0.8	0.7	1.0	1.2	1.3	1.2	1.8
Feb 87	1.6	1.4	1.9	2.2	2.3	2.3	2.4
Mar 87	2.8	2.8	3.4	3.8	3.8	4.3	3.2
Apr 87	3.4	3.6	4.3	4.7	4.3	5.2	3.3
May 87	4.1	4.3	5.1	5.6	5.1	5.9	4.9
Jun 87	5.4	5.5	6.1	6.7	5.1	6.1	6.1
Jul 87	5.3	5.6	6.5	7.2	7.7	8.2	
Dec.-Feb. Average	1.1	0.9	1.3	1.5	1.6	1.6	2.1
Mar.-May Average	3.4	3.6	4.3	4.7	4.4	5.1	3.8
June-July Average	5.4	5.6	6.3	7.0	6.4	7.2	6.1
Global Average	3.0	3.1	3.7	4.1	3.9	4.3	3.4

* Calculated with AWSET program (cranfield University, UK)

Table 2. Daily reference evapotranspiration calculated through different equations at Lugo, northern Spain, from January to October 1998 and from January to October 2000.

Lugo (43ºN, 480 m altitude)

Monthly ET	Penman-Monteith*	Penman*	Penman-FAO*	P. Open Water*	Priestley-T (DSSAT)	P-FAO (DSSAT)	Hargreaves	A Pan
	mm/d	mm/d	mm/d	mm/d	mm/d	mm/d	mm/d	mm/d
Jan 98	1.1	1.0	1.2	1.4	1.1	1.4	0.8	0.8
Feb 98	1.5	1.4	1.8	2.1	2.0	2.0	1.7	0.9
Mar 98	2.6	2.6	3.1	3.5	3.0	3.5	2.4	1.8
Apr 98	2.1	2.4	2.7	3.2	2.7	3.1	2.3	1.4
May 98	3.7	4.0	4.7	5.2	4.6	5.2	3.9	2.9
Jun 98	4.2	4.5	5.3	5.8	5.2	5.9	4.6	3.6
Jul 98	4.5	4.8	5.7	6.2	5.6	6.3	4.5	3.7
Aug 98	4.4	4.7	5.6	6.1	5.6	6.6	4.6	3.5
Sept 98	2.8	2.9	3.3	3.8	3.3	3.8	2.9	1.7
Oct 98	1.7	1.6	2.0	2.2	2.0	2.1	1.7	0.9
Jan.-Mar. Average	1.7	1.7	2.0	2.3	2.0	2.3	1.6	1.1
Apr.-Jun. Average	3.3	3.6	4.2	4.7	4.1	4.8	3.6	2.6
Jul.-Sept. Average	3.9	4.1	4.9	5.4	4.8	5.6	4.0	3.0
Global Average	2.9	3.0	3.5	3.9	3.5	4.0	3.0	2.1

Monthly ET	Penman-Monteith*	Penman*	Penman-FAO*	P. Open Water*	Priestley-T (DSSAT)	P-FAO (DSSAT)	Hargreaves
	mm/d	mm/d	mm/d	mm/d	mm/d	mm/d	mm/d
Jan 00	0.8	0.6	1.0	1.1	1.3	1.1	0.9
Feb 00	1.2	1.1	1.4	1.6	1.5	1.5	1.4
Mar 00	2.1	2.1	2.6	3.0	2.8	3.1	2.3
Apr 00	1.8	2.0	2.3	2.7	2.3	2.6	2.2
May 00	3.2	3.5	4.1	4.6	4.1	4.5	3.8
Jun 00	4.6	4.9	5.9	6.4	5.8	6.6	5.2
Jul 00	4.2	4.5	5.3	5.8	5.2	5.9	4.3
Aug 00	4.1	4.3	5.1	5.6	5.2	5.8	4.4
Sept 00	3.0	3.0	3.5	4.0	3.8	4.2	3.4
Oct 00	1.5	1.4	1.7	2.0	1.9	1.9	1.8
Jan.-Mar. Average	1.3	1.3	1.7	1.9	1.9	1.9	1.5
Apr.-Jun. Average	3.2	3.5	4.1	4.6	4.1	4.6	3.7
Jul.-Sept. Average	3.7	3.9	4.6	5.1	4.7	5.3	4.1
Global Average	2.6	2.7	3.3	3.7	3.4	3.7	3.0

* Calculated with AWSET program (cranfield University, UK)

CONCLUSIONS

At both locations, differences between ET_0 estimations obtained through the different calculation methods are sufficiently large to show that we should stress the importance of employing the right ET_0 equation for advising growers on water management through a modelling approach.

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