EVAPOTRANSPIRATION ESTIMATES FOR WATER BALANCE SCHEDULING IN THE UK

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INTRODUCTION

One means of determining when irrigation should be supplied is through the use of a soil water balance, or soil water budget. This involves keeping an 'account' of water input into the soil (rainfall and irrigation) and water output (evapotranspiration and drainage) on a daily basis. Although rainfall and irrigation amounts are easily measured on the farm, estimating the evapotranspiration is a complex procedure. Most water balance irrigation scheduling methods are based on a daily estimate of the reference evapotranspiration[1] (ET_o), which is then modified according to the crop being grown, its stage of growth and the soil water content.

There are two basic alternatives to estimating the daily rate of evapotranspiration:

1. To use a physically based equation, such as the Penman, or Penman-Monteith equations to estimate ET_o from daily weather records, or

2. To measure the evaporation from some other, wet surface and relate this to ET_o.

WEATHER BASED METHODS

Long-term averages

The Agricultural Climate of England and Wales (Ministry of Agriculture Fisheries and Food, 1976) presents average potential evapotranspiration figures for each month of the year for agro-climatic regions of England and Wales. However, these average figures conceal considerable year-to-year variability. Local weather stations
If a farmer is on good terms with the local met office station or agricultural college, it may be possible to obtain daily weather data (air temperature, humidity, wind speed and sunshine) free of charge. A computer program (Hess, 1996) or spreadsheet (Hess and Stephens, 1993) can then be used to calculate ETo using the Penman, or Penman-Monteith equation.

Table 1 shows that in the peak year, ET_o may be at least 30mm/month higher than the average year. Perhaps, more critically, in the lowest year, ET_o may be 40mm/month less than the average. Scheduling using average values can therefore lead to serious under or over irrigation in all but 'average' years.

[1]Reference evapotranspiration is taken to be the potential evapotranspiration from a well watered, short green grass surface.

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Table 1 Range of average monthly ET_o for Silsoe (1962-96), mm/month

	Maximum	1 in 5 dry year	**Average**	Minimum	1996
April	64	59	**54**	40	58
May	99	90	**79**	54	77
June	127	103	**92**	61	115
July	124	109	**96**	54	112
August	112	91	**79**	53	90
September	64	55	**49**	29	59

MORECS

Daily ET_o for the previous week can be supplied by the Met. Office Rainfall and Evaporation Calculation System (MORECS). Weather data are collected from a network of synoptic weather stations and interpolated for grid squares covering the whole of the UK. The interpolated values are then used to calculate ET_o using and Penman 'type' approach (Thompson et al., 1981). Weekly reports are sent to the farm by fax at a charge of about £9.00 / week.

Automatic Weather Stations

An automatic weather station can record the necessary weather data on the farm, usually at hourly or shorter time intervals and store the data on a computer. A computer program, such as AWSET (Hess, 1995) can be used to calculate ET_o using the Penman-Monteith equation. There are several automatic weather stations on the market in the UK ranging in price from less than £1,000 to over £4,000, however, a system suitable for irrigation scheduling should cost less than £2,000.

Although automatic weather station have the ability to monitor weather over very short time intervals, it has been shown that the improved accuracy resulting from using hourly weather data over daily averages has a negligible effect on the timing of irrigation (Hess, 1996).

EVAPORIMETERS

The evaporation of water from some device can be measured and related to ET_o.

Evaporation pans

In many parts of the world, irrigation is scheduled by use of a Class 'A' evaporation pan (Doorenbos, 1976). This is a 1.21m (4ft.) diameter circular pan filled with water. The daily rate of evaporation from the pan is determined from the change in water

level (adjusted for rainfall). However, the pan evaporation may be 25% to 100% greater than ET_o depending on the location of the pan and the weather conditions. Published tables (Doorenbos and Pruitt, 1977) suggest that for UK the ratio of ET_o to pan evaporation would be ≈0.8, although Figure 1 shows that for Silsoe in 1996, the ratio of the 10-day average ET_o to pan evaporation was only 0.63.

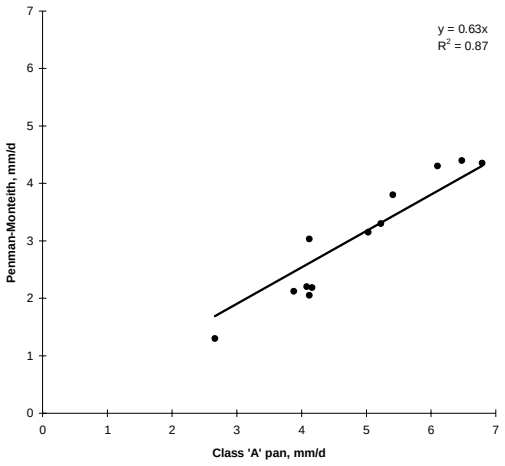


Figure 1 Relationship between 10-day average ET_o and Class 'A' pan evaporation for Silsoe (June - September 1996).

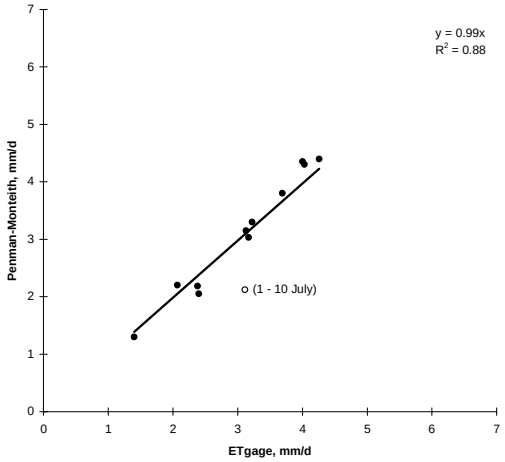


Figure 2 Relationship between 10-day average ET_o and ETgage™ evaporation for Silsoe (June - September 1996).

Atmometers

Whereas an evaporation pan measures the evaporation of water from an open surface, an atmometer measures evaporation from a wet, porous surface, commonly a ceramic disk. Atmometers have been used since the early 1900's to study plant transpiration, however in recent years the ceramic plate has been covered by green canvas or Gore-Tex® to more accurately simulate the transpiration from a plant. The so-called 'modified atmometer' (Altenhofen, 1985) has been compared with Penman ET in Colorado (Broner and Law, 1991; Altenhofen, 1992) and Israel (M. Meron, *pers. com*.) and a close agreement has been observed. The ETgage™, made in Colorado, USA, is available with different covers to simulate different crops. It sells for $230 (≈£140).

Figure 2 shows the relationship between 10-day average Penman-Monteith ET_o and evaporation from ETgage (a commercially available modified atmometer) for Silsoe in the summer of 1996. It shows that on average, the ETgage is a very close approximation to Penman-Monteith ET_o (99%) and the scatter is generally low (R^2 = 0.88). However, on occasions the evaporation from the atmometer was considerably below Penman-Monteith ET_o.

EFFECT OF EVAPOTRANSPIRATION ESTIMATION METHOD ON IRRIGATION SCHEDULE

The effect of using four different methods to estimate ET_o on the timing of irrigation was tested during the 1996 season. The Irrigation Water Requirements (IWR) computer program (Hess, 1997) was used to simulate the irrigation schedule for maincrop potatoes grown on a medium textured soil for 25 May to 30 August 1996 using:

1. ET_o calculated by the Penman-Monteith equation from daily weather data collected at Silsoe College.

2. Evaporation from the ETgage™ located at Silsoe College.

3. Evaporation from a Class 'A' evaporation pan located at Silsoe College.

4. Long term average (1962-96) daily ET_o for each month for Silsoe.

The results are shown in Table 2. Assuming that the Penman-Monteith method is the most accurate, then using the ETgage™ would have resulted in the same total irrigation amount and a similar distribution of irrigation through the season. The biggest differences would have occurred in at the end of June / early July when using the ETgage™ would have resulted in the third irrigation being applied 11 days late. During this period, readings from the ETgage™ were unusually lower than the Penman-Monteith values (see Figure 2), possibly due to poor maintenance. The other irrigations would all have been within a few days of the ideal date.

Table 2 Predicted irrigation timing and amount using four estimates of ET_o for maincrop potatoes in Silsoe, 1996.

	Penman-Monteith		ETgage™		Class 'A' Pan		Long term mean	
Irrigation number	Date	Amount mm	Date	Amount mm	Date	Amount mm	Date	Amount mm
6	14-Jun	30	16-Jun	30	11-Jun	30	29-May	12
7	21-Jun	30	24-Jun	30	17-Jun	30	21-Jun	30
8	30-Jun	30	11-Jul	30	22-Jun	30	30-Jun	30
9	13-Jul	30	18-Jul	30	30-Jun	30	14-Jul	30
10	20-Jul	30	23-Jul	30	12-Jul	30	23-Jul	30
11	01-Aug	30	07-Aug	30	17-Jul	30	08-Aug	30
12					21-Jul	30		
13					31-Jul	30		
14					06-Aug	30		
Total*		240		240		330		222

* Five irrigations of 12mm each would have been applied prior to 25 May 1996. As no data were available for the ETgage™ prior to this date, the above comparison shows the effect of using different methods after 25 May 1996 only.

Using the Class 'A' evaporation pan, even with a local calibration, would have resulted in significant over irrigation in late June / July. Three extra irrigations, totalling 90mm would have been applied.

Using the long-term average ET_o would have resulted in an extra (unnecessary) 12mm irrigation during the scab control period (late May). However, this was compensated by missing the first 30mm application in mid-June. Irrigation dates from mid-June onwards were surprisingly close to those predicted using the real daily ET_o.

CONCLUSIONS

Where daily weather data are available, the Penman-Monteith equation should give the best estimate of reference evapotranspiration. The method has been shown to be reliable in a wide range of environments (Allen et al., 1994), provided that the weather data themselves are reliable. Where weather conditions are fairly consistent, spatially, then data from a nearby meteorological station, or interpolated by MORECS should be adequate. Where there is significant local variability, e.g. in coastal areas, an on-farm automatic weather station may be more appropriate.

The results from a single trial in Silsoe in 1996 suggest that, with careful maintenance and measurement, a modified atmometer such as the ETgage™, can give estimates of ET_o which are close to those obtained using the Penman-Monteith equation. Day-to-day values may differ as the gauge can only be read to ± 1mm, however, when averaged over the period of a typical irrigation cycle (10-days) the day-to-day errors cancel out and the impact on an irrigation schedule is small. Such a device would be an appropriate instrument to use for less sensitive irrigated crops and where the interval between irrigations is long (e.g. sugar beet). Caution need to be expressed however, as poor maintenance of the instrument can produce misleading results.

Although simple to construct and operate, an evaporation pan needs to be locally calibrated and does not give good agreement with the Penman-Monteith estimate. In the case study, relying on an evaporation pan would have resulted in significant over-irrigation. An evaporation pan would not be recommended for anything other than a rough guide to relative rates of ET.

Perhaps surprisingly, using the long-term mean monthly ET_o resulted in similar irrigation dates and amounts to using the actual daily values, emphasising that ET_o is much less variable from year to year than rainfall.

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