

2.8 Evapotranspiration

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Key points

- Evapotranspiration is the combined loss of water to the atmosphere from evaporation from soil and plant surfaces, and transpiration through plants.
- Many factors affect the rate of water loss by evapotranspiration – the weather, the crop, the environment and management.
- Crop evapotranspiration (ET_c) can be estimated using a crop coefficient (K_c) and a reference crop evapotranspiration (ET_o).
- The Penman-Monteith approach is the preferred method to estimating ET_o .
- Evapotranspiration is difficult to measure directly. It can be estimated using meteorological data or the Class A Pan.
- The Class A Pan must be correctly sited and maintained for meaningful estimates of ET_o to be made. It should only be used for estimates greater than 10 days duration.

Estimates of ET_o can be used to aid irrigation scheduling and calculate evaporative losses from storage and reticulation systems.

A thorough but straightforward introduction to evapotranspiration concepts and scheduling is provided in WATERpak Chapter 2.1 and should be sufficient for most on-farm purposes. The information in this chapter is included for additional background.

What is evapotranspiration?

Evapotranspiration (ET) is the collective term for water lost to the atmosphere by evaporation from a range of surfaces (rivers, dams, channels, soils and wet vegetation) and transpiration through plants. Transpiration results from the vaporisation of water within plant tissues and its subsequent loss through the small openings on the plant leaf called **stomata**.

Evaporation is the conversion of water from liquid to vapour. This process requires energy, energy provided by direct solar radiation and the air temperature. As water is lost to the surrounding air it becomes saturated, and evaporation will slow down if the wet air is not displaced by dry air. The replacement of this saturated air with dry air depends on wind

speed. Thus, solar radiation, air temperature, air humidity and wind speed all affect the rate of evaporation. Where soil is the evaporating surface, the degree of shading by the crop and the amount of water available at the soil surface will also affect evaporation. The meteorological factors driving evaporation also influence transpiration.

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between them. Apart from soil surface wetness, the evaporation from a cropped soil is mainly determined by the fraction of radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and shades more and more of the soil surface. When the crop is small, water is mainly lost by soil evaporation, but, as the crop develops and completely covers the soil surface, transpiration becomes the main process.

The ET rate is normally expressed in millimetres (mm) per unit time – it expresses the amount of water lost from a cropped surface in units of water depth. The loss of 1 mm of water is the loss of 10 m³ of water per hectare (10,000 litres per hectare).

Factors affecting evapotranspiration

Weather

The weather factors affecting evapotranspiration (ET) are radiation, air temperature, humidity and wind speed. The evaporation power of the atmosphere is expressed by the reference crop evapotranspiration (ET_0): it represents the ET from a standardised vegetated surface.

Crop

Crop type, variety and development stage affect the rate of ET from crops grown in large, well-managed paddocks. Differences in resistance to transpiration, crop height, crop roughness, reflection, ground cover and crop root characteristics result in different ET levels in different crop types under identical environmental conditions.

Environmental conditions

Factors that limit crop development reduce ET – for example, soil salinity, inadequate nutrition, soil compaction, diseases and pests. ET is also affected by groundcover, plant density and soil water content.

Management

The ET rate is also affected by management practices that affect the climate and crop. Here are some of the ET-related effects of management:

- Cultivation practices and irrigation method can alter the microclimate and affect the crop characteristics or the wetting of the soil and crop surface.

- Windbreaks reduce wind velocities and decrease ET rate of the field directly beyond the barrier.
- Micro-irrigation systems that apply water directly to the root zone of crops leave the major part of the soil surface dry, thereby limiting evaporation losses.
- Surface mulches, when the crop is small, substantially reduce soil evaporation.

Evapotranspiration concepts

Reference crop evapotranspiration (ET_0)

ET_0 is the evapotranspiration rate from a grass reference surface with specific characteristics. This reference surface resembles an extensive surface of green, well-watered grass with a uniform height of 12 cm, actively growing and completely shading the ground. The soil surface is moderately dry, resulting from a weekly irrigation frequency.

This concept was introduced to study the evaporative demand of the atmosphere independent of crop type, crop development and management practices.

ET_0 is only affected by climatic factors. Consequently, it can be computed from weather data. The Penman-Monteith method is recommended as the sole method for determining ET_0 because it closely approximates grass ET_0 , is physically based, and incorporates both physiological and aerodynamic parameters. Procedures have also been developed for estimating missing climatic parameters.

Crop evapotranspiration under standard conditions (ET_c)

Crop ET under standard conditions (ET_c) is the ET from disease-free, well-fertilised crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions. A crop coefficient (K_c) is used to estimate ET_c from the Penman-Monteith estimate for ET_0 , using the formula below:

$$ET_c = K_c \times ET_0$$

ET_c differs from ET_0 under the same climatic conditions due to differences in leaf structure, stomatal characteristics, aerodynamic properties and solar radiation reflectance. The crop coefficient for a given crop changes from sowing until harvest, as explained in WATERpak Chapter 2.1 and the DPI Note [Irrigation: water balance scheduling](#). Table 2.8.1 summarises the seasonal crop coefficients for various crops.



Table 2.8.1. Crop Coefficients (K_c) for major irrigated field crops.

Crop	K_c initial	K_c mid-season	K_c end of season
Barley	0.30	1.15	0.25
Chickpea	0.40	1.00	0.35
Cotton	0.35	1.15 – 1.20	0.70 – 0.50
Maize	0.30	1.20	0.35
Navy bean	0.40	1.15	0.35
Peanut	0.40	1.15	0.60
Sorghum	0.30	1.00 – 1.10	0.55
Soybeans	0.40	1.15	0.50
Sunflower	0.35	1.15	0.35
Wheat	0.30	1.15	0.25

Standard crop coefficients relate to crops under disease free, well fertilised, optimum soil moisture and full production conditions. Often crops do not meet these conditions, and the crop coefficient (K_c) can be adjusted under these circumstances to better reflect the actual crop conditions. However this may be difficult to do with accuracy, and usually involves at least some additional measurement, for example of leaf area index (LAI). Newly developed tools such as [IrriSat](#) can use regular satellite imagery of the vigour of individual fields to provide an improved measure of K_c and hence ET_c .

Determining evapotranspiration

ET measurement

Evapotranspiration is difficult to measure. Approaches used for ET measurement include:

- measure computed from the vertical gradient of air temperature and water vapour via the Bowen ratio method.
- directly measure the flux of water vapour movements using the eddy covariance method.
- estimation of the various components of the soil water balance. This could include cumulative soil water loss measured using soil moisture monitoring tools. Some components such as subsurface flow, deep percolation and capillary rise are difficult to measure. This approach usually can only give ET estimates over periods longer than a week.
- lysimeter studies using crops grown in isolated tanks filled with disturbed or undisturbed soil. A requirement of lysimeters is that vegetation both inside and immediately outside of the lysimeter be perfectly matched. Historically this requirement has not always been the case and has resulted in incorrect ET_c and K_c data.

ET computed by meteorological data

ET is commonly computed from weather data, as it is difficult or expensive to obtain accurate field measurements using the other techniques mentioned. There are a large number of equations that have been developed to estimate ET_o from meteorological data. Some of these approaches are only valid under specific climatic and agronomic conditions. The Modified Penman method has been found to overestimate ET_o , while the alternative Blaney-Criddle and pan evaporation methods show variable adherence to ET_o .

Since 1990, the Penman-Monteith method has been recommended as the standard method for estimating ET_o . The ET from crop surfaces under standard conditions (ET_c) is found from the formula:

$$ET_c = K_c \times ET_o$$

where K_c = crop coefficient

ET_o = reference crop evapotranspiration

The Bureau of Meteorology has developed [maps of ET](#) for Australia. The Point Potential ET is calculated using Frederick Morton's potential ET approach. It is very similar to the Penman-Monteith ET_o . These maps have also been published by the Bureau of Meteorology as Wang et al. (2001) [Climatic Atlas of Australia – Evapotranspiration](#).

Daily estimates of Penman-Monteith ET_o can be obtained from a nearby weather station fitted with the appropriate measurement sensors (solar radiation, maximum and minimum air temperature, relative humidity, and wind speed). These weather stations may be at a Bureau of Meteorology site or a research

station, or part of a weather station network such as those operated by Hydrodata Networks. Irrigators can also purchase and install their own automatic weather station (AWS).

ET estimated from pan evaporation

Pan evaporation is an historic method of estimating evapotranspiration which has now been replaced by the Penman-Monteith method discussed previously. As Penman-Monteith data is now widely available, pan evaporation methods are no longer recommended. However a short discussion of pan evaporation is included below as this data may still be used in a limited number of circumstances.

Evaporation from an open water surface provides an index of the integrated effect of radiation, air temperature, air humidity and wind on ET.

The standard open water surface used in Australia to estimate ET_0 is the Class A Pan. It is a circular pan, 1.2 m in diameter and 250 mm deep. It is made of galvanised iron and mounted on a wooden open frame platform which is 150 mm above ground level. The pan must be level. A stilling well located on the side of the Class A Pan has a level sensor and is used to record the water depth. The pan should be located in the centre of a grassed area, 20 m by 20 m, open on all sides. It should be located in the centre or leeward side of large cropped fields. A bird cage should be used to prevent animals from drinking from the pan.

It is filled with water to 50 mm below the rim. Water is lost from the pan by evaporation. The amount evaporated is determined daily by measuring the amount of water needed to replace that evaporated.

The Class A Pan has been used for over 40 years in Australia. The relationship between evaporation from a Class A Pan and ET_0 is given by the formula:

$$ET_0 = K_p \times E_{pan}$$

Where K_p = pan coefficient

E_{pan} = pan evaporation (mm/day)

The K_p values vary with the size and state of the upwind buffer zone, the relative humidity and wind speed. It can also vary with the height of the surrounding crop, painting of the pan, and the level at which water is maintained in the pan. For a pan placed in a short green cropped area and 100 m on the windward side of a dry surface, the K_p ranges from 0.7 (with wind speed below 2 m/s and the average relative humidity below 40%) to 0.85 (with wind speed below 2 m/s and the average relative humidity above 70%). For a pan placed in a dry fallow area, 100 m on the windward side of a green crop and with similar conditions, the K_p ranges from 0.55 to 0.75.

Because of the variability in the siting and maintenance of Class A Pans, evaporation from them is not necessarily comparable between pans. The appropriate K_p should be used to adjust data from Class A Pans so that a meaningful estimate of ET_0 can be obtained. Using these values to estimate ET_0 for periods less than 10 days is not recommended.

Use of evapotranspiration

Estimates of ET_0 can be used in several ways. Firstly, they can be used to assist in the design of irrigation systems in order to meet peak water requirements – an example of this is given in WATERpak Topic 5.5 'Centre pivots and lateral move machines'.

Secondly, they can be used to assist in irrigation scheduling decisions. They are the basis of the water balance scheduling approach outlined in [Irrigation: water balance scheduling](#).

Thirdly, they can be used to estimate the losses of water from storage and reticulation systems on farm. ET_0 estimates can be combined with dam factors to estimate evaporation losses from these systems. Note that local and seasonal conditions will influence the value of the dam factor. Further information is included in WATERpak Chapter 1.6..

References

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