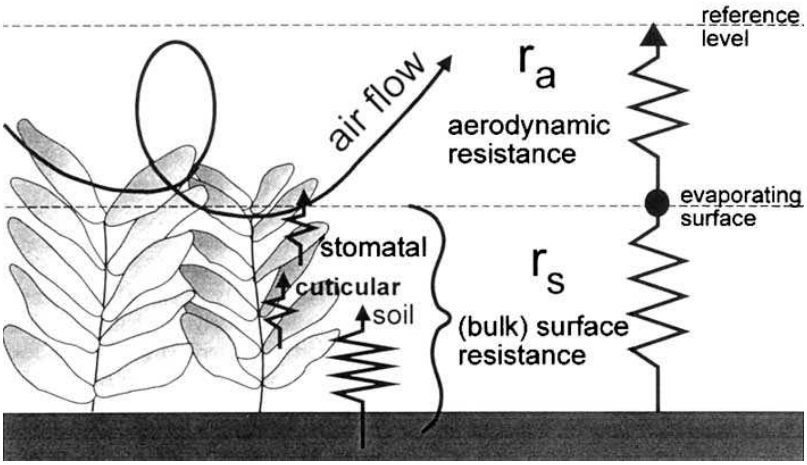
Evapotranspiration

Evapotranspiration (ET) represents the combination of two separate processes: evaporation whereby water is lost from the soil surface and transpiration which is the water lost from the crop itself.



Evaporation

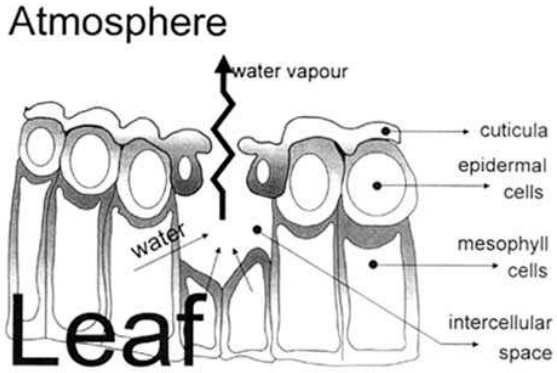
Evaporation is the process whereby liquid water is converted to water vapour (vaporisation) and removed from the evaporating surface (vapour removal). Water evaporates from a variety of surfaces, such as lakes, rivers, pavements, soils and wet vegetation.

The driving force to remove water vapour from the evaporating surface is the difference between the water vapour pressure at the evaporating surface and that of the surrounding atmosphere. As evaporation proceeds, the surrounding air becomes gradually saturated and the process will slow and might stop if the wet air is not transferred to the atmosphere. The replacement of the saturated air with drier air depends greatly on wind speed. Hence, solar radiation, air temperature, air humidity and wind speed are climatological parameters to consider when assessing the evaporation process.

Where the evaporating surface is the soil surface, the degree of shading of the crop canopy and the amount of water available at the evaporating surface are other factors that affect the evaporation process.

Transpiration

Transpiration consists of the vaporisation of liquid water contained in plant tissues and the vapour removal to the atmosphere. Crops predominantly lose their water through stomata. Nearly all water taken up is lost by transpiration and only a tiny fraction is used within the plant.



Transpiration, like direct evaporation, depends on the energy supply, vapour pressure gradient and wind. Hence, radiation, air temperature, air humidity and wind terms should be considered when assessing transpiration. The transpiration rate is also influenced by crop characteristics, environmental aspects and cultivation practices. Different kinds of plants may have different transpiration rates. Not only the type of crop, but also the crop development, environment and management should be considered when assessing transpiration.

FAO Modified Penman Monteith Equation

The FAO Penman-Monteith is a simplified representation of the standard Penman Monteith model. Where the standard model can be tailored to any given growing situation or crop (varying crop heights, leaf area index, surface resistance etc), the FAO model is customised around a standard reference crop.

The FAO Penman-Monteith method was developed by defining the reference crop as a hypothetical crop with an assumed height of 0.12 m, with a surface resistance of 70 s m^{-1} and an albedo of 0.23, closely resembling the evaporation from an extensive surface of green grass of uniform height, actively growing and adequately watered. The FAO method provides values that are more consistent with actual crop water use data worldwide.

The FAO Penman Monteith model used to estimate ET_o, the reference evapotranspiration, is expressed as:

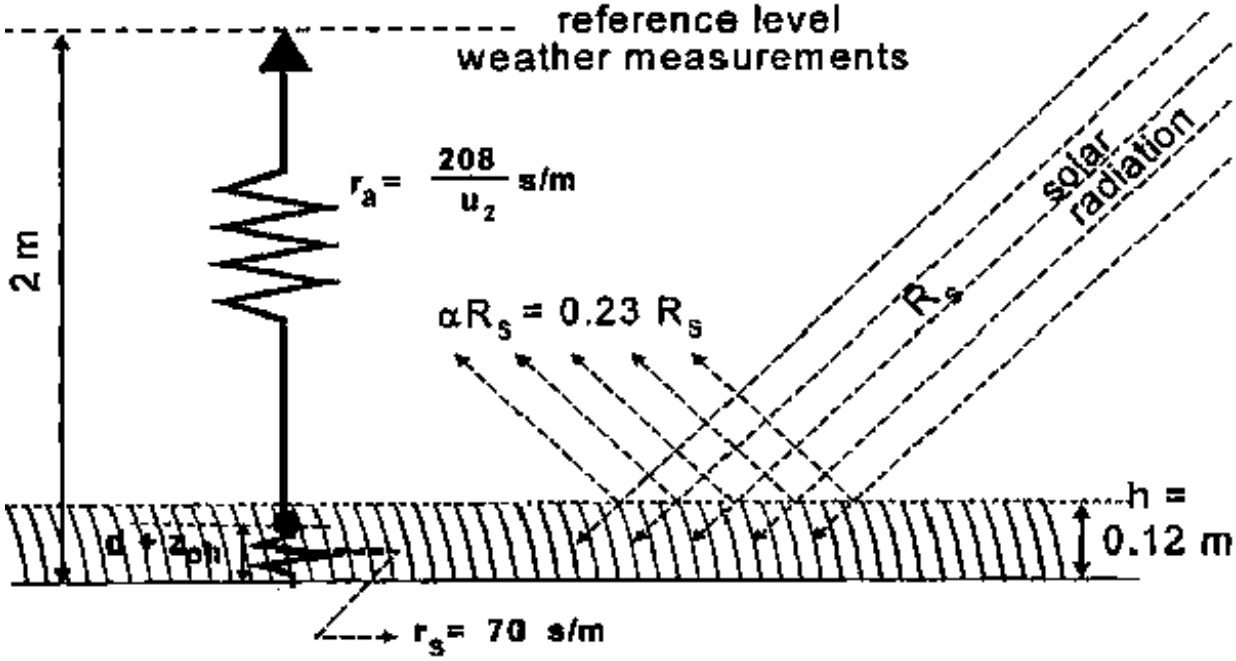
$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)} \quad (6)$$

where

ET_o	reference evapotranspiration [mm day^{-1}],
R_n	net radiation at the crop surface [MJ m^{-2} day^{-1}],
G	soil heat flux density [MJ m^{-2} day^{-1}],
T	mean daily air temperature at 2 m height [°C],
u_2	wind speed at 2 m height [m s^{-1}],
e_s	saturation vapour pressure [kPa],
e_a	actual vapour pressure [kPa],
$e_s - e_a$	saturation vapour pressure deficit [kPa],
□	slope vapour pressure curve [kPa °C^{-1}],
□	psychrometric constant [kPa °C^{-1}].

The reference evapotranspiration, ET_o, provides a standard to which:

- evapotranspiration at different periods of the year or in other regions can be compared;
- evapotranspiration of other crops can be related.



The equation uses standard climatological records of solar radiation, air temperature, humidity and wind speed. To ensure the integrity of computations, the weather measurements should be made at two metres (or converted to that height) above an extensive surface of green grass, shading the ground and not short of water.

Units

The evapotranspiration rate is normally expressed in millimetres (mm) per unit time. The rate expresses the amount of water lost from a cropped surface in units of water depth. The time unit can be an hour, day, decade, month or even an entire growing period or year.

As one hectare has a surface of 10 000 m^2 and 1 mm is equal to 0.001 m, a loss of 1 mm of water corresponds to a loss of 10 m^3 of water per hectare. In other words, 1 mm day^{-1} is equivalent to 10 m^3 ha^{-1} day^{-l}.

Water depths can also be expressed in terms of energy received per unit area. The energy refers to the energy or heat required to vaporise free water. This energy, known as the latent heat of vaporisation (□), is a function of the water temperature. For example, at 20°C, □ is about 2.45 MJ kg^{-1}. In other words, 2.45 MJ are needed to vaporise 1 kg or 0.001 m^3 of water. Hence, an energy input of 2.45 MJ per m^2 is able to vaporise 0.001 m or 1 mm of water, and therefore 1 mm of water is equivalent to 2.45 MJ m^{-2}. The evapotranspiration rate expressed in units of MJ m^{-2} day^{-1} is represented by □ ET, the latent heat flux.

Reference crop evapotranspiration (ET_o)

The evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ET_o. The reference surface is a hypothetical grass reference crop with specific characteristics. The concept of the reference evapotranspiration was introduced to study the evaporative demand of the atmosphere independently of crop type, crop development and management practices. As water is abundantly available at the reference evapotranspiring surface, soil factors do not affect ET. Relating ET to a specific surface provides a reference to which ET from other surfaces can be related. It obviates the need to define a separate ET level for each crop and stage of growth. ET_o values measured or calculated at different locations or in different seasons are comparable as they refer to the ET from the same reference surface.

The only factors affecting ET_o are climatic parameters. Consequently, ET_o is a climatic parameter and can be computed from weather data. ET_o expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. The FAO Penman-Monteith method is recommended as the sole method for determining ET_o. The method has been selected because it closely approximates grass ET_o at the location evaluated, is physically based, and explicitly incorporates both physiological and aerodynamic parameters.

Experimentally determined ratios of ET_c/ET_o, called crop coefficients (K_c), are used to relate ET_c to ET_o or $ET_c = K_c\ ET_o$.