Evapotranspiration

Evaporation

Evaporation is the diffusive process during which a liquid changes into a gas. It is the physical process by which any liquid escape from the surface in to the air in gaseous state, at a temperature below its boiling point. Water absorb the heat energy from sun and surrondings and this energy is used for evaoporation. The volume evaporated per unit area in a unit time (mm/day) is called as evaporation rate. Measured by US class A Open Pan Evaporimeter, Sunken Evaporimeter, Pitche Evaporimeter

Transpiration

Transpiration is the loss of water from the living parts of the plant through the stomato, cuticular and lenticular of the plant. The water is mainly losst due the negative water potential gradient from plant to atmosphere. Measured by Steady State Porometer & soil covered Lysimeter

Evapotranspiration (ET)

It is the combined loss of water i.e evaporation and transpiration from the plant canopy (including soil surface).

Evapotranspiration

Potential Evapotranspiration (PET)

The maximum water lost through evaporation from wet soil and transpiration from 8-15 cm tall short cut grass, covering ground completely, under unlimited water supply. In other words it is the atmospheric demand of a particular day. Also called as reference crop evapotranspiration (mm/day).

Consumptive Use (CU)

The sum of volume of water taken by vegetation for transpiration and evaporation from soil, plus water used by the plant for metabolic process (mm/day).

Transpiration Ratio

The effectiveness of the plants in the use of water was often given in terms of its transpiration ratio. This is amount of water transpired by a crop in its growth to produce unit weight of dry matter and is also called as Transpiration Efficiency.

Transpiration and its significance

Transpiration: A Necessary Evil

Transpiration is considered as evil because coniderable amount of water is lost to the atmosphere which lead to the water deficiency in the soil and plant. It is the necessary process because water soluble nutrients from soil are absorbed by plant with water. Transpiration process helps plants in translocation of plant products. The other important advantage of the transpiration is that it work as thermoregulatory mechanism in plant and dissipate the heat load. Thus, saves the plants from the over heating. Transpiration process also saves plant from harmful substances depositing in the plant. Salts in the soil also move in response to evaporative demands.

Factors Affecting ET

Factors which affect ET from Plant & Soils are:

i) Those affecting water supply i.e.,

1. Soil storage capacity
2. Rainfall
3. Irrigation.

ii) Those affecting energy supply

1. Light: supply energy; Stomata open in light and close in the dark
2. Temperature: Humidity / vapour pressure function of temperature.
3. Relative Humidity: Less humidity higher temperature. Increases difference - incurred. Decrease temperature increase vapour pressure - reducing the saturation deficit. Therefore higher temperature - increase in Temperature.

Factors Affecting ET

4. Wind: Saturated unit is replaced by dry air around the plant - increased temperature cooling effect on leaves vapour pressure different decreases.

5. Plant characters:

a) Root/shoot - ratio

b) Leaf characteristics (thickness, number of stomata, smoothness, vex layer etc)

c) More LAI- Transpiration high

d) Thick cuticle - epidermal hair - less transpiration.

When R/S ratio is more or equal then Transpiration will be more.

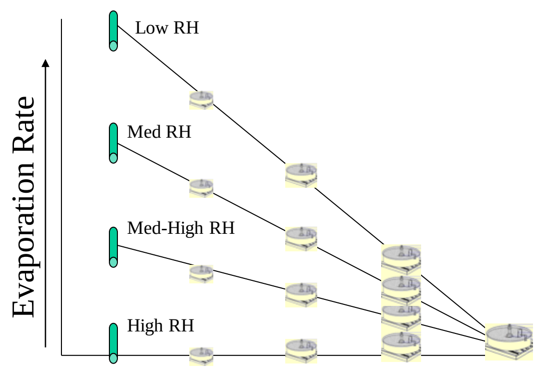
PE - Evaporation form a free water surface.

AE - Actual Evaporation.

AE is always less than PE

Measurement/Computation of AET/PET

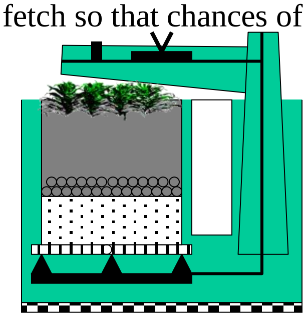
Measurement: Pan Size Effect



PET = Epan x pan coefficient

Measurement: Lysimeter

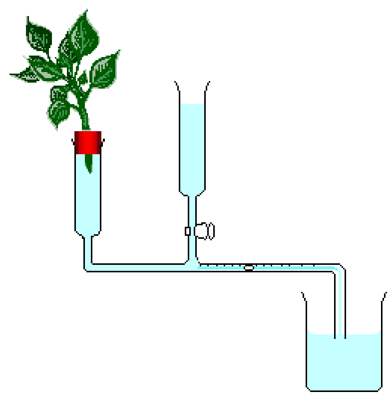
Lysismeter is the most accurate instrument to measure the loss of water from soil and crop surface. Lysimeter is considered reference for other methods. The precautions that should be taken during lysimetric observations are that the soil inside the lysimeter should be exact representation of the field. The environmental conditions, plant population, plant health should be kept at par with rest of the field. There should be sufficient fetch so that chances of errors could be ruled out.



Weighing Lysimeter

Transpiration Measurement: Potometer

A **potometer** is a device used for measuring the rate of water uptake of a leafy plant shoot. The main reason for water uptake by a cut shoot is transpiration.



Potometer

Computation of PET

Potential Evapotranspiration (PET)

Indirect methods – Certain climatic parameters are used. This method involves the principle that water use by crops is due to evaporation demand. Evaporation involves various climatic elements. Some of the methods are listed here

A) Hydrological (water balance approach)

B) Climatological Methods: a) Temperature based (Thornthwaite method, Blaney–Criddle method, Hargreave Method, Linacre Method) b) Solar Radiation based (Regression method, Makkink method, c) Solar radiation and temperature based (Jenson-Haise method, Caprio method, Idso method, d) combination approach (Penman method, Penman-Montheith method, Van Bavel method, Stayer-McIlroy method, Pristley-Taylor method)

C) Micrometeorological Approach: a) Mass transfer (Dalton method), b) Aerodynamic (Holzman method), c) Energy balance (Bowen ratio), d) Resistance (Monteith approach), e) Eddy flux determination (Swinbank method).

Thornthwaite Method

$$ET_0 = 16 \times \left(\frac{10T_i}{I}\right)^a \left(\frac{N}{12}\right)\left(\frac{1}{30}\right)$$

$$I = \sum_{i=1}^{12} \left(\frac{T_i}{5}\right)^{1.514}$$

$$a = \left(492390 + 17920I - 771I^2 + 0.675I^3\right) \times 10^{-6}$$

where,
T_i is the mean monthly temperature [°C],
N is the mean monthly sunshine hour.
N/12 can be replaced with already available coefficients generated using mean latitudinal sunshine hours

Penman-Monteith Equation

Radiation + Aerodynamic

$$LE_{PM} = \frac{\Delta(R_n - G)}{\Delta + \gamma\left(1 + \frac{r_c}{r_a}\right)} + \frac{\rho C_p [e_s(T) - e] / r_a}{\Delta + \gamma\left(1 + \frac{r_c}{r_a}\right)}$$

Where,
R_n is the net radiation,
G is the soil heat flux,
(e_s - e) represents the vapour pressure deficit of the air,
ρ is the mean air density at constant pressure,
Cp is the specific heat of the air,
Δ represents the slope of saturation vapour pressure temp. relationship,
γ is the psychrometric constant, and
r_c and r_a are the (bulk) surface and aerodynamic resistances

How do we get the aerodynamic resistance (r_a)?

Eddy Covariance for ET

In turbulent flow, vertical flux can be presented as:
($s=\rho_c/\rho_a$ is a mixing ratio of substance 'c' in the air)

$$F = \overline{\rho_a w s}$$

Reynolds decomposition is used then to break into means and deviations:

$$F = \overline{(\overline{\rho_a} + \rho'_a)(\overline{w} + w')(\overline{s} + s')}$$

Open parenthesis:

$$F = (\overline{\rho_a}\,\overline{w}\,\overline{s} + \cancel{\overline{\rho_a}\,\overline{w}\,\overline{s'}} + \cancel{\overline{\rho_a}\,\overline{w'}\,\overline{s}} + \overline{\rho_a}\,\overline{w's'} + \cancel{\overline{\rho'_a}\,\overline{w}\,\overline{s}} + \overline{\rho'_a w s'} + \overline{\rho'_a w'}\,\overline{s} + \overline{\rho'_a w' s'})$$

Averaged deviation from the average is zero

Equation is simplified: $F = (\overline{\rho_a}\,\overline{w}\,\overline{s} + \overline{\rho_a}\,\overline{w's'} + \overline{w}\,\overline{\rho'_a s'} + \overline{s}\,\overline{\rho'_a w'} + \overline{\rho'_a w' s'})$

Then important assumption is made (for conventional Eddy Covariance) – density fluctuations are assumed negligible:

$$F = (\overline{\rho_a}\,\overline{w}\,\overline{s} + \overline{\rho_a}\,\overline{w's'} + \cancel{\overline{w}\,\overline{\rho'_a s'}} + \cancel{\overline{s}\,\overline{\rho'_a w'}} + \cancel{\overline{\rho'_a w' s'}}) = \cancel{\overline{\rho_a}\,\overline{w}\,\overline{s}} + \overline{\rho_a}\,\overline{w's'}$$

Then another important assumption is made – mean vertical flow is assumed negligible for horizontal homogeneous terrain (no divergence/convergence):

$$F \approx \overline{\rho_a}\,\overline{w's'}$$

'Eddy flux'