Evapotranspiration

Transpiration is the process by which water leaves the body of a living plant and reaches the atmosphere as water vapor. The water is taken up by the plant – root system and escapes through the leaves. The important factors affecting transpiration are: atmospheric vapor pressure, temperature, wind, light intensity and characteristics of the plant, such as the root and leaf systems.

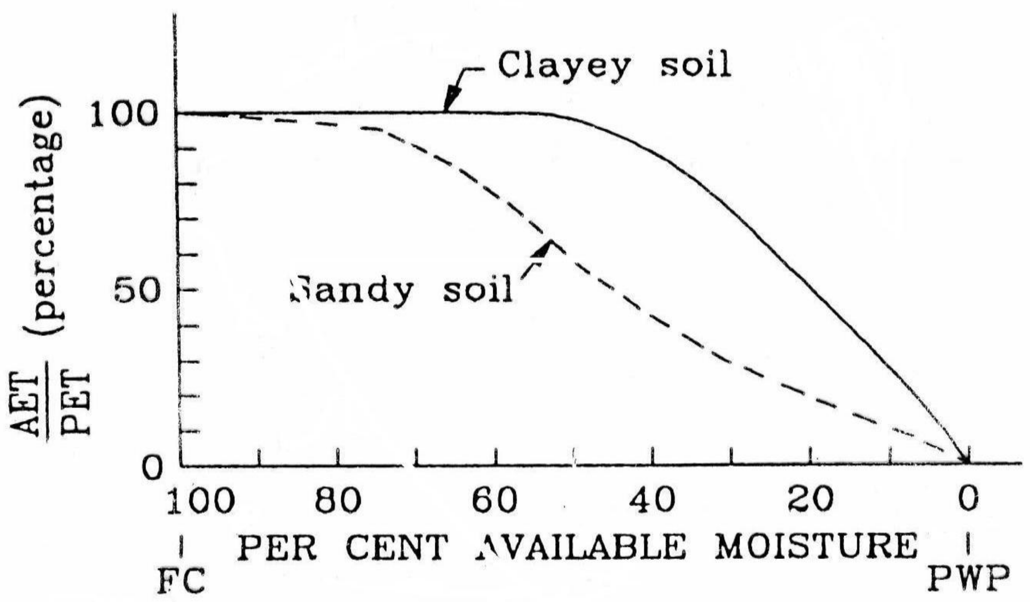

Fig. Variation of AET

Potential Evapotranspiration (PET)

If sufficient moisture is always available to completely meet the needs of vegetation fully covering the area, the resulting evapotranspiration is called potential evapotranspiration (PET).

Actual Evapotranspiration (ACT)

The real evapotranspiration occurring in a specific situation is called actual evapotranspiration (ACT).

Field Capacity (FC)

Field capacity is the maximum quantity of water that the soil at field simply drains away.

Permanent Wilting point (PWT)

permanent wilting point is the moisture content of a soil at which the moisture is no longer available in sufficient quantity to sustain the plants.

If the water supply to the plant is adequate, soil moisture will be at the field capacity and ACT will be equal to PET. If the water supply is less than PET, the soil dries out and the ratio AET/PET with available moisture depends upon the type of soil and rate of drying. Generally, for clayey soils, AET/PET ≈ 1.0 for nearly 50% drop in the permanent wilting point, the AET reduces to zero as shown in figure. For a catchment in a given period of time, the hydrologic budget can be written as

$$P - R_s - G_o - E_{act} = \Delta S$$

Where P = precipitation, R_s = surface runoff, G_o = subsurface outflow,

E_{act} = actual evapotranspiration (ACT) and ΔS = change in the moisture storage.

Measurement of Evapotranspiration

The measurement of evapotranspiration for a given vegetation type can be carried out in two ways:

(i) by using Lysimeters or

(ii) by the use of Field plots

Evapotranspiration = precipitation + irrigation input – increase in soil storage – ground water loss

Evapotranspiration Equations

Penman's Equation

$$PET = \frac{AH_n + E_a\gamma}{A+\gamma}$$

Where PET = daily potential evapotranspiration in mm per day

A = slope of the saturation vapour pressure vs temperature curve at the mean air temperature, in mm of mercury per °C

H_n = net radiation in mm of evaporable water per day

E_a = parameter including wind velocity and saturation deficit

γ = psychrometric constant = 0.49 mm of mercury/ °C

The net radiation estimated by the following equation:

$$H_n = H_a(1-r)\left(a + b\frac{n}{N}\right) - \sigma T^4{}_a\left(0.56 - 0.092\sqrt{e_a}\right)\left(0.10 + 0.90\frac{n}{N}\right)$$

Where

H_n = incident solar radiation outside the atmosphere on a horizontal surface, expressed in mm of evaporable water per day.

a =a constant depending upon the latitude Φ and is given by a = 0.29 cosΦ

b = a constant with an average value of 0.52

n = actual duration of a bright sunshine in hours

N = maximum possible hours of bright sunshine

r = reflection of co-efficient (albedo)

Usual ranges of values of r are given below:

Surface	range of r values
Close ground corps	0.15 - 0.25
Bare lands	0.05 - 0.45
Water surface	0.05
Snow	0.45 - 0.95

σ = Stefan-Boltzman constant = 2.01×10^{-9} mm/day

T_a = mean air temperature in degrees Kelvin = 273+ °C

e_a = actual mean vapour pressure in the air in mm of mercury

The parameter E_a is estimated as

$$E_a = 0.35\left(1 + \frac{u_2}{160}\right)\left(e_w - e_a\right)$$

in which

u_2 =mean wind speed at 2 m above ground in km/day

e_w = saturation vapour pressure at mean air temperature in mm of mercury

e_a = actual vapour pressure, defined earlier

For the computation of PET, data on n, e_a, u_2 mean air temperature and nature of surface (i.e. value of r) are needed. These can be obtained from actual observations or through available meteorological data of the region.

TABLE SATURATION VAPOUR PRESSURE OF WATER

Temperature (°C)	Saturation vapour pressure e_w (mm of Hg)	A (mm/°C)
0	4.58	0.30
5.0	6.54	0.45
7.5	7.78	0.54
10.0	9.21	0.60
12.5	10.87	0.71
15.0	12.79	0.80
17.5	15.00	0.95
20.0	17.54	1.05
22.5	20.44	1.24
25.0	23.76	1.40
27.5	27.54	1.61
30.0	31.82	1.85
32.5	36.68	2.07
35.0	42.81	2.35
37.5	48.36	2.62
40.0	55.32	2.95
45.0	71.20	3.66

$$e_w = 4.584 \exp\left(\frac{17.27\,t}{237.3 + t}\right) \text{ mm of Hg, where } t = \text{temperature in °C}$$

TABLE MEAN MONTHLY SOLAR RADIATION AT TOP OF ATMOSPHERE, H_a IN mm OF EVAPORABLE WATER/DAY

North latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0°	14.5	15.0	15.2	14.7	13.9	13.4	13.5	14.2	14.9	15.0	14.6	14.3
10°	12.8	13.9	14.8	15.2	15.0	14.8	14.8	15.0	14.9	14.1	13.1	12.4
20°	10.8	12.3	13.9	15.2	15.7	15.8	15.7	15.3	14.4	12.9	11.2	10.3
30°	8.5	10.5	12.7	14.8	16.0	16.5	16.2	15.3	13.5	11.3	9.1	7.9
40°	6.0	8.3	11.0	13.9	15.9	16.7	16.3	14.8	12.2	9.3	6.7	5.4
50°	3.6	5.9	9.1	12.7	15.4	16.7	16.1	13.9	10.5	7.1	4.3	3.0

TABLE MEAN MONTHLY VALUES OF POSSIBLE SUNSHINE HOURS, *N*

North lati-tude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0°	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
10°	11.6	11.8	12.1	12.4	12.6	12.7	12.6	12.4	12.9	11.9	11.7	11.5
20°	11.1	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
30°	10.4	11.1	12.0	12.9	13.7	14.1	13.9	13.2	12.4	11.5	10.6	10.2
40°	9.6	10.7	11.9	13.2	14.4	15.0	14.7	13.8	12.5	11.2	10.0	9.4
50°	8.6	10.1	11.8	13.8	15.4	16.4	16.0	14.5	12.7	10.8	9.1	8.1

Example: Calculate the potential evapotranspiration from an area in the month of November by Penman's fomula. The following data are available:

Latitude	:	28^0 4′N
Elevation	:	230 m (above sea level)
Mean monthly temperature	:	19^0 C
Mean relative humidity	:	75%
Mean ovserved sunshine hours	:	9 h
Wind velocity at 2 m height	:	85 km / day
Nature of surface cover	:	Close-ground green crop

Solution : From table

$A = 1.00$ mm/ °C

$e_w = 16.50$ mm of Hg

From Table

$H_a = 9.506$ mm of water/day

From Table

$N = 10.716$ h

$n/N = 9/10.716 = 0.84$

From given data

$e_a = 16.50 \times 0.75 = 12.38$ mm of Hg

$a = 0.29 \cos 28^0 4' = 0.2559$

$b = 0.52$

$\sigma = 2.01 \times 10^{-9}$ mm/ day

$T_a = 273 + 19 = 292$ K

$\sigma T_a^4 = 14.6132$

r = albedo for close-ground green crop is taken as 0.25

Form Eq.

$$H_n = 9.506 \times (1-0.25) \times [0.2559 + (0.52\times0.84)] - 14.613 \times (0.56-0.092\sqrt{12.38}) \times (0.10 + (0.9 \times 0.84))$$

$$= 4.936 - 2.946$$

$$= 1.990 \text{ mm of water /day}$$

From Eq.

$$E_a = 0.35 \times \left(1 + \frac{85}{160}\right) \times (16.50 - 12.38)$$

$$= 2.208 \text{ mm/day}$$

From Eq. noting the value of $\gamma = 0.49$

$$PET = \frac{(1 \times 1.990) + (2.208 \times 0.49)}{(1.00 + 0.49)} = 2.06\, mm / day$$

Examle: Using the data of the above example, estimate the daily evaporation from a lake situated in that place.

Solution: For estimating the daily evaporation from a lake, Penman's equation is used with the albedo r=0.05.

Hence

$$H_n = (4.936) \times \frac{(1.0 - 0.05)}{(1.0 - 0.25)} - 2.946$$

= 6.252 – 2.946 = 3.306 mm of water/day

E_a = 2.208 mm/day

From Eq.

PET = Lake evaporation

$$= \frac{(1.0 \times 3.306) + (2.208 \times 0.49)}{(1.0 + 0.49)}$$

= 2.95 mm/day