Estimation of Evaporation

Water Budget Method

This method is based on hydrological continuity equation

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E_L = lake evaporation

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From above, evaporation can be estimated as

$$E_L = P + (V_{is} - V_{os}) + (V_{ig} - V_{og}) - T_L - \Delta S$$

Quantities V_{ig}, V_{og} and T_L can not be measured; these are to be estimated someway.

Example

A reservoir had an average surface area of 20 km^2 during June 2005. In that month, the average rate of inflow was 10 m^3/s, outflow was 15 m^3/s, monthly rainfall was 10 cm and reduction in storage was 16 Mm^3. Assuming the seepage losses to be 1.8 cm, estimate the evaporation in that month.

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Or, E_L = (4.68/20)$\times$100cm = 23.4 cm

Question

Estimate the evaporation for a month for a lake of 500 hectare surface area. The mean discharge from the lake is estimated to be 1.00 m^3/s. The monthly rainfall is about 10 cm. A stream flows with an average discharge of 2.00 m^3/s into the lake. The water level in the lake dropped about 5 cm in the month. The seepage losses are negligible.

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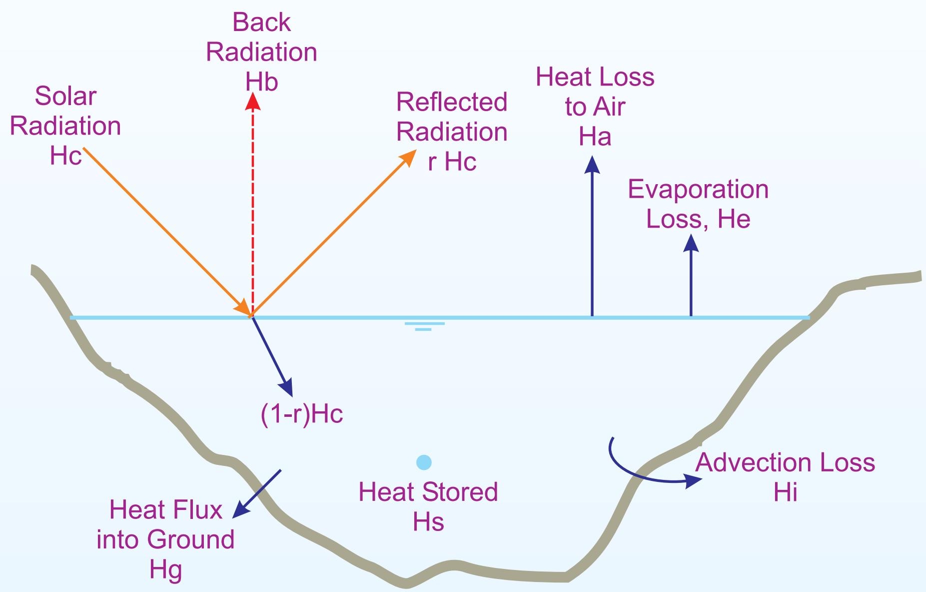
Answer: 66.84 cm

Energy Budget Method

The energy available for evaporation is determined by considering i) incoming energy, ii) outgoing energy and iii) energy stored in the water body over a known time interval.



Net radiation,

$$H_n = (1-r)H_c - H_b = H_a + H_e + H_g + H_s + H_i$$

Now, $H_e = \rho L E_L$, so

$$E_L = \frac{H_n - (H_a + H_g + H_s + H_i)}{\rho L}$$

Example

Calculate the evaporation rate from an open water source, if the net radiation is 300 W/m^2 and the air temperature is 30°C. Assume value of zero for sensible heat (Ha), ground heat flux, heat stored in water body and advected energy. The density of water at 30°C is 996 kg/m^3.

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$$E_L = 1.239577 \times 10^{-7}\,\frac{m}{s} = 1.239577 \times 10^{-7} \times 24 \times 60 \times 60 \times 1000\,\frac{mm}{day} = 10.71\,\frac{mm}{day}$$

Reduction of Lake Evaporation

Lake Evaporation

Lakes or reservoirs are large water bodies. They absorb and store heat energy. This stored heat transforms the water into vapour and as a result huge amount of water is being lost every year. The water volume lost due to evaporation from a reservoir in a month is calculated as

$$V_E = A\, E_{pm}\, C_p$$

where, V_E= monthly volume of water lost in evaporation (m^3); A=monthly average surface area of the reservoir; E_{pm}= pan evaporation in m/month/m^2; C_p= pan coefficient.

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(Remember: A dam with storage capacity > 60Mm^3 is called a large dam. Here, the annual evaporation is 1300 Mm^3!)

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In the previous example, if we can reduce about 50% of the annual evaporation loss using cetyl alcohol, then we can save 650 Mm^3, that is equivalent to 10 large dams!

Example

The average water spread areas that are likely to be maintained during the operation of a reservoir after its completion and the observed monthly pan evaporations at a proposed reservoir site are given below. Estimate the annual evaporation loss from the reservoir in Mm^3. If 75% of this loss can be prevented and the water thus saved is utilized to irrigate a crop with a requirement of 57cm of water, how much area can be irrigated? Assume a pan coefficient of 0.70.

Month	Surface Area (ha)	Pan Evap.(cm)
Jan	872.0	10.2
Feb	797.0	15.3
Mar	754.5	25.4
Arp	739.5	30.5
May	726.0	28.0
Jun	717.5	17.8
Jul	735.0	15.3
Aug	765.0	14.0
Sep	807.5	14.0
Oct	850.0	15.3
Nov	891.0	12.7
Dec	917.0	10.2

Solution

Month	Surface Area (ha)	Pan Evp.(cm)	Lake Evp (cm)	Lake Evp. Vol (Mm^3)
Jan	872.0	10.2	7.14	0.622608
Feb	797.0	15.3	10.71	0.853587
Mar	754.5	25.4	17.78	1.341501
Arp	739.5	30.5	21.35	1.578833
May	726.0	28.0	19.60	1.422960
Jun	717.5	17.8	12.46	0.894005
Jul	735.0	15.3	10.71	0.787185
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				$\sum = 11.39892$

Note: Lake evaporation = Pan evaporation $\times$ 0.7

Lake evaporation volume = (Lake evaporation $\times 10^{-2}$) $\times$ (Surface area $\times 10^{4}$) $\times 10^{-6}$ Mm^3

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Depth of water required for irrigation = 57cm
Area that can be irrigated with 70% of annual evaporation volume saved
= $(0.75 \times 11.40 \times 10^{6})/(57 \times 10^{-2})$ m^2 =

Solution

Month	Surface Area (ha)	Pan Evp.(cm)	Lake Evp (cm)	Lake Evp. Vol (Mm^3)
Jan	872.0	10.2	7.14	0.622608
Feb	797.0	15.3	10.71	0.853587
Mar	754.5	25.4	17.78	1.341501
Arp	739.5	30.5	21.35	1.578833
May	726.0	28.0	19.60	1.422960
Jun	717.5	17.8	12.46	0.894005
Jul	735.0	15.3	10.71	0.787185
Aug	765.0	14.0	9.80	0.749700
Sep	807.5	14.0	9.80	0.791350
Oct	850.0	15.3	10.71	0.910350
Nov	891.0	12.7	8.89	0.792099
Dec	917.0	10.2	7.14	0.654738
				$\sum$ = 11.39892

Note: Lake evaporation = Pan evaporation $\times$ 0.7
Lake evaporation volume = (Lake evaporation $\times 10^{-2}$) $\times$ (Surface area $\times 10^{4}$) $\times 10^{-6}$ Mm^3

Annual evaporation loss = 11.40 Mm^3
Depth of water required for irrigation = 57cm
Area that can be irrigated with 70% of annual evaporation volume saved
= (0.75 $\times$ 11.40 $\times 10^{6}$)/(57 $\times 10^{-2}$) m^2 = 1500 ha

Question

Question 1

During a daily routine observation, 10.8 litres of water was added to bring the water surface in the evaporation pan to the marked level. The nearby raingauge measured 3.6 mm of rainfall. What was the evaporation recorded for the day if the diameter of the pan is 122 cm?

Answer:

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Question 2

What is the evaporation, if 4.75 litres of water is removed from an evaporation pan of diameter 1.22 m and the simultaneous rainfall measurement is 8.8 mm?

Answer:

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Question 2

What is the evaporation, if 4.75 litres of water is removed from an evaporation pan of diameter 1.22 m and the simultaneous rainfall measurement is 8.8 mm?

Answer: 4.74 mm

Transpiration

Transpiration Process

Transpiration is the process by which water vapour leaves from a living plant through the stomata of the leaves to the atmosphere. It is one of the important processes in the hydrological cycle by which the part of the precipitation falling on (and entering into) the ground is returned back to the atmosphere. This water, existed in the form of moisture in the soil near the root zone, is extracted by the plant roots for the photosynthesis process.

Factors Affecting Transpiration

Following factors affect the transpiration process:

- Vapour Pressure
- Temperature
- Wind
- Light Intensity
- Plant characteristics

Transpiration is essentially confined to daylight hours and the rate of transpiration depends on the growth periods of the plant. Evaporation, on the other hand continues all through day and night.

Measurement of Transpiration

It is not possible to measure the field transpiration loss under existing field conditions, due to wide variations in various factors controlloing the transpiration process. Hence, measurement of transpiration is usually done in the laboratory under controlled conditions.

Usually, **phytometer** is used to measure transpiration. It is a closed water tight tank filled with soil for plant growth. The soil surface is sealed to prevent evaporation. Plant roots are connected to the soil and the plant is exposed to the atmosphere. Water is applied periodically to the soil for the plants growth. Periodical measurements of the weights of the phytometer alongwith the weight of water added from time to time give an estimate of amount of transpiration.

The transpiration value obtained from phytometer is multiplied by a coefficient to obtain field transpiration value.

Evapotranspiration

Evapotranspiration

While transpiration takes place, the land area in which plants stand also loose moisture due to evaporation from soil. Hence, for irrigation, it is considered advantageous to consider evaporation and transpiration processes under one head: ***evapotranspiration***. It is also called as ***consumptive use***.

Evapotranspiration (E_t) or Consumptive Use (C_u) is the total water lost from an agricultural land with crops, due to evaporation from the soil and transpiration by the plants. It is usually expressed in terms of depth. Evapotranspiration represents the most important aspect of water loss in the hydrologic cycle.

PET and AET

For a particular atmospheric condition, evapotranspiration depends on the availability of water.

- 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 (AET): If sufficient moisture is not available, the real evapotranspiration occurring in a specific situation is called Actual Evapotranspiration (AET).

- Field Capacity (Fc): It is the maximum quantity of water that the soil can hold against gravity. Any higher moisture input to a soil at field capacity simply drains away.

- Permanent Wilting Point (PWP): It is the moisture content of a soil at which the moisture is no longer available in sufficient quantity to sustain the plants. At this stage, whatever small amount of water is held by the soil, can not be extracted by the plant roots and the plants wilt. Difference between Fc and PWP is called available water, i.e., the moisture available for plant growth.

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Comparison

- If adequate moisture is available, soil moisture will be at Fc and AET = PET.
- If soil dries out and water is not supplied, AET<PET

For clayey soils, AET=PET, upto 50% drop in moisture content. At PWP, AET$\approx$0.

Factors Affecting Evapotranspiration

The factors that govern evaporation and transpiration also govern the evapotranspiration process. Usually PET is controlled by meteorological factors, whereas AET is also affected by plant and soil factors.

PET tends to increase as the temperature, sunshine and wind speed increase and humidity decreases.Radiation supplies the energy for the evapotranspiration process. A close relationship exists between the net solar radiation and evapotranspiration.

AET, on the other hand is influenced by the soil and plant characteristics. When the vegetaion surface is dry and when the soil moisture falls below Fc, AET rate will be limited by the flow rate through the soil pores. It is observed that reduction in the density of vegetation cover reduces the evapotranspiration rates.

Measurement of Evapotranspiration

Lysimeter

Measurement of Evapotranspiration

Lysimeter

A lysimeter consists of a circular tank about 60 to 90 cm in diameter and 180 cm deep. It is filled with with soil and the particular crop for which the evapotranspiration is required. It is buried in the agricultural ground so that its top is in flush within the surrounding ground surface. The sides of the of the lysimeter are impervious whereas the bottom is pervious. Evapotranspiration is estimated in terms of the amount of water required to maintain constant moisture conditions within the tank.

The limitation of lysimeter is that difference may exist between the lysimeter and natural conditions of soil profiles, soil moisture regime, plant rooting characteristics, methods of water application, water table etc.

Lysimeter gives PET values.

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Field experimental plots

Field plots are suitably selected agricultural fields. For the growth of the plant, amount of water added to the plot through precipitation and irrigation, are measured alongwith runoff. Moisture content in various layers of the soil within root zone are measured at the beginning and at the end of the crop season. Then the evapotranspiration is computed as

$$E_T = I - Q - \Delta S$$

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where E_T is the evapotranspiration, I is the total inflow (precipitation + irrigation), Q is the runoff and ΔS is the increase in soil moisture storage; all are in terms of depth.

Estimation of Evapotranspiration

Blaney-Criddle Formula

This is an empirical formula which assumes that the PET is related to hours of sunshine and temperature. The PET in a crop-growing season is given by

$$E_T = 2.54 \times K \times F$$

$$F = \sum P_h \overline{T}_f / 100$$

where,

E_T = PET in a crop season

K = an empirical coefficient, depends on the type of crop,

F = sum of monthly consumptive use factors for the period,

P_h = monthly percent of annual day-time hours, depending on the latitude of the place,

$\overline{T}_f$ = mean monthly temperature in $^\circ$F.

Example 1

Estimate the PET of an area for the season November to February in which wheat is grown. The area is at a latitude of 30°N with mean temperatures and P_h values as given below. Use Blaney-Criddle formula and take K = 0.65.

Month	Nov	Dec	Jan	Feb
Temp (°C)	16.5	13.0	11.0	14.5
P_h (%)	7.19	7.15	7.30	7.03

Solution:

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Solution:

Month	$\overline{T}_f$($^\circ$C)	$\overline{T}_f$($^\circ$F)	P_h(%)	$P_h\overline{T}_f/100$
Nov	16.5	61.7	7.19	4.436
Dec	13.0	55.4	7.15	3.961
Jan	11.0	51.8	7.30	3.781
Feb	14.5	58.1	7.03	4.084
			$\sum P_h\overline{T}_f/100$=	16.263

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So, $E_T = 2.54 \times K \cdot F = 2.54 \times 0.65 \times 16.263 = 26.85$ cm.