Rain Making Methods

Principles of rainmaking: Clouds are classified into warm and cold clouds based on cloud top temperature. If the cloud temperature is positive these clouds are called warm clouds and if it is negative they are called as cold clouds. The nucleus needed for precipitation differs with type of clouds. Hygroscopic materials are necessary as nucleus for warm clouds

Cloud seeding: Cloud seeding is one of the tools to mitigate the effects of drought. It is defined as a process in which the precipitation is encouraged by injecting artificial condensation nuclei through aircrafts or suitable mechanism to induce rain from rain bearing cloud. The rain drops are several times heavier than cloud droplets. These mechanisms are different for cold and warm clouds.

Seeding of cold clouds

This can be achieved by two ways (1. Dry ice seeding and 2. Silver Iodide seeding).

1.Dry ice seeding

- Dry ice (solid carbon-dioxide) has certain specific features. It remains as it is at –80°C and evaporates, but does not melt. Dry ice is heavy and falls rapidly from top of cloud and has no persistent effects due to cloud seeding.
- Aircrafts are commonly used for cloud seeding with dry ice.
- Aircraft flies across the top of a cloud and 0.5 – 1.0 cm dry ice pellets are released in a steady stream.
- While falling through the cloud a sheet of ice crystals is formed.
- From these ice crystals rain occurs.

This method is not economical as 250 kg of dry ice is required for seeding one cloud. To carry the heavy dry ice over the top of clouds special aircrafts are required, which is an expensive process.

2. Silver Iodide seeding

Minute crystals of silver iodide produced in the form of smoke acts as efficient ice-farming nuclei at temperatures below –5°C. When these nuclei are produced from the ground generators, these particles are fine enough to diffuse with air currents. Silver iodide is the most effective nucleating substance because; its atomic arrangement is similar to that of ice. The time for silver iodide smoke released from ground generator to reach the super cooled clouds was offer some hours, during which it would draft a long way and decay under the sun light. The appropriate procedure for seeding cold clouds would be to release silver iodide smoke into super cooled cloud from an aircraft. In seeding cold clouds silver iodide technique is more useful than dry ice techniques, because, very much less of silver iodide is required per cloud. There is no necessity to fly to the top of the cloud, if area to be covered is large.

Seeding of warm clouds

1) Water drop Technique

Coalescence process is mainly responsible for growth of rain drops in warm cloud. The basic assumption is that the presence of comparatively large water droplets is necessary to initiate the coalescence process. So, water droplets or large hygroscopic nuclei are introduced in to the cloud. Water drops of 25 mm are sprayed from aircraft at the rate of 30 gallons per seeding on warm clouds.

2) Common salt technique

Common salt is a suitable seeding material for seeding warm clouds. It is used either in the form of 10 per cent solution or solid. A mixture of salt and soap avoid practical problems. The spraying is done by power sprayers and air compressors or even from ground generators. The balloon burst technique is also beneficial. In this case gun powder and sodium chloride are arranged to explode near cloud base dispersing salt particles.

EVAPORATION – TRANSPIRATION, EVAPOTRANSPIRATION – POTENTIAL EVAPOTRANSPIRATION – DEFINITION AND THEIR IMPORTANCE IN AGRICULTURAL PRODUCTION.

Evaporation: A physical process in which liquid water is converted into its vapour. Evaporation is the most important water loss term in water balance equation.

Importance of Evaporation in crop plants

1) Evaporation is an important process of hydrologic cycle.
2) The evaporation from the soil is an important factor deciding the irrigation water requirements of a crop
3) In modifying the microclimate of a crop the evaporation from the soils is an important factor for consideration.
4) Evaporation is the most important of all the factors in the heat budget, after radiation.
5) The evaporation is also one of the most important factors in the water economy.
6) Since, a certain amount of evaporation also demands a definite amount of heat, it provides a link between water budget and heat budget.

Factors affecting evaporation

The evaporation from a fully exposed water surface is the function of several environmental factors

1. Environmental factors
   a. Water temperature
      With an increase of temperature the kinetic energy of water molecules increases and surface tension decreases which increases evaporation.
   b. Wind
      The evaporation from fully exposed surface is directly proportional to the velocity of wind and vice-versa, because dry wind replaces the moist air near water. The process of evaporation takes place continuously when there is a supply of energy to provide latent heat of evaporation (540 calories / gram of water).
   c. Relative humidity
      The evaporation is greater at low RH than at high RH.
   d. Pressure
      The evaporation is more at low pressure and less at high pressure.

2. Water factors
   a. Composition of water
      The dissolved salts and other impurities decreases the rate of evaporation. The evaporation is inversely proportional to the salinity of water.
   b. Area of evaporation
      The larger the area of exposure, greater will be the evaporation.

Transpiration: This is a physiological phenomenon, which takes place only in living plants. The loss of water from living parts of the plant is known as Transpiration. The loss of water through stomatal openings of the leaves is termed as stomatal transpiration. The loss of water through cuticle is known as cuticular transpiration and from lenticels is known as lenticular transpiration.

Importance of transpiration on crop plants

1. Dissipation of radiant energy by plant parts
2. Translocation of water in the plants
3. Translocation of minerals in the plant

Factors affecting transpiration

I. Environmental factors

1. Light: By directly opening and closing the of stomata there is periodicity in the transpiration rate. Indirectly by increasing the temperature of leaf cells the transpiration is increased.
2. Atmospheric humidity: The rate of transpiration is almost inversely proportional to atmospheric humidity.
3. Air Temperature: Increase in Temperature results in opening of stomata which in turn increases transpiration.
4. Wind velocity: The higher the wind speed higher the transpiration

II. Plant factors

1. Plant height: Water need of the crop varies with height.
2. Leaf characteristics: Reduction in leaf area brings reduction in transpiration.
3. Availability of water to the plant: If there is little water in the soil the tendency for dehydration of leaf causes stomatal closure and a consequent fall in transpiration.

Differences between evaporation and transpiration

Sl	Evaporation	Transpiration
1.	Controlled by meteorological factors	Controlled by both meteorological and plant factors
2.	Diffusive resistant is absent	Diffusive resistance occurs due to internal leaf geometry and presence of stomata.
3.	Also occurs in night due to advective heat transportation.	Reduced in the night due to closure of stomata.
4.	This is purely a physical phenomenon which takes place from any exposed surface with moisture.	This is physiological phenomenon which takes place only in living plants.
5.	This takes place through any openings or pores	This takes place through guard cells of stomata, cuticle and lenticules etc.

Leaf wetness

It refers to the presence of liquid water on the leaf surface.

There are three sources of water for the surface of leaves:
(i) precipitation (interception),
(ii) overhead irrigation and
(iii) dew.

- Three quantities commonly used to describe leaf wetness are the amount of water retained per unit leaf area, the portion of the leaf covered by liquid water and the duration of leaf wetness.
- These leaf wetness properties depend mostly on plant specific characteristics (leaf area and angle, surface wettability) and meteorological conditions, and can significantly affect the water balance of individual plants and canopy
- The maximum amount of water which can be retained per unit leaf area before it starts to drip off varies among species, ranging from 0.1 to 500 ml m^{-2}.

Plants can benefit from low as well as high water retention, i.e. leaf wetness.

- For example, low water retention improves water balance under dry conditions by allowing water to easily reach the soil before it evaporates from the plant surface.
- On the other hand, in the case of excessive rain, interception can delay precipitation inflow to the soil and provide optimal partitioning of water balance components

Water evaporates from the wet leaf surface as from any other open water (or water–covered) surface, air temperature and humidity as well as wind speed predominantly affect water removal from the leaf surface.

It is important to note that a plant surface covered with water is not available for transpiration because retained water covers stomas and actually affects gas exchange between plants and their environment.

Meteorological conditions, crop and soil characteristics, environmental conditions and crop management affect the intensity of evapotranspiration

Physics of Evapotranspiration

Transpiration is the vaporization of liquid water in plant tissues and vapor removal to the atmosphere

--Vaporization occurs in intercellular spaces of the plant tissue, while exchange with the atmosphere occurs through and is controlled by plant stomata.

--Transpiration is predominant once the crop has developed and the canopy shades more and more of the surface

ET is an energy controlled process requiring the conversion of available radiation energy (sunshine) and sensible energy (heat contained in the air) into latent energy (energy stored in water vapor molecules)

Factors Affecting Evapotranspiration

Weather

Crop characteristics

Management

Environmental conditions

Crop Characteristics

Crop type and variety

Height, roughness, stomatal control, reflectivity, ground cover, rooting characteristics

Stage of development

Management

Irrigation method

Irrigation management

Cultivation practices

Fertility management

Disease and pest control

Environmental Conditions

Soil type, texture, water-holding capacity

Soil salinity

Soil depth and layering

Poor soil fertility

Exposure/sheltering

Evapotranspiration: Evapotranspiration denotes the quantity of water transpired by plants or retained in the plant tissue plus the moisture evaporated from the surface of the soil. As long as the rate of root uptake of soil moisture balances the water losses from the canopy, evapotranspiration continues to occur at its potential rate. When the rate of root water uptake falls below the transpiration demand, actual transpiration begins to fall below the potential rate. This is either because the soil cannot supply water to roots quickly or the plant can no longer extract water to meet the evaporational demand.

Reference Evapotranspiration (ET_0): This represents the maximum rate of evapotranspiration from an extended surface of 8 to 10 centimeters tall green grass cover, actually growing and completely shading the ground under limited supply of water.

Potential Evapotranspiration (PET): Potential evapotranspiration (PET) for any crop is obtained from reference evapotranspiration and crop factors (Kc) when water supply is unlimited.

$$PET = Kc \times ET_0$$

Importance of Evapotranspiration and Potential Evapotranspiration for crop plants

1. Estimation of the soil moisture there by planning irrigation schedule of crops.
2. Understanding relationship between the crop yield and irrigation water.
3. Guiding for the production of a crop with a fully developed canopy.
4. The evapotranspiration can also help to demarcate soil climatic zones including the drought prone areas.
5. These will form the base for developing suitable soil and crop management practices, crop varieties, water conservation techniques, cropping pattern and ways to improve productivity rainfed crops.

Estimation of Evapotranspiration (ET)

$$ET = \frac{0.408\Delta\,(Rn - G) + \gamma\,\dfrac{900\,u2}{T + 273}\,(es - ea)}{\Delta + \gamma\,(1 + 1.34\,u2)}$$

ETo = Reference evapotranspiration [mm day^{-1}]

Rn = Net radiation at the crop surface [MJ$m^{-2}day^{-1}$]

G = Soil heat flux density [MJ$m^{-2}day^{-1}$]

T = Mean of daily air temperature [°C]

u2 = Wind speed at 2 m height [m s^{-1}]

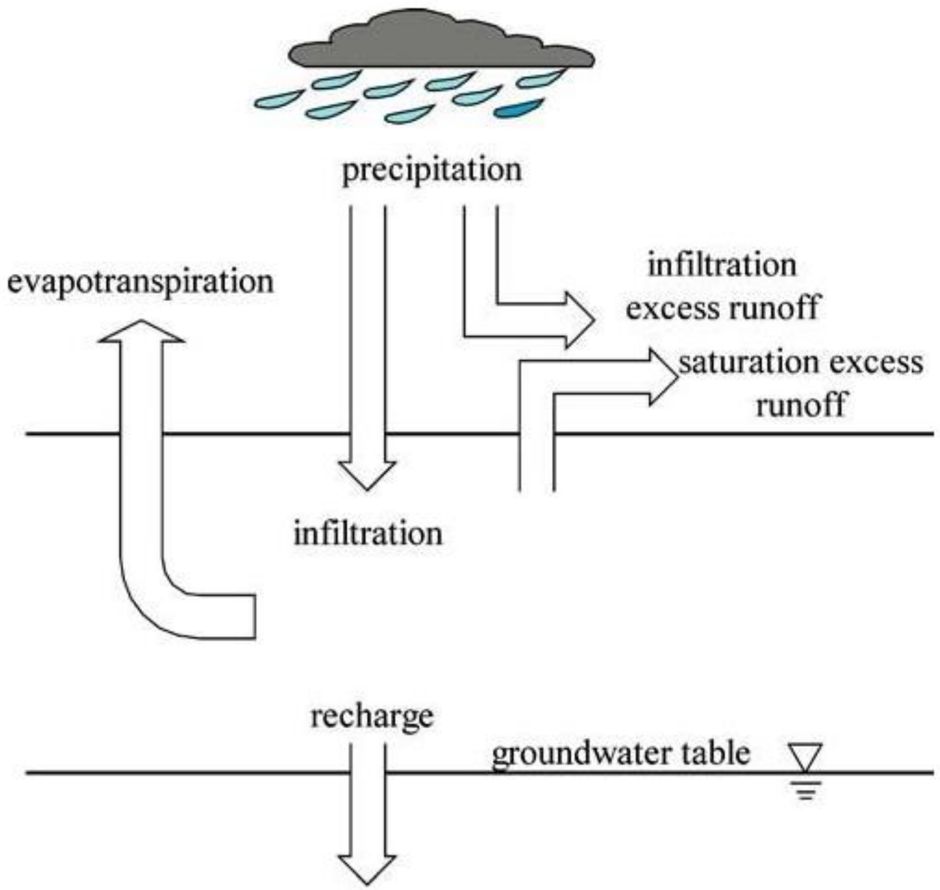
es = Saturation vapour pressure [kPa]

ea = Actual vapour pressure [kPa]

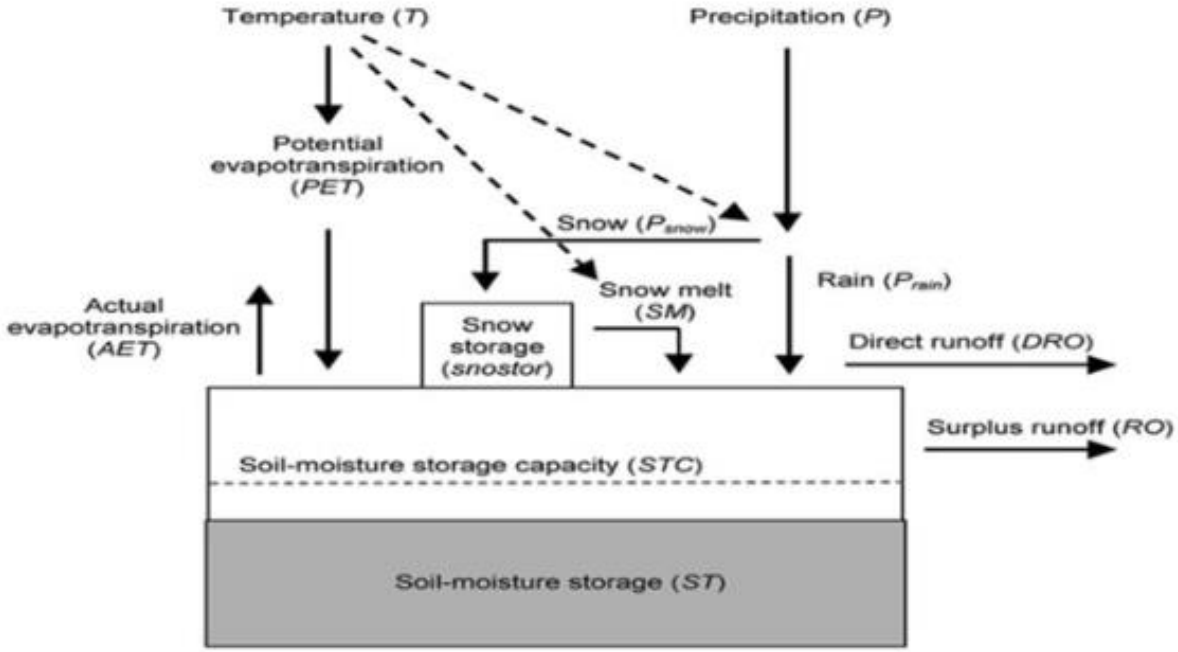
Δ = Slope vapour pressure curve [kPa $^{\circ}C^{-1}$]

γ = Psychometric constant [kPa $°C^{-1}$].

Water Budget Concept



'Thronthwaite' Water Budget Model



Ground Water - Water Balance Equation

The following equation is a generalized form of water balance equation, which applies to any assessment unit irrespective of it being an administrative unit, a watershed or an aquifer. This water balance equation holds good for any part of the year and for the annual water balance as well.

$$\Delta S = R_{rainfall} + R_{other} - B - GE_{all} - ET \pm L \pm O_{inflow/outflow}$$

ΔS =Change in storage in ground water reservoir

$R_{rainfall}$ =Recharge from rainfall

R_{other} =Recharge from other sources

B = Base flow

GE_{all} = Ground water draft for all uses

ET = Evapotranspiration losses

L =Leakage to or from deeper aquifers

$O_{inflow/outflow}$ =Net inflow/outflow across the boundary of the assessment unit

or

$$\Delta S = R_{rainfall} + R_{other} - GE_{all} \pm V_{outnet}$$

The status of the soil water for an irrigated crop needs monitoring regularly to assist the irrigation manager in making irrigation decisions. Typically, irrigation scheduling can be done in two ways. One is by directly monitoring soil-water by using soil moisture sensors. The other way is to use weather data to account for soil-water in the rooting depth by soil-water balance approach. This method is usually referred to as weather-based or evapotranspiration (ET_c) - based irrigation scheduling or water balance method.

How to use the water balance method

Estimating soil water using the water-balance approach is done by accounting for all the incoming and outgoing water from the soil root zone (Figure 1). Major inputs include precipitation (P) or rainfall and irrigation (Irr). Outputs include ET_c, runoff (R) and deep percolation (DP). Daily soil water depletion in the rooting zone is calculated using the equation below:

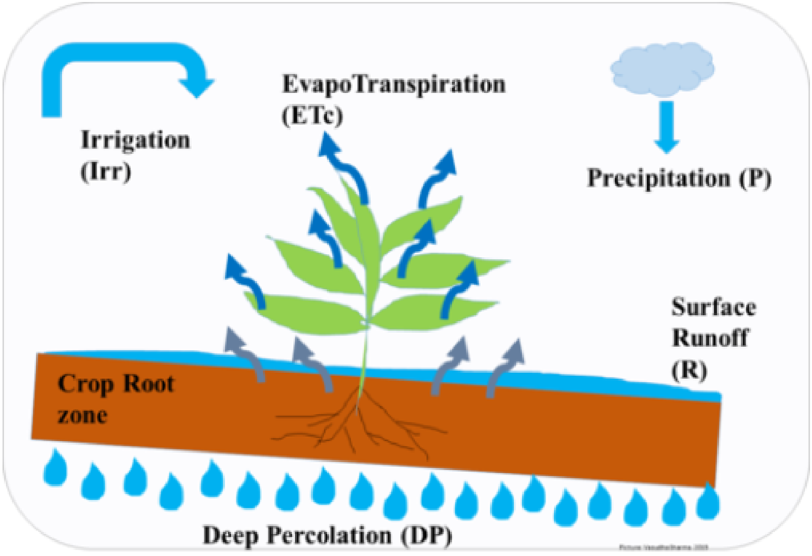


Figure 1. Soil water balance components.

$Dc - Dp = ET_c - P - Irr + R + DP$ (Equation 1)

Where Dc stands for soil water deficit (net irrigation requirement) in the rooting zone on current day, Dp is the previous day soil moisture deficit, ET_c is crop evapotranspiration on the current day, P is precipitation for the current day, Irr is the irrigation amount for the current day, R is the surface runoff and DP is the deep percolation.

Since it is very difficult to estimate R and DP in the field, **these variables can be accounted for by setting Dc to zero** whenever water additions (P and Irr) to the root zone are greater than water subtractions ($Dp + ET_c$). Using these assumptions, equation 1 can be simplified to:

$Dc = Dp + ET_c - P - Irr$ (Equation 2)