HYDROLOGY
IRRIGATION

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TSPSC AEE SYLLABUS

Hydrological cycle; Rainfall – types and measurement, network design; Infiltration - Φ- index; Runoff – process, factors and determination of runoff, dependable yield; Floods – flood hydrograph, computation of flood peak using rational formula, unit hydrograph method and Gumbel's extreme value methods; Groundwater – types of aquifer and properties, Darcy's law, specific yield, steady radial flow to wells in confined and unconfined aquifers; Irrigation – types and advantages, soil water plant relationship, consumptive use, duty, delta, base period, crops and their water requirements; Single and multipurpose projects; Dams – classification, forces and design of Gravity dam and Earth dam; Spillways – types, energy dissipation, stilling basin, Appurtenances; Canals – alignment, Kennedy's and Lacey's theories, lining of Canals; Weirs – components, design of vertical drop and sloping glacis weir; Seepage forces – Bligh's Theory, Khosla's theory; Canal falls – types and design principles; Cross drainage works – classification and design principles of aqueducts; Hydropower – classification and principle components of Hydroelectric power plants

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Water demand assessment: Storages and their yields. Ground water yield and well Hydraulics. Water logging and drainage design. Design of rigid boundary canals, Lacey's and tractive force concepts in canal design, Lining of Canals, Sediment transport in canals, Non-overflow and overflow dams and their design, Energy dissipaters, Design of head works, Distribution works, Falls, Crossdrainage works, Outlets, River training.

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Definition, necessity, benefits, 2II effects of irrigation, types and methods of irrigation, Hydrology – Measurement of rainfall, run off coefficient, rain gauge, losses from precipitation – evaporation, infiltration, etc Water requirement of crops, duty, delta and base period, Kharif and Rabi Crops, Command area, Time factor, Crop ratio, Overlap allowance, Irrigation efficiencies Different type of canals, types of canal irrigation, loss of water in canals Canal lining – types and advantages Shallow and deep to wells, yield from a well Weir and barrage, Failure of weirs and permeable foundation, Slit and Scour, Kennedy's theory of critical velocity Lacey's theory of uniform flow Definition of flood, causes and effects, methods of flood control, water logging, preventive measure Land reclamation, Characteristics of affecting fertility of soils, purposes, methods, description of land and reclamation processes Major irrigation projects in India.

1 PRECIPITATION AND GENERAL ASPECTS OF HYDROLOGY

The word Hydrology is derived from the Greek words "Hydor" (means water), "logos" (means science. Hydrology is the science that deals with the occurrence, circulation and distribution of water on the earth surface, below the earth surface and even in the atmosphere.

Applications of Hydrology

- To estimate yield from a drainage basin.
- To design hydraulic structures.
- To design and operate water resources engineering projects, such as irrigation, water supply, flood control, hydro power and navigation.

Hydrologic Cycle

- The various aspects such as precipitation, evaporation, transpiration, infiltration & runoff can be explained in terms of a cycle known as the "Hydrologic cycle".
- Sun is the main source of energy for this cycle.
- The concept of hydrologic cycle has been developed by *Vitruvius.*
- A qualitative representation of the hydrologic cycle first introduced by *Horton.*

Catchment Area

- The area which drains water into a river or stream is called the catchment area of that stream at a given location.
- It is also called as Drainage basin (or) Ridge Line.
- It is a line which divides one catchment area from its neighbouring catchment area.

  (In British English this is referred as 'Watershed')

PRECIPITATION

It denotes all the forms of water that reach the earth from the atmosphere. The usual forms are rainfall, snowfall, gail, frost ans dew. Of all these, only the first two contribute significant amounts of water. Rainfall veing the predominant from of presipitation causing stream flow, especially the flood flow in a majority of rivers in India. The magnitude of precipitation varies with time and space.

For precipitation to from:

- The atmosphere must have moisture.
- There must be sufficient nuclei present to aid condensation.
- Weather conditions must be good for condensation of water vapour to take place
- The products of condensation must reach the earth. Under proper weather conditions, the water vapour condenses over nuclei to from tiny water droplets of sizes less then 0.1mm in diameter.

Forms of Precipitation

Rain : It is the principal form of precipitation in India. Precipitation in the form of water droplets of size ranging from 0.5mm to 6 mm and intensity more than 1mm/hr is called as Rain.

S.No.	Type	Intensity
1.	Light Rain	1 mm/hr - 2.5 mm/hr
2.	Moderate Rain	2.5 mm/hr - 7.5 mm/hr
3.	Heavy Rain	> 7.5 mm/hr

Drizzle : Precipitation in the form of fine sprinkle of numerous water droplets of size less than 0.5mm and intensity less than 1mm/hr is known as Drizzle.

Snow : Snow consist of ice crystals having average density 0.1g/cc or less than 1 mm In India snow occurs only in Himalayan Region.

Sleet : It is frozen rain drops of transparent grains which forms when rain falls through air at subfreezing temperature.

Glaze : When rain or drizzle comes in contact with solid body at freezing temperature 0^0C the water drops freeze to form an ice coating called Glaze or freezing rain.

Hail : Precipitation in the form of large lumps of ice of size more than 8mm.

Dew (or) Frost : Moisture above the ground condenses during the night and deposit above the ground in the form of fine water drops known as Dew (or) Frost.

TYPES OF PRECIPITATION

Convective Precipitation:

In this type of precipitation, a packet of air which is warmer than the surrounding air due to localised heating rises because of its lesser density. Air from cooler surroundings flows to take up its place, thus setting up a convective cell. The warm air continues to rise, undergoes cooling and results in precipitation.

Ex: Rains during early summer.

Orographic Precipitation:

- The moist air masses may get lifted up to higher altitudes due to the presence of mountain barriers and consequently undergo cooling, condensation and precipitation. Such precipitation is known as Orographic precipitation.

Ex: Precipitation at Hilly and mountainous Regions.

- **Front:**

  Front is the interface between two distinct air masses, under certain favourable conditions, when a warm air mass and cold air mass meet, the warmer air mass is lifted over the colder one with the formation of a front the ascending warmer air cools adiabatically with the consequent formation of clouds and precipitation.

Cyclonic Precipitation:

- Generally air mass moves from high pressure region to low pressure region and low pressure region act as chimney in which swirling of air mass will take place, air mass rises upto greater heights adiabatically condenses and reaches back to the earth surface as precipitation.
- High intensity rainfall occur in this type of precipitation.
- In a cyclone winds direction is anticlockwise in Northern hemisphere

Index of Wetness

This index is used to find the rainfall variation or deviation for a particular year and it is given as,

$$\text{Index of Wetness (in\%)} = \frac{\text{Rainfall in any year}}{\text{Average Rainfall of all the years (at least 30 years)}} \times 100$$

Percentage of Rain deficiency = 100 - Percentage of Index of wetness

Ex: If Index of Wetness is 60% then the deficiency of rain is 40%

S.No.	Rain Deficiency in (%)	Conditions
1.	30-45	Large Deficiency
2.	45-60	Severe Deficiency
3.	>60	Disaster Deficiency

DROUGHT

Drought is a hydrological extreme like flood, various types of droughts are as follows :

Meteorological Drought : Meteorological drought is situation where there is more than 25% decrease in precipitation from normal precipitation over an area.

Hydrological Drought : If the presence of water in streams, lakes, rivers and various underground sources is below the average level then it is called "Hydrological Drought"

Agricultural Drought : It is characterised by insufficient supply of moisture required for the growth of crop or plants. It is expressed by using a term called Aridity Index (A.I)

$$\text{Aridity Index(A.I.)} = \frac{\text{PET} - \text{AET}}{\text{PET}} \times 100$$

PET (Potential Evapotranspiration) - This refers to the water consumed by plants if sufficient moisture is available during the growth period.

AET (Actual Evapotranspiration) - It is the actual moisture available under the pre-vailing conditions.

Clasification based on Aridity Index
- = 0 → Non arid region
- = 1-25% → Mild arid region
- = 26-50% → Moderate arid region
- > 50% → Severe arid region.

MEASUREMENT OF PRECIPITATION

- Precipitation is measured essentially in terms of vertical depth of water that would accumulate on a level surface. If precipitation is retained where it fell, it can be expressed in terms (or) cm of water.
- Precipitation is measured by using instrument called **Raingauges**, also called as Pluviometer (or) Ombrometer (or) Odometer (or) Hyetometer.
- The gauge must be set as near the ground as possible to reduce wind effects but it must be suffeciently high to prevent splashing, flooding, etc.,

For setting up a raingauge, the following considerations are important:

- The Ground must be level and open and the instrument must possess a horizontal catchment surface.
- The instrument must be surrounded by an open fenced area of atleast 5.5 m x 5.5 m.
- No object should be nearer to the instrument than 30 m height or twice the height of nearest obstruction.

TYPES OF RAIN GAUGE

Rain gauge can be broadly classified into two categories as

- Non Recording Rain Gauge
- Recording Rain gauge

Non Recording Rain Gauge: Measure the depth of precipitation.

Symon's Rain gauge:

- Commonly used rain gauge in India.
- Diameter of collector is 127 mm (Approximately 5 inches) and height of 30.5 cm above the ground level.
- This rain gauge can also be used to measure snowfall by removing funnel and receiving bottle and the snow is allowed to collect in the outer metal container. The snow is then melted and the depth of resulting water is measure.

IMD Rain gauge: (India Meteorological Department)

Recently IMD has switched over to the use of fibre Glass Reinforced polyester rain gauge which comes in two variants having a collecting area 100 cm^2, 200 cm^2 and known as IMD Raingauge.

Recording Type Rain Gauge : In the total rain gauges atleast 10% should be Recording type.

These Rain gauges produce a continuous plot of rainfall against time and provide valuable data of intensity and duration of rainfall for hydrological analysis of storms.

- **Weighing - Bucket Type:**
  - In this rain gauge, the catch from the funnel empties into a bucket mounted on a weighing scale.
  - It gives a plot of the accumulated rainfall against the elapsed time, i.e. the mass curve of rainfall.
  - This method gives mass curve of rainfall.

- **Tipping - Bucket Type:**
  - It gives data on Intensity of rainfall.
  - This instrument is ideally suited for digitalising of the output signal.
  - We can locate it at rural places also.
- **Natural - Syphon Type:**
  - This type of recording raingauge is also known as float-type raingauge.
  - The Rainfall collected by a funnel shaped collector is led into a float chamber causing a float to rise.
  - This type of rain gauge is adopted as the standard recording type rain gauge in India
  - This method gives the mass curve of rainfall.

Note :

Natural-syphon type is a standard recording type Rain gauge in India and is described by **IS : 5235 - 1969**.

RAINGAUGE NETWORK

Network Density

From practical considerations of Indian Conditions the Indian Standard (IS:4987-1968) recommends the following densities as sufficient

In plains : 1 station per 520 km^2.

In regions : 1 station per 260-390 km^2 for areas of average elevation of 1000m

In Predominantly : 1 station per 130 km^2 for hilly areas with heavy rainfall.

Adequacy of Rain gauge Stations

If there are already some rain guage stations in a catchment, the optimal number of stations that should exist to have an assigned percentage of error in the estimation of mean rainfall is obtained by statistical analysis as

$$N = \left[\frac{C_v}{\varepsilon}\right]^2$$

Where

N = optimal number of stations

ε = allowable percentage error in the estimate of the mean rainfall

C_v = Coefficient of variation of rainfall values at the existing m stations (in percent)

If there are 'm' stations in the catchment each recording rainfall values P_1, P_2..... P_i.....P_m in a known time, the coefficient of variation C_v is calculated as:

$$C_v = \frac{\sigma_{M-1}}{(\bar{P})} \times 100$$

Where

σ – Standard deviation, $\bar{p}$ = Mean value of Rainfall expressed in (cm).

$$\sigma_{m-1} = \sqrt{\left[\frac{\sum_{i=1}^{m}(P_i - \bar{P})^2}{m-1}\right]} = \text{Standard deviation}$$

P_i = Precipitation magnitude in the i^{th} station

$$\bar{P} = \frac{\sum_{i=1}^{m} P_i}{m} = \text{Mean precipitation}$$

PREPARATION OF DATA

- Before using the rainfall data in application, it is necessary to check the data for continuity and consistency.
- The continuity of record may be broken with missing data.
- The missing data can be estimated by using the data of the neighbouring station. In these calculations the normal rainfall is used as a standard of comparison. The normal rainfall is the average value of rainfall ai a particular date, month or year over a specified 30-year period. The 30-year normals are recomputed every decade. Thus the term normal aaaual percipitation at station A means the average annual precipitation at A based on a specified 30-years of record.

ESTIMATION OF MISSING DATA (MISSING RAINFALL DATA)

- Sometimes, the rainfall amount at a certain rain gauge station for a certain days may be missing due to the absence of an observer (or) some instrument failure. In such cases it might be needed to estimate the missing - rainfall amount by approximating the values from the data of nearby raingauge stations.
- Given the annual precipitation values $P_1, P_2, P_3, \ldots\ldots P_m$ at neighbouring M stations 1, 2, 3,.....M respectively, it is required to find the missing annual precipitation 'P_x' at a station 'X' not included in the above 'M' stations. A comparison of the recordings of these stations are made by using their normal rainfall as standard of comparision.

  Normal rainfall is average value of rainfall over a specified 30 year period.

  Case-i: If the normal annual precipitations at various stations differ from 'N_x' within about 10% of the normal annual precipitation at station 'X' then from a simple arithmetic mean method 'P_x' is given as

$$P_x = \frac{1}{M}(P_1 + P_2 + P_3 + \ldots\ldots\ldots\ldots + P_m)$$

  Case-ii: If the normal annual precipitations at various stations differs from 'N_x' by more than 10% of the normal annual precipitation at station 'X' then from 'Normal Ratio Method' 'P_x' is given as

$$P_x = \frac{N_x}{m-1}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \ldots\ldots\ldots\ldots\ldots + \frac{P_m}{N_m}\right]$$

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1 IRRIGATION PRINCIPLES PRACTICES AND PROJECT

Definition of Irrigation

Irrigation may be defined as the process of artificial application of water to the soil or land for the growth of agricultural crops.

In other words, it is a science of planning and designing a water supply for the agricultural land to protect the crops from adverse effects of weather.

Main Concerns in Irrigation

Main concerns in irrigation are as follows:

- What should be the methods of irrigation
- How much moisture could be retained by the soil in their pores
- What should be the adequate time to irrigate the soil (i.e. optimum frequency of irrigation)

  In other words, after how much depletion of moisture level we should apply the next watering

Advantages of Irrigation

- **Increase in crop yield:**

  Increase in crop yields occur on account of good irrigation systems leading to increase in food production.

- **Protection against famines:**

  Food production of a country can be increased by availing irrigation facilities. This helps preventing famine situations.

- **Revenue Generation:**

  Assumed supply of irrigation water leads to growing of superior crops by the farmers. Farmers become prosperous by selling the crops while governments revenue is generated by imposing taxes on irrigation water.

- **Avoidance of mixed cropping:**

  Mixed cropping means sowing of two or more crops together in the same field when weather conditions are not favorable for a particular type of crop. The need of mixed cropping is eliminated if we have good irrigation facility.

- **Navigation:**

  Irrigation canals may be used for inland navigation. Inland navigation is useful for communication and transportation.

- **Hydroelectric Power Generation:**

  Major river valley projects are planned to provide hydroelectric power together with irrigation. Thus, at the same time dual purpose is served.

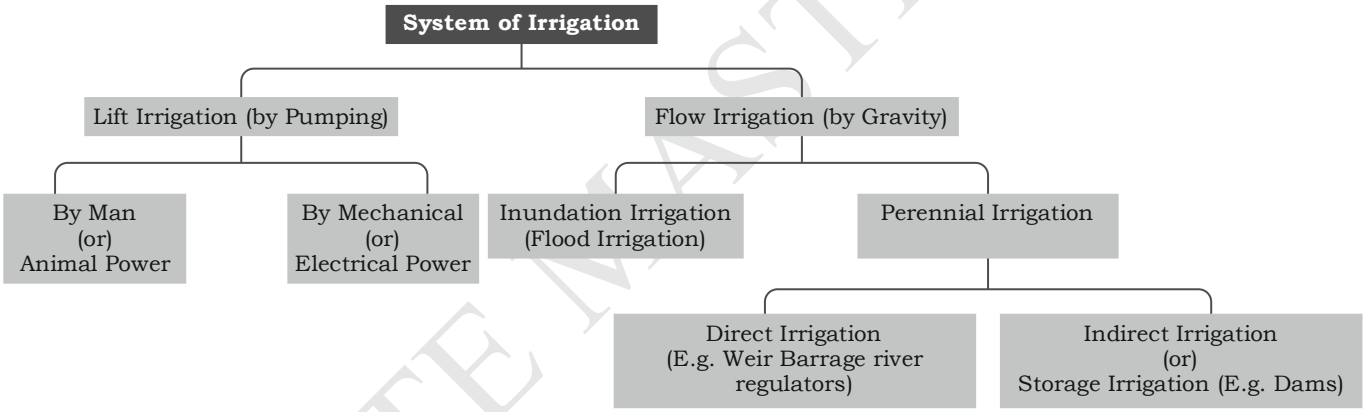
- **Generation of employment opportunities:**

  During construction of irrigation works like canal headworks, weir/barrage, overhead irrigation works, employment opportunities are generated.

Disadvantages of Irrigation

- **Wastage of irrigation water** : Abundant supply of irrigation water tempts the cultivators to use more than the required amount of water.
- **Formation of marshy land** : Excessive seepage of water from irrigation canals may lead to formation of marshy lands along the course of the canals.
- **Dampness in weather** : Temperature of the commanded area of irrigation project gets lowered considerably and the area may become damp. Dampness in the area lead to occurrence of diseases originating from dampness.
- **Loss in valuable lands** : In various cases, valuable lands get submerged when storage reservoirs are formed on account of construction of weirs, barrages or dams.

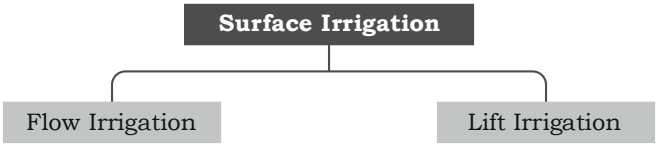
Systems of Irrigation



Surface and Sub Surface Irrigation

Surface Irrigation

- In this method, irrigation water is distributed to the agricultural land through small channels which flood the area upto a required depth.
- Water is applied and distributed either by gravity or pumping
- This method is good for soils with low to moderate infiltration capacities and lands with uniform terrain



Flow irrigation

- Water available at higher level is supplied to a lower level by the action of gravity.

Lift irrigation

- Water avaiblable at lower level is lifted to a higher level by mechanical or manual means and then supplied for irrigation (e.g. pumps etc.)
- Mostly tubewells are used for this purpose

Flow irrigation can be further subdivided into.

- Perennial irrigation
- Flood irrigation

Subsurface Irrigation

- In this method, water flows underground and nourishes plant roots by capilarity.
- Water is applied to the root zones of crops by underground network of pipes.
- The network consists of main pips, sub main pipes and lateral perforated pipes.
- This method is suitable for soils which are hightly permeable.

It may be divided into following two types

Natural SubOirrigation

- Leakage water form channels during its passage through sub soil irrigates crops sown on lower lands.

Artificial Sub-irrigation

- In this method, a system of open jointed drain is artificially laid below the soil.
- This is costly process, so recommended in areas where crops provide high returns.

Methods of Irrigation

Irrigation water can be applied to crop lands using one of the following irrigation methods.

Surface irrigation

- Uncontrolled (or wild or free) flooding method
- Border strip method
- Check method
- Basin method, and
- Furrow method

Subsurface Irrigation

Sprinkler Irrigation

Trickle (Drip) Irrigation

Each of the above methods have some advantages and disadvantages, and the choice of the method depends on the following factors:

- Size, shape, and slope of the field.
- Soil characteristics
- Nature and availability of the water supply subsystem
- Types of crops being grown

- Intial development costs and availability of funds, and
- Preferences and past experience of the farmer

Uncontrolled Flooding

- Ditches are excavated in the field.
- Water from these ditches are allowed to flow across the field without any restriction by opening the field regulators.
- In case of controlled free flooding, surplus water flows throught he waste water channel and is discharged into the river or drainage.
- In this method, cost of land preparation is low and cost of labour is high
- The main disadvantage is that the water application efficiency is low (especially when flooding is not controlled).
- In this case, we have series of field channels connected to the main supply channel.

Border Flooding

- In this method, land is divided into a series of long, uniformly graded, narrow strips separated by low levees (i.e. small bunds).
- Here, levees guide the flow of water down the field.
- Usually, ength of strips is in the range 100 to 400 m whereas width of strips is in the range 10 to 20 m.
- This method is suitable when the area is levelled in direction perpendicular to the flow in order to prevent water from concentrating on either side of the border
- Water is allowed to flow from supply ditch into each strip and during its travel water gets infiltrated into the soil
- As soon as the water reaches the lower end of the strip, water supply to that strip is turned off
- This is the most popular method of flooding.

Note :

If the land is not properly graded and there is cross slope, the irrigation water will not spread evenly over the field.

Time taken by irrigation water to irrigate an area

Time required by irrigation water to irrigate an area can be given by following formula

$$t = 2.303\frac{y}{f}\log_{10}\left(\frac{Q}{Q - fa}\right)$$

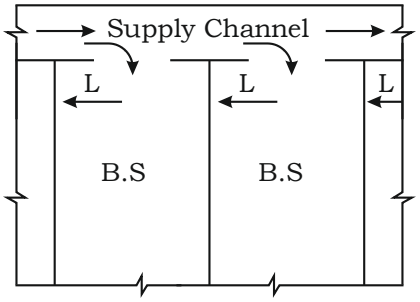
Where,

Q = Discharge through the supply ditch

y = Average depth of water flowing over the strip

f = Rate of infiltration of the soil

A = Area of the land irrigated



B.S = Border Strips
L = Leeves

Maximum area that can be irrigated with a supply ditch

If we have a supply ditch of discharge Q and soil having infiltration capacity f, then

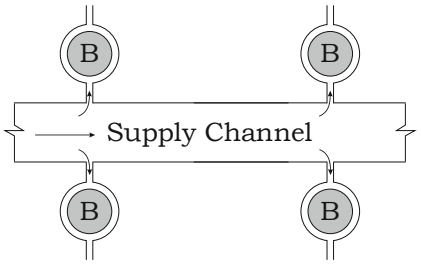
$$A_{max} = \frac{Q}{f}$$

Check Flooding

- In this method, agricultural area is divided into small plots (known as checks) by surrounding the area with low and flat levees. These levees act as check bunds.
- Check bunds are generally constructed along the contours
- Water is supplied to the check basins through the field channels which are connected with the supply channel.
- Water is retained inthese check basins for sometime to allow for infiltration into the soil.
- This method is suitable for both more permeable and less permeable soils.
- Close growing crops such as jowar or paddy are most preferred
- Some loss of cultivable area due to levees.

Basin Flooding

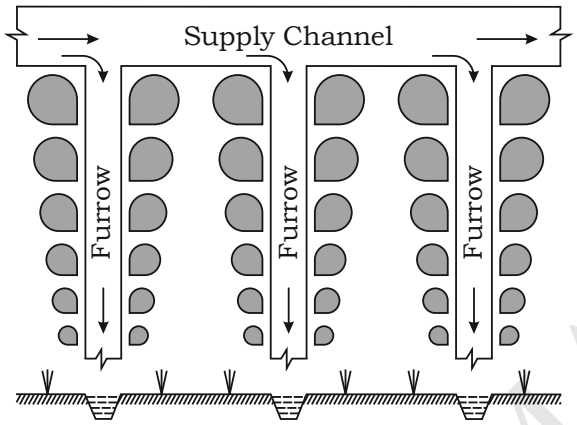
- This method is mainly employed for watering orchards
- In this method, one or more trees are generally enclosed by circular channel through which water flows.
- This circular channel acts as a basin
- Each basin is connected to the field channel while field channel is connected to the supply channel.
- This method is most suitable for crops that are unaffected by standing water present over long period of time.



B = Basin

Furrow Method

- In this method, water is supplied to the land by digging narro channels at regular interval.
- These narrow channels are called furrow
- Water infiltrates through the wetted perimeter of the furrows and moves vertically and then laterally to saturate the soil.
- Usually, crops are grown on the ridges between the furrows
- Depth of the furrows varies from 8 to 30 cm while length of furrows are around 400 m
- This method is suitable for row crops like sugarcane, groundnut, potato, tobacco etc.
- Preferred on flat area or gentle slopes.



Subsurface Irrigation

Subsurface irrigation (or simply sub irrigation) is the practice of applying water to soils directly under the surface. Moisture reaches the plant roots through capillary action. The conditions which favor sub irrigation are as follows:

- Impervious subsoil at a depth of 2 meters or more.
- A very permeable subsoil
- A permeable loam or sandy loam surface soil
- Uniform topographic conditions, and
- Moderate ground slopes

In natural sub irrigation, water is distributed in a series of ditches about 0.6 to 0.9 meter deep and 0.3 meter wide having vertical sides. These ditches are spaced 45 to 90 meters apart. Sometimes, when soil conditions are favorable for the production of cash crops (i.e. high-priced crops) on small areas, a pipe distribution system is placed in the soild well below the surface. This method of applying water is known as artificial sub-irrigation. Soils which permit free lateral movement of water, rapid capillary movement in the root-zone soil, and very slow downward movement of water in the subsoil are very suitable or artificial sub-irrigation. The cost of such methods is very high. However, the water consumption is as low as one-third of the surface irrigation methods. The yield also improves.

Sprinkler Irrigation Method

- In this method, irrigation water is applied to the land in the form of spray
- Water is sprayed by employing the network of main pipe, sub main pipes and lateral pipes.
- Lateral pipes may be perforated at the top and sides or it may contain series of nozzles through which water comes out as a fountain
- In present scenario, we are using mainly rotating sprinkles.

Advantages of Sprinkler irrigation method

- Can be efficiently sued for wide range of topography, soils and crops
- Erosion of soil can be controlled
- Water is uniformly applied
- 80% of water application efficiency achieved
- Labour cost is reduced as no land preparaton is required
- No land levelling is required

Disadvantages of Sprinkler irrigation method

- System is a bit costly to install, operate and maintain
- Continuous supply of power is required
- Corners remain unirrigated
- Under high wind condition and high temperature, application efficiency becomes poor
- High saline water at higher temperature causes leaf burning

Drip Irrigation Method (Trickle irrigation)

- It is the latest method of irrigation
- In this method, water and fertilizer are slowly and directly applied to the root zone of the order to minimize the evaporation and seepage losses
- Specially designed emitters and drippers are used for ths purpose
- This method is best suited for row crops and orchards (eg. tomatoes, grapes, corn, cauliflowers, cabbage etc.)

Advantages of drip irrigation

- Water requirement is minimal
- Evaporation losses are close to negligible
- Highest rate of vegetative growth is achieved in this method
- Soil surface is least wetted and hence occurrence of diseases due to dampness decreases
- No land levelling is required
- No soil erosion takes place
- Less labour is required