Irrigation Engineering

Irrigation

- Irrigation is defined as a process of supplying water to crops artificially. The science of planning and designing a water supply system to the plants, crops, for their normal growth during the period of no rainfall with the help of dam, weir, barrage, reservoir and canal system with head works, cross drainage works, and miscellaneous works of canal like canal fall is called Irrigation Engineering.

Irrigation

Necessity of Irrigation

- The following are some factors which govern the necessity of irrigation:
- **Insufficient Rainfall.**
- Irrigation is necessary in the areas where rainfall is insufficient for the satisfactory growth of the crops and the plants.
- **Uneven or Non-Uniform Rainfall Distribution**
- If the distribution of rainfall in the zone of crop area

Necessity of Irrigation

- **Improvement of Perennial Crops.**
- Some of the perennial crop requires water throughout the year. But rainfall is not uniform in all seasons of the year. These crops cannot be produced perennially without water for all the seasons. For the growth or production of those perennial crops, irrigation is necessary.
- **Development of Desert Area.**
- The dry and desert areas can be converted to a beautiful cropland if irrigation water can be supplied as per need.

Necessity of Irrigation

Benefits of Irrigation

The following are the benefits of irrigation:

- **Yields of crops**

  Yield of crop can be increased by irrigation even in the period of low rainfall.

- **Optimum benefits**

  Optimum use of water is possible by irrigation to obtain maximum output.

Benefits of Irrigation

- **Elimination of mixed cropping**

  The areas where irrigation is not assured, mixed cropping is adopted. Mixed cropping means sowing different crops to-geather in the same field. Mixed cropping is not desirable as different amount of water and field conditions. Farmers are not benefitted. If irrigation water is assured, mixed cropping may be eliminated and single superior crop may be grown to get the maximum benefits.

- **Prosperity of farmers**

  If irrigation water is assured throughout the year, farmers can grow two or more crops in a year which adds to their prosperity.

Benefits of Irrigation

- **Sources of Revenue**

  When water tax is taken from farmers for supplying water, it adds to the revenue of the country.

- **Hydro-Electric Power Generation**

  The reservoir from which irrigation water is supplied, may be used for generation of power. Besides, the canals in field have some canal falls or drops in which mini hydro-projects may be installed.

Benefits of Irrigation

- **Water Supply:**

  Irrigation water may be used as source for domestic and industrial water supply.
- **General Communication:**

  The inspection road beside the canal bank may serve as communication link in remote village areas.
- **Navigation:**

  If the irrigation canals are big and deep, they may be used as navigable water way.

Benefits of Irrigation

- **Aesthetic View:**

  New man-made lake if preserved carefully, may increase aesthetic view of the surroundings.

- **Development of fishery**

  Reservoir and canals may be utilized for development of fishery.

- **Tree Plantation**:

  Trees can be grown along the bank of the canal, which increase the wealth from timber and help in controlling soil erosion of the bank.

Benefits of Irrigation

- **Protection from Famine:** Food production is increased due to irrigation by producing more crops used as food. This protects a country from famine situation.
- **Increase of Groundwater Level.**
- Due to constant seepage and percolation of water from canal, groundwater level in the nearby area is increased.
- **Aid to Civilization.**
- Irrigation water is normally available from river valley project. Some tribes living near the valley, adopt irrigation as their profession, increase production, live peacefully which leads to the general civilization of the country.

Benefits of Irrigation

- **Nutrition of Population**
- Due to irrigation, increased agricultural production takes place and this production improves the nutrition of the people.
- **Recreation**
- Recreation facilities like parks, restaurants may be developed near the canal banks or reservoir sites.
- **Social and Cultural Improvement.**
- If increases the cultural and social level of population living nearby canals and reservoirs. Tourists interest in the area of newely constructed reservoir may be enhanced.
- **Self-Sufficiency in Food**
- Irrigation makes the country self-sufficient in food by improving the production.

Benefits of Irrigation

Ill- Effects of Irrigation

- Besides benefits, there are some ill-effects of irrigation also. However, benefits are more than ill-effects.
- **Effects on Raising Water Table**.
- In unlined irrigation canal, excessive seepage of water through bed and sides takes place which raises the water table of the surrounding areas. Soil in the root zone of the crop is saturated and become alkaline which is harmful to the crops and plants. Thus the nearby area may be waterlogged.
- **Damp Climate.**
- Temperature of the command area of an irrigation projects may be lowered and damp climate prevails, which adversely affect the health of the community living in this area.
- **Breeding Places of Mosquitoes**
- Due to excess application of water, seepage and leakage from canal, marshy land may be formed leading to breeding place of mosquitos.

Ill- Effects of Irrigation

Ill- Effects of Irrigation

- **Loss of Valuable Land**
- Valuable land may be submerged due to construction of reservoir by dam, weir and barrages.
- **Return of Revenue**
- Irrigation projects are complex and expensive. If project fails due to absence of regular maintenance, return of revenue to the government becomes low compared to its cost of construction. Maintenance cost is quite high for normal functioning of the project.

Types of Irrigation

- Two main types of irrigation are:
- **Flow Irrigation:**
- Flow irrigation is that type of in which flow of water to crop field from the source takes place due to component of gravity force. This flow Irrigation may be further classified into:
- **Perennial Irrigation:**
- In this type of source of water is from a river which is perennial. A weir or barrage is constructed across this river. Sometimes dam may be constructed to form a reservoir upstream. Main canal with a regulator is constructed where one or both banks supply water to the crop field. This type is reliable as water is available during the whole period of the year.

Flow Irrigation

Perennial Irrigation

Types of Irrigation

- **Inundation or flood irrigation**
- It is that type of irrigation in which no control structures like weir, barrage, regulator, etc are constructed. During rainy season, water level in the river rises and canal bed level is kept below **High Flood Level (HFL)** of the river. The portion of water above the canal bed is diverted to inundate the crop field.
- This inundation water is drained off or allowed to absorb in the crop field prior to planting the crop. The whole system depends on the water level in the river. Although no such expenditure is involved in this system, over-irrigation may damage the crops. Therefore, this system is not popular.

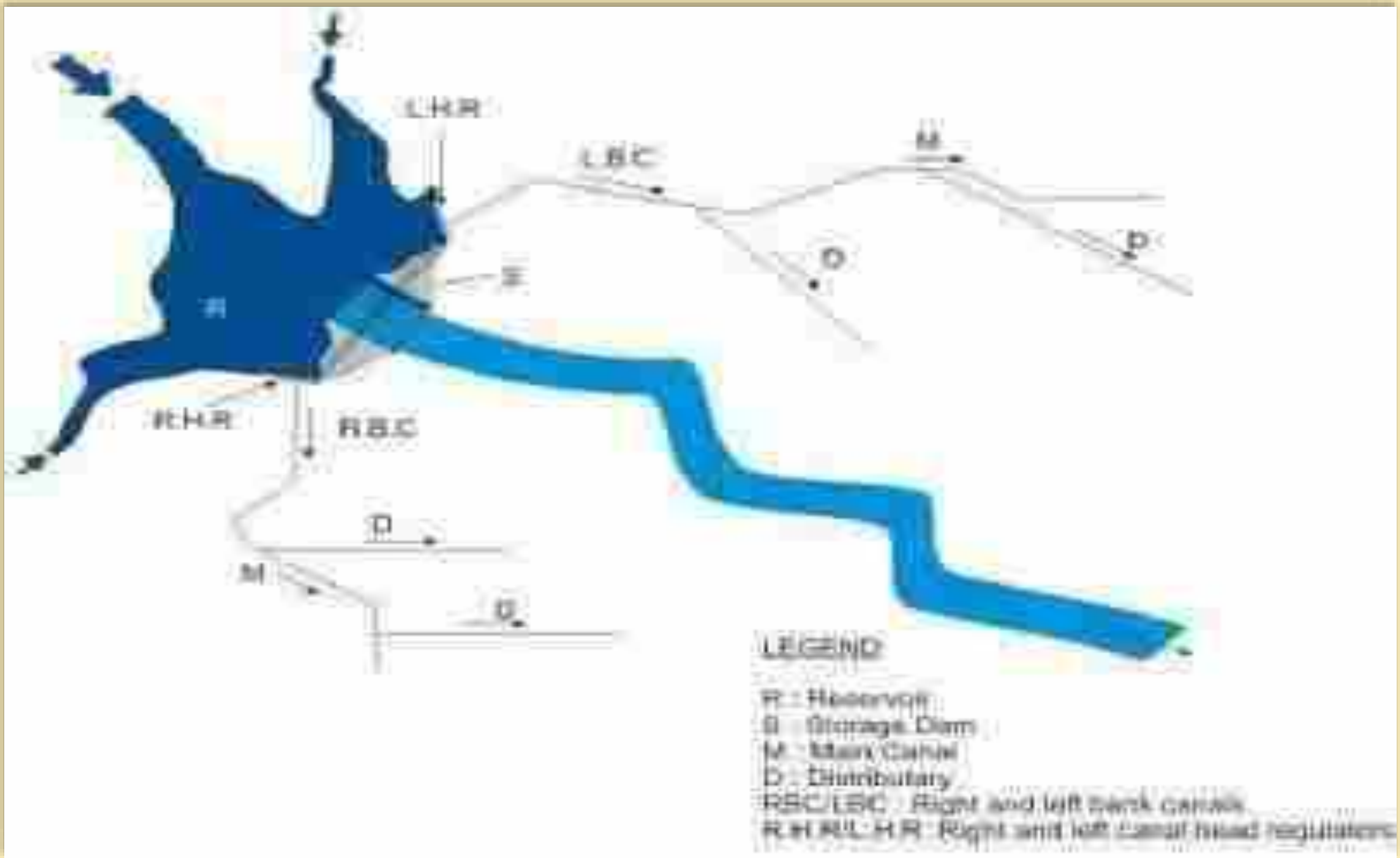
Inundation or flood irrigation

Types of Irrigation

- **Direct Irrigation: Diversion Scheme**
- In Direct Irrigation no storage of water upstream of diversion weir is provided. Water is directly diverted to canals, without any storage. Water through the canals with regulators is diverted directly to the canals.
- **Storage Irrigation: Storage Scheme**
- Adam is constructed across the reservoir to store water upstream in a reservoir. It is of a bigger magnitude, water stored is used for hydroelectric production, water supply, etc. besides irrigation depending upon the volume of water stored. A network of canal system is used. In this scheme bigger area could be irrigated to raise more crops. The scheme is costlier than other schemes.

Direct Irrigation: Diversion Scheme

Storage Irrigation: Storage Scheme



Types of Irrigation

- **Combined Storage and Diversion Scheme**.
- In this system, a dam is constructed across a river to form a reservoir. This stored water is used to produce electricity. A powerhouse is constructed just downstream of the dam. The discharge from the lower house is fed back into river downstream of the dam, a pickup weir at a suitable side is constructed to divert this available water to the crop field by the canals.

Combined Storage and Diversion Scheme.

- This type of scheme and the combined storage and diversion scheme, along with main aim of irrigation, following aims and purposes may be served
- Hydroelectric power generation
- Water supply
- Flood Control in the river valley
- Fishery
- Recreation

Combined Storage and Diversion Scheme

Types of Irrigation

- **Lift Irrigation**:
- Lift Irrigation is the process of lifting water normally from underground sources and sometimes from surface source by pump, i.e. mechanical power or man or animal power and then direct this lifted water is supplied to the agricultural field. In remote villages, if electric energy is not available in open well, shallow and deep tube wells.

Lift Irrigation

Advantages and Disadvantages of Two Types of Irrigation

- In Lift Irrigation, farmers can supply water to the crop field according to their need, hence there is no possibility of over irrigation which may occur in flow irrigation.
- Water table is lowered considerably in lift irrigation. Therefore, there is no possibility of water that may happen in surface irrigation.
- In lift irrigation, as water is directly applied to the field, loss of water due to seepage in conveyance of flow irrigation is less.

Advantages and Disadvantages of Two Types of Irrigation

- Initial cost of construction in flow irrigation system is quite high as it requires to construct a barrier like dam or weir, other hydraulic structure like canal headworks, silt excluder or rejector, etc. But in lift irrigation initial cost is quite low as it does not require any hydraulic structures.
- As the loss of water is small in lift irrigation, duty of water is very high.
- Maintenance cost in flow irrigation is higher than lift irrigation.
- More than one crop may be grown in a year in the same crop field in lift irrigation.
- Yield of crop in flow irrigation is more than lift irrigation water.

Different Types of Soil

- **Residual Soil**
- It is formed due to disintegration of natural rocks by the action of air, moisture, frost and vegetation.

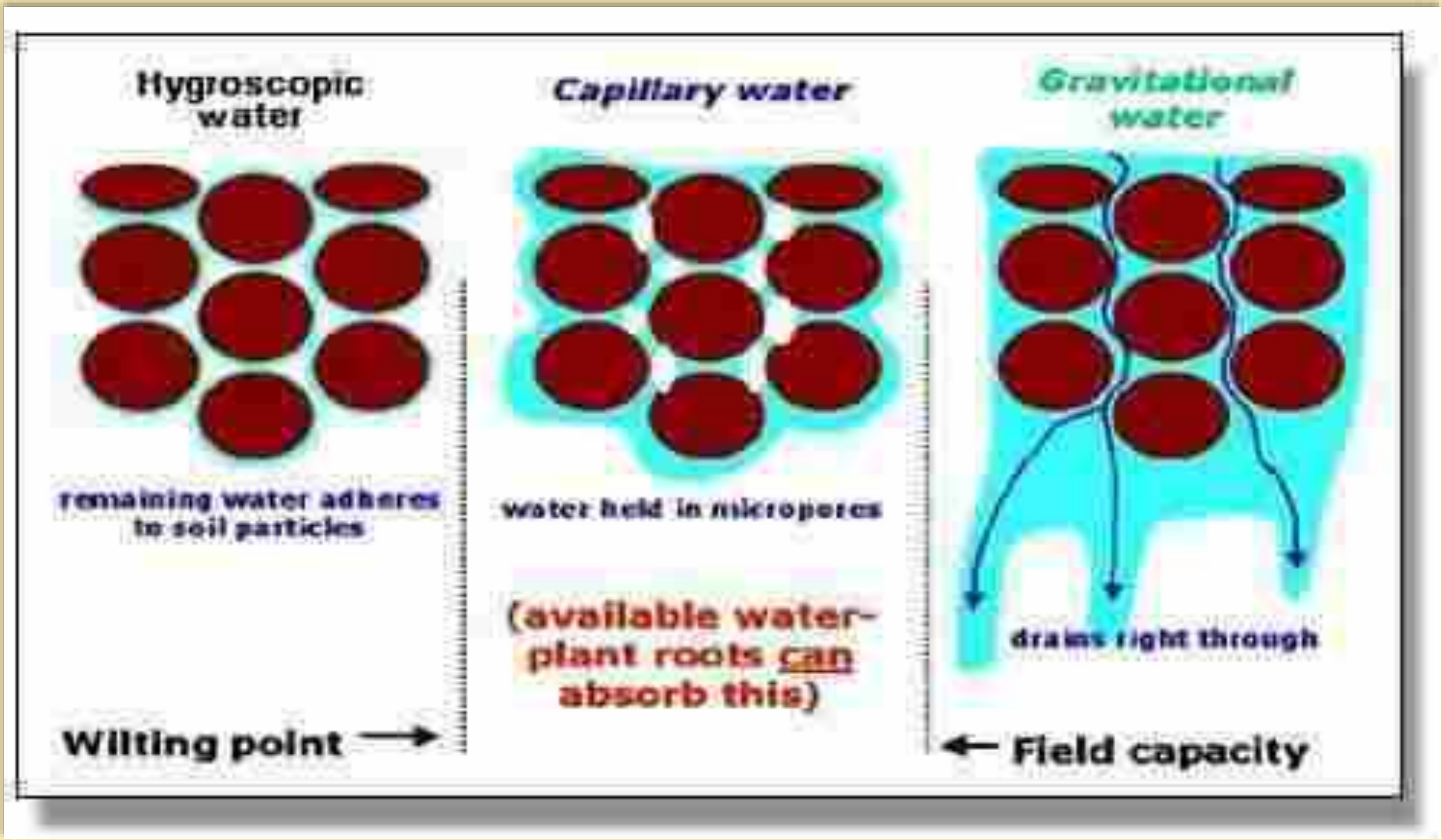
- **Alluvial Soil**
- This soil is formed by the deposition of silt, sediment by the river during flood time. This soil is available in Indo-Gangetic plains, the Brahmaputra basin and basin of other big rivers of India. Alluvial soil has very good moisture retention capacity and is strong in chemicals, manure essential for crop and plant growth.

Different Types of Soil

Types of Soil water or Soil Moisture

- When water fills the soil surface by irrigation or by rainwater, it is absorbed by the soil. The amount of absorption is different for different types of soil. The water absorbed by pores is called soil water or soil moisture. Some of the soil water are:
- **Gravitational Water**
- It is that water which drains into the soil under the influence of gravity. After irrigation and rainfall this water remains in the soil and saturates it preventing circulation of air and void spaces.
- **Capillary Water**
- Below the gravitational water, a part of water held by the soil by the capillary action of surface tension force against gravity. This part of water is absorbed by the root zone of the crop.
- **Hygroscopic Water**
- Water attached to soil particles through loose chemical bond is termed as hygroscopic water. This water can be removed from the soil only by application of heat. During draught situation, plant roots can extract small fraction of this water.

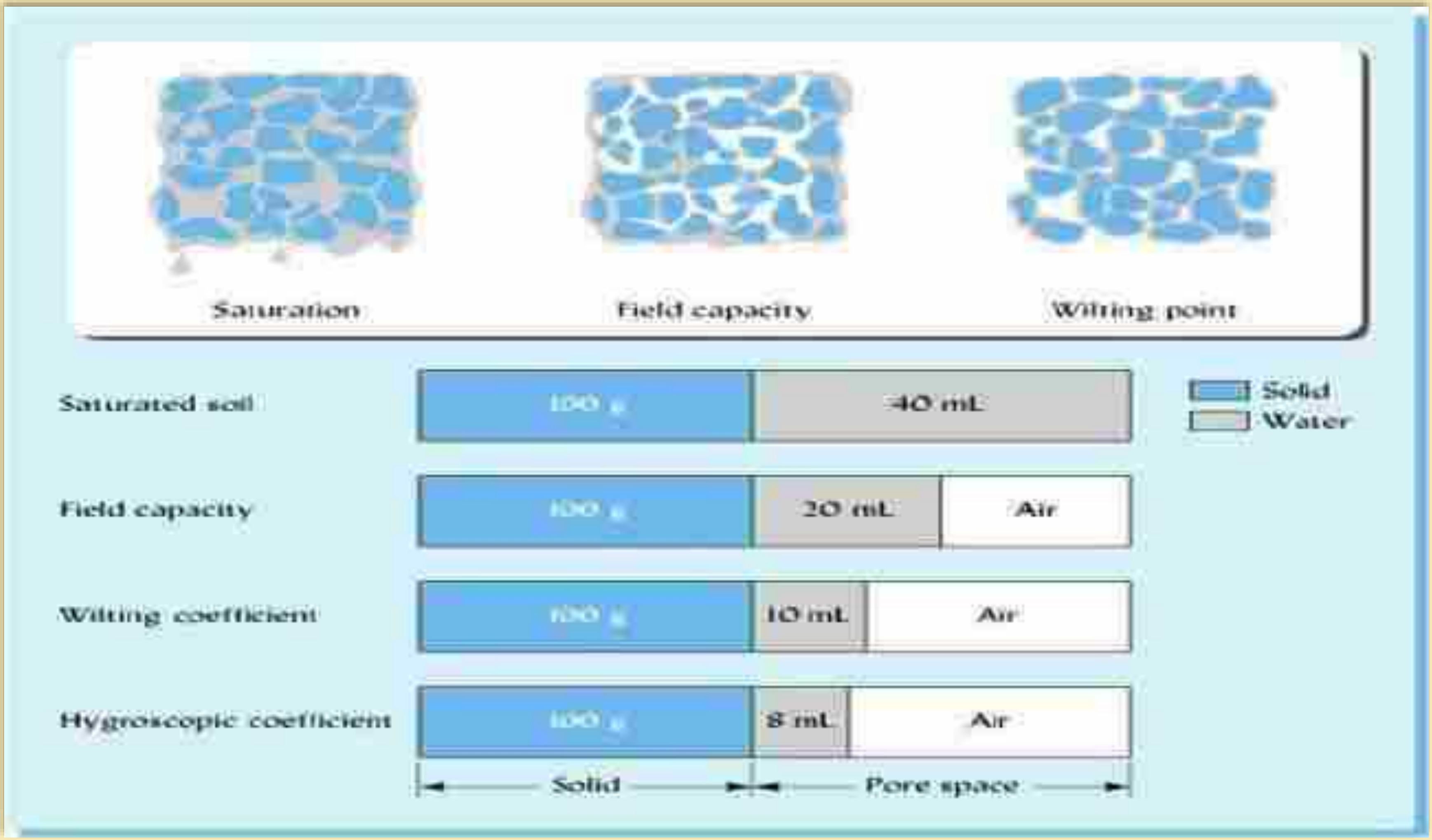
Types of Soil water or Soil Moisture



Permanent Wilting Coefficient

- Permanent wilting point or wilting coefficient is that water content at which plants can no longer extract sufficient water from soil for its growth. It is the lower end of available moisture range. At this point wilting of the plant occurs. It is expressed in percentage.

Permanent Wilting Coefficient



Ultimate Wilting

- In Ultimate Wilting, the plant cannot regain its turgidity even if sufficient water is added to the crop, the crop will die.

Limiting Soil Moisture Conditions

- For satisfactory growth of crops, it is essential to maintain readily available water in the soil. If the soil moisture is either deficient or excessive, the growth of the crop is retarded. If the soil moisture is slightly more than wilting coefficient, plant has to expend extra energy, hence growth is hampered. Again if water supply is excess, it fills the pores with water driving out the required air or oxygen for plant growth. Thus to maintain a satisfactory or healthy growth of the plant, optimum moisture content is necessary.

Water Requirement of Crops

- **Factors Affecting Water Requirements:**

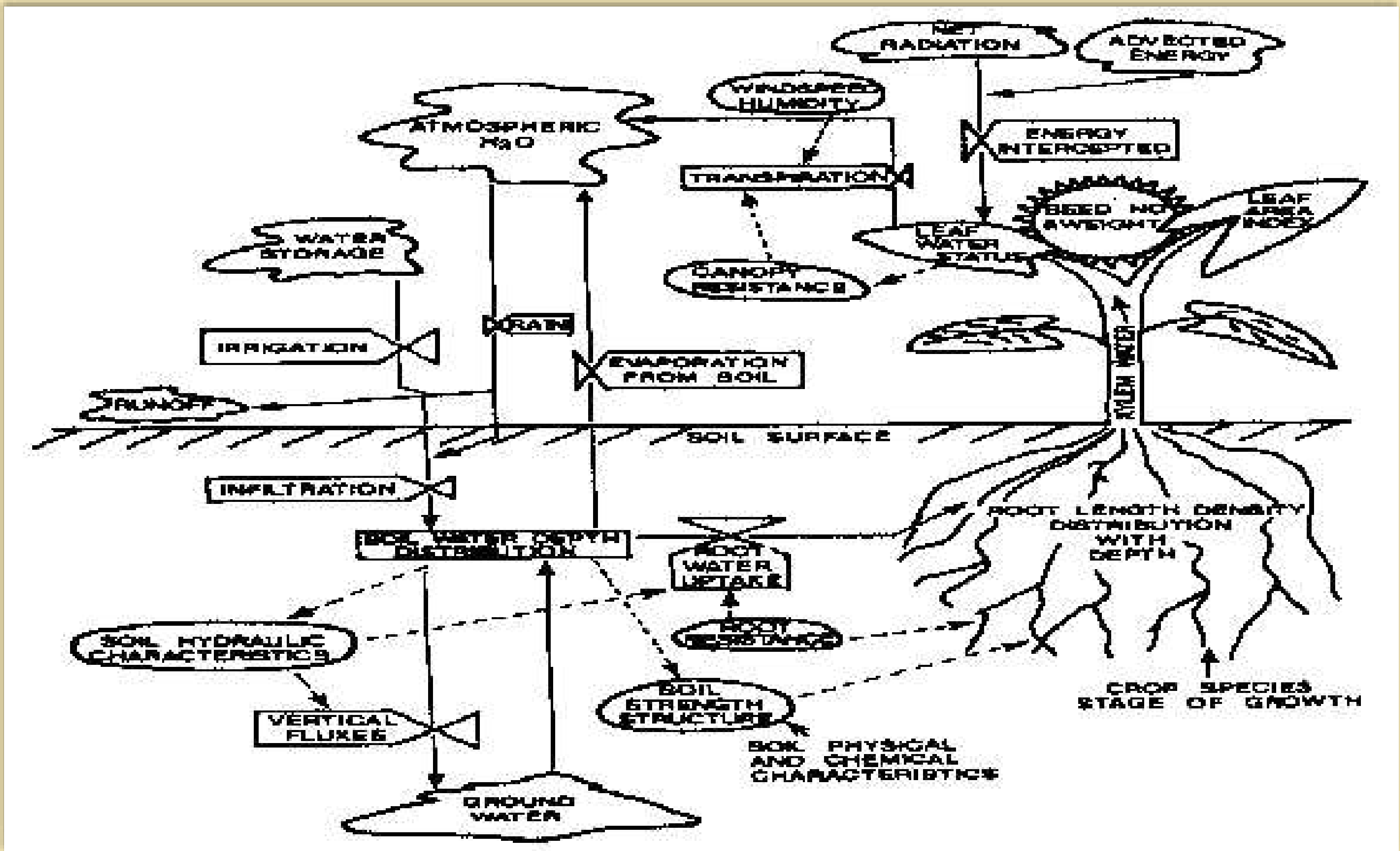
- **Water Table**
- Depending upon position of water table to ground surface or much below, water requirement may be less or more, respectively.
- **Climate**
- The evaporation loss in hot climate, hence, water requirement will be more and in cold climate water requirement will be less.
- **Type of soil**
- If soil is porous (i.e. sandy) water percolates quickly, retention of water is less, therefore, water requirement is more. But in clayey soil, water requirement is less.
- **Method of Ploughing**
- In deep ploughing, soil can retain water for a longer period and water requirement is less.

Water Requirement of Crops

- **Factors Affecting Water Requirements:**

- **Intensity of Irrigation**
- Intensity of irrigation means the ratio of area under cultivation to the total culturable area. If this intensity is more, more area is under cultivation, hence water requirement is more.
- **Ground slope**
- In steep ground water flows down quickly, finds little time to absorb required amount of water, hence, water requirement is more. For flat slope, water flows slowly, finds enough time for absorption, hence, water requirement is less.
- **Method of application of water**
- In surface flow irrigation, evaporation is more and in sub-surface irrigation, evaporation loss is minimum. Hence, water requirement is more in surface irrigation than sub-surface irrigation.

Water Requirement of Crops



Definitions of some Common Important Terms

- **Gross Command Area (GCA)**
- It is the area up to which irrigation canals are capable of supplying water for irrigation purpose.
- **Culturable Command Area (CCA)**
- It is the area on which crops can be grown satisfactorily.
- **Cash Crops**
- Crops like vegetables, fruits are cultivated by farmers to sell in the market to meet the current financial requirements and they are called cash crops.

Definitions of Some Common Important Terms

- **Crop Rotation**
- The process of changing type of crop to be grown in the same field is known as crop rotation. It has been found that if same crop is grown in the same land every year, fertility of the land gets diminished and crop production is reduced. The necessary salt required by the same crop for growth is exhausted. If crop rotation is adopted, fertility of soil is restored.

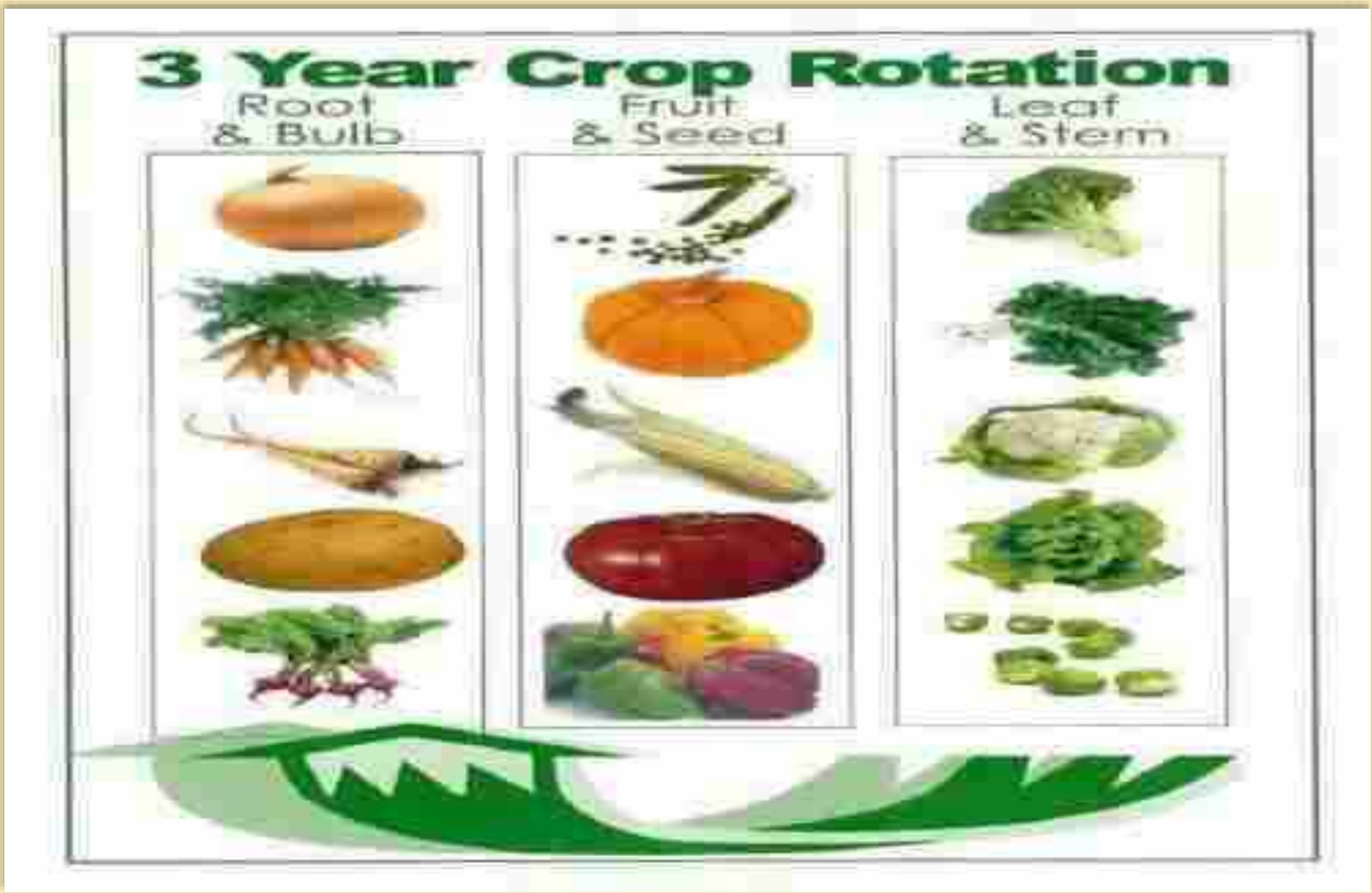
Crop Period

- It is the period required by a crop from the time of sowing to the time of harvesting.

Intensity of Irrigation

- Intensity of irrigation means the ratio of area under cultivation to the total culturable area. If this intensity is more, more area is under cultivation, hence water requirement is more.

Crop Rotation



Definitions of some Common Important Terms

- **Base Period or Base (B)**
- It is the period in days during which flow is continued for a particular crop.
- **Delta** (Δ)
- It is total depth of water provided to a crop during the entire period.
- **Duty (D)**
- It is the total area irrigated by a unit discharge running continuously during the base period and its unit is area/ cumec. Thus, duty gives the relationship between the volume of water and area of the crop which it matures, i.e.

Relation between Duty (D), Base (B) and Delta (Δ)

- Let, D= Duty of crop in ha / cumec
- B=Base period of crop in days
- Δ =Delta is depth of water in m.
- Now 1 cumec of water running continuously for a period of Bdays provides a volume of
- [(B x 24 x 60 x 60) x 1] m^3
- Amount of water required to flood 1ha of land with a depth Δ m = $(1 \times 10^4)\ m^2 \times \Delta\ m$

Relation between Duty (D), Base (B) and delta (Δ)

- Hence, the area in ha that can be irrigated by 1 m^3/sec running for the base period B days, i.e., i.e.
- Duty= $\frac{B \times 24 \times 60 \times 60}{10^4 \times \Delta} = \frac{8.64\, B}{\Delta}$

Methods of Improving Duty

- If the factors affecting duty may be made less effective, duty of water may be improved. Thus, methods of improving duty are:
- Suitable and efficient method of applying water to the crop should be used.
- Canals should be lined to reduce seepage loss. Water should be conveyed quickly to reduce evaporation loss.
- Idle length of the canal should be reduced.
- Construction parallel canals to run side by side, F.S.L. is reduced to minimize the losses.

Methods of Improving Duty

- Proper ploughed and leveled crop land improves duty.
- The source of supply should provide good quality of water.
- Crop rotation, if practiced, improves duty.
- Volumetric assessment of water with water tax compels the farmers for economic use of water which improves duty.
- The farmers must be trained to apply correct quantity of water at right time.
- Maintenance of irrigation project from headworks to the end of canal by the administrative should be adequate.

Intensity of Irrigation

- Intensity of Irrigation means the ratio of area under cultivation to the total culturable area. If the intensity is more, more area is under cultivation, hence water requirement is more.

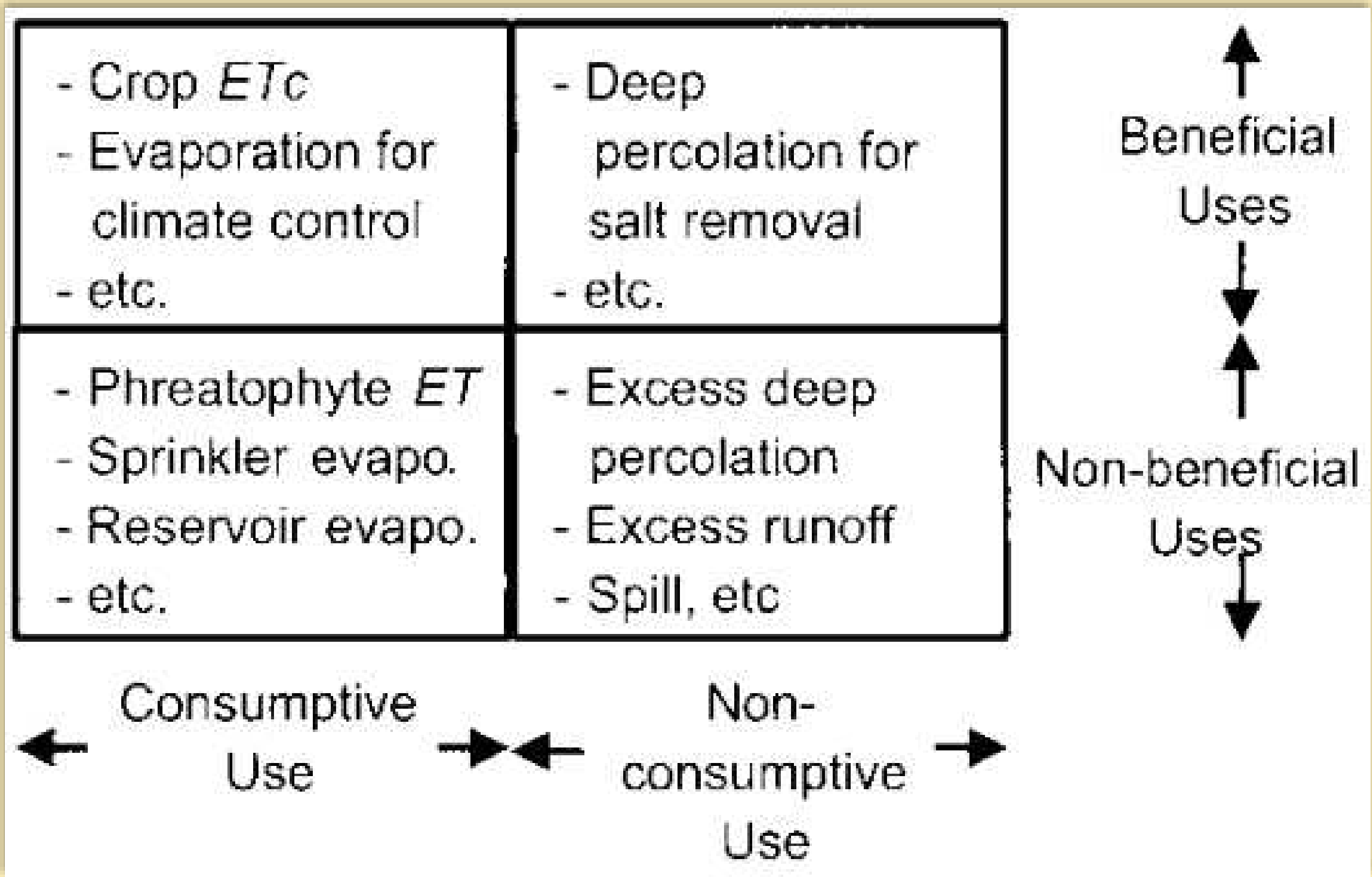
Consumptive Use of Water (CU)

- Water requirement of crop is the total quantity of water from the time the crop is sown to the time it is harvested. This water requirement may vary from crop to crop, from soil to soil and period to period. Water required to meet the demand of evapo-transpiration and metabolic activities of the crop to-geather is known as consumptive use (CU) of water

Factors Affecting Consumptive Use (CU)

- Evaporation which is dependent on humidity
- Mean monthly temperature
- Monthly precipitation
- Wind velocity in the locality which affects evaporation
- Soil type and its topography
- Cropping pattern, growth stage and type of crop
- Growing season of the crop
- Method of applying irrigation
- Irrigation water depth
- Day light hours

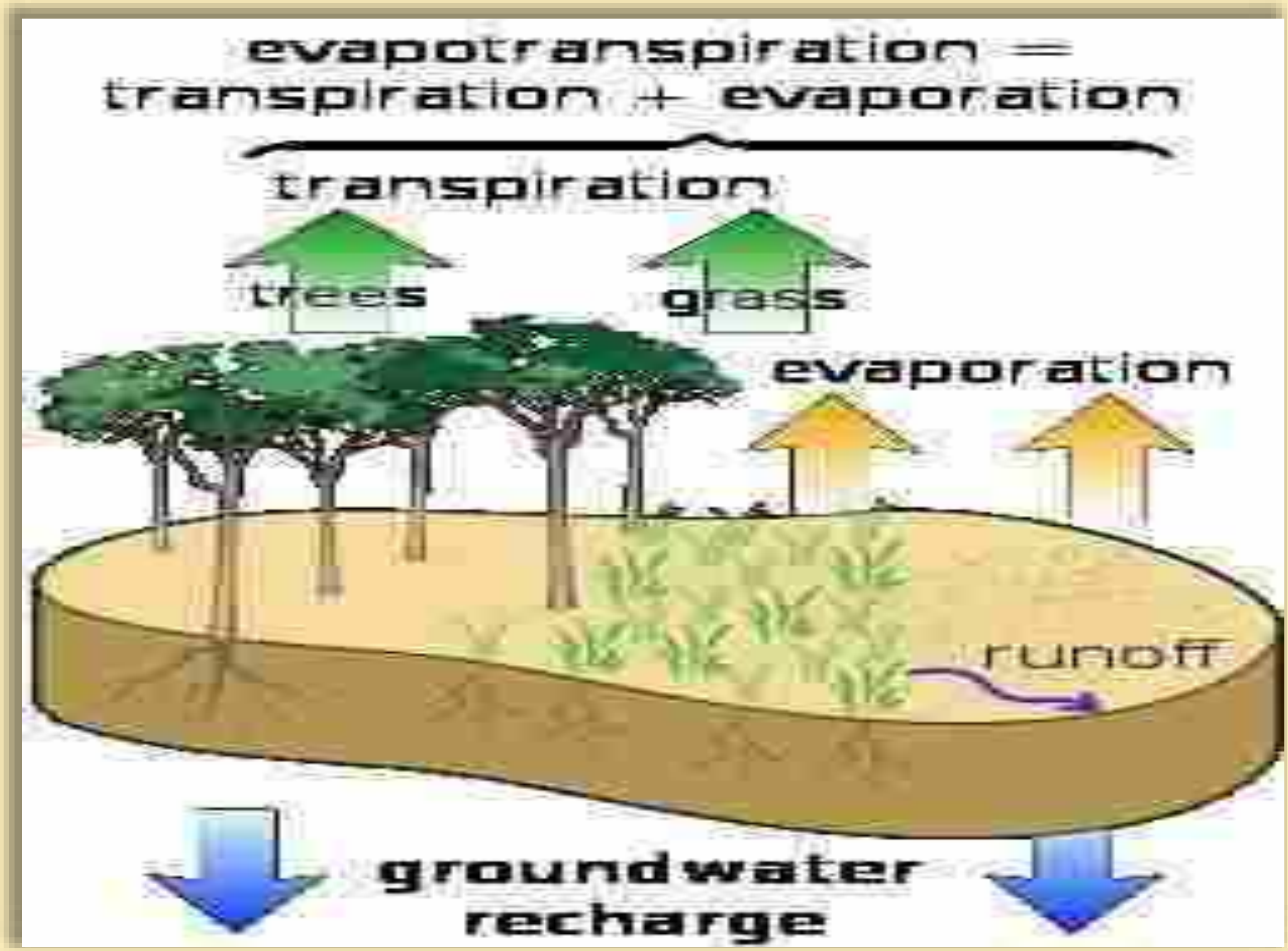
Factors Affecting Consumptive Use (CU)



Evapo Transpiration

- Evapotranspiration (ET) is a term used to describe the sum of evaporation and plant transpiration from the Earth's land surface to atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and water bodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through stomata in its leaves. Evapotranspiration is an important part of the water cycle.

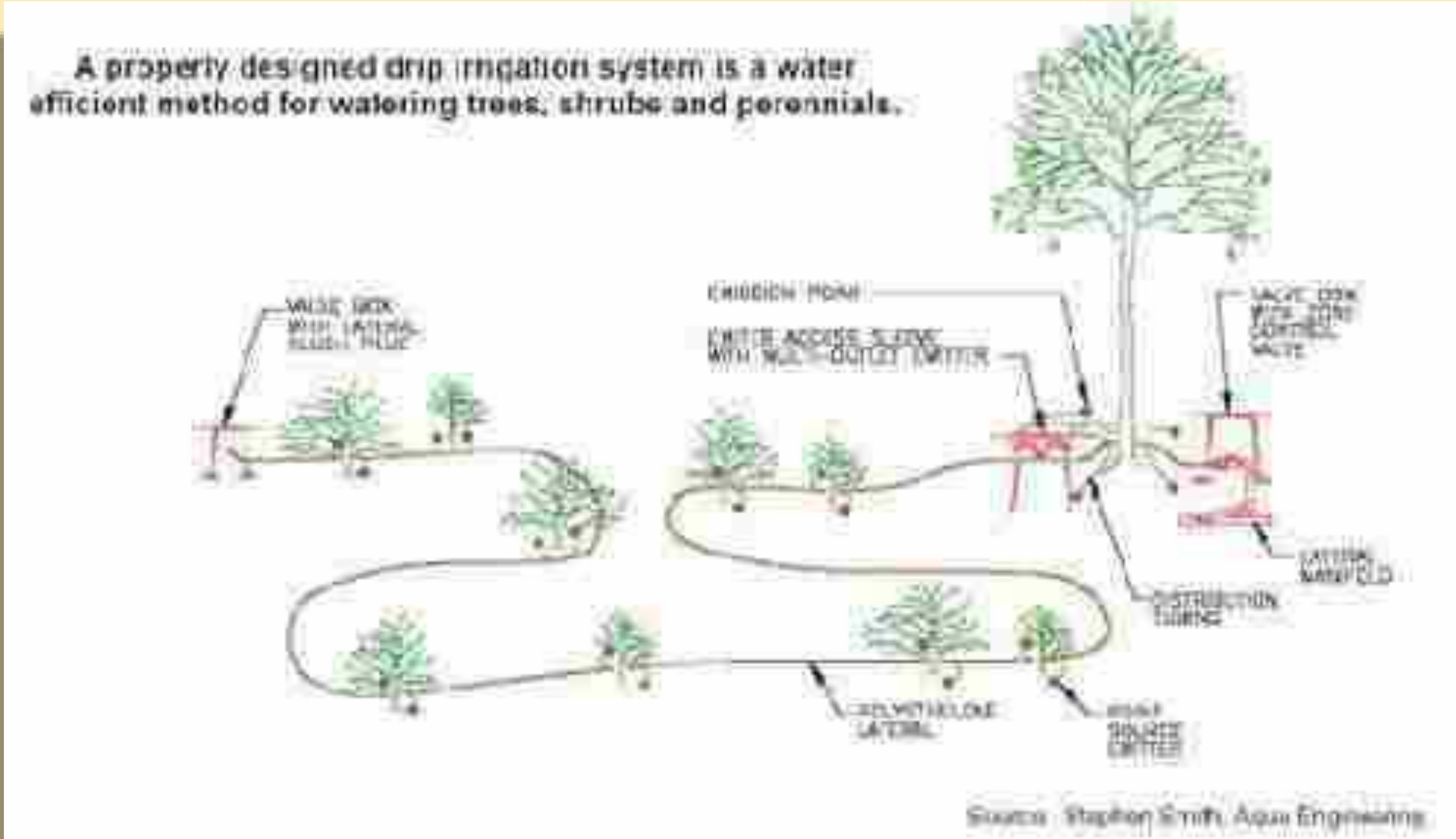
Evapo Transpiration



Irrigation Efficiency

- It is the water stored in the root zone after losses to the water pumped or supplied in the system, i.e. it is the ratio of the water output to the water input and usually expressed in percentage. Loss of water occurs in conveyance, water application, water storage and water use. Therefore**, irrigation efficiency may be efficiency in conveyance, efficiency in water application, efficiency in storage and efficiency in water use**.
- For ex, if 1 cumec of water is pumped to the farm, but 0.75 cumec is delivered in length of 1 km from the well, the loss (1-0.75) =0.25 cumec is due to conveyance.
- Therefore, Efficiency of water conveyance= $\frac{0.75}{1.0} \times 100 = 75\%$

Irrigation Efficiency



Assessment of Irrigation Water

Assessment of Irrigation Water

- Irrigation projects are undertaken by the government with the primary object of supplying water to the cultivator for raising crops to give maximum yield. Charges are levied on the cultivator for making use of irrigation water. The charges are not only defray maintenance and operation costs but also include some return on the capital investment on the project.

Assessment of Irrigation Water

- Irrigation charges are not uniform in all the states of India. Generally the water charges comprises of one or more of the following elements.
- Water rate, depending on the kind and **extent of crop**.
- Increment in land revenue, base on increased benefit derived annually.
- Providing **Irrigation facilities**.

Assessment of Irrigation Water

- **Betterment Levy** representing the government's share.
- **Irrigation Cess** being the annual charge per hectare of irrigable area.
- Water rates are collected by all state governments in the form of **water rate, surcharge on land revenue, irrigation Cess** etc.
- The rate at which water is charged for different crops vary from state to state. Rates are paid charges on the area basis for different crops.

Method of Assessment

- The various methods of assessment of irrigation water are:
- **(i) Assessment on area basis or crop basis:**
- The factors to be considered: Cash value of the crops.
- **Water Requirements of Crops**
- Time and demand of irrigation water.
- **Drawbacks of this system are:** Wasteful use of water as the charges are not made on the basis of actual quantity of water but on the area of crop.
- (b) Unequal distribution of water. The irrigators at the head reach of canal draw more water than due share and irrigators at the tail end of canal suffer.

Method of Assessment

- **(ii) Volumetric Assessment**
- Charges are levied on the basis of actual volume of water supplied at the outlet head. Most economical use of water in the field leads to more extent of irrigation area.
- It requires installation of water metres at all irrigation outlets in the canal system

Method of Assessment

- **(iii) Composite rate assessment**
- Combined land revenue and water tax are levied from the cultivators. It is not much common method of assessment.
- **(iv) Permanent Assessment or Betterment Levy.**
- In area where canals are provided as insurance against drought, the farmers are levied at a fixed rate every year irrespective of the fact whether or not they use the canal water. In drought year, the farmers are allowed to draw canal supplies without paying charges extra to normal betterment levy.

Relation between Duty (D), Base (B) and Delta (Δ)

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- Duty= $\dfrac{B \times 24 \times 60 \times 60}{10^4 \times \Delta} = \dfrac{8.64\, B}{\Delta}$

Cropping Seasons

Kharif	15th June – 14 th Oct.	Rice, Jowar, Cotton Maize, Ground Nut, Tur, Udid, Bajari etc.
Rabi	15th Oct. – 14 th Feb.	Wheat, Gram, Linseed, Mustard, Dhana, Karadai, Fodder etc.
Hot weather	15th Feb. – 14th Jun.	Vegetables
Eight montly	15th June – 14th Feb.	Tobacco, Cotton
Annual (Perennial)	15th June – 14 th June next	Sugarcane, Orthards Banana tanks 12 to 18 months.

Examples

Calculate the delta for kharif crop having duty as 2500 ha/cumec. (B for kharif = 123 d)

Using the equation:

$$\text{Duty} = \frac{8.64\ B}{\Delta}$$

Therefore,

$$\Delta = \frac{8.64\ B}{\text{Duty}} = \frac{8.64 \times 123}{2500}$$

$$\Delta = 0.42 \text{ m or } 42.5 \text{ cm}$$

Examples

- **An area irrigated by a distributary is 220 ha out of which 150 ha is Jowar (kharif) and 70 ha sugarcane, if delta for Jowar is 45 cm and that of sugarcane is 180 cm, average transit losses during Kharif are 20 % and annual transit losses are 40 %; Calculate the duty of each crop at the head of distributory.**
- **(B=120 d for Jowar, B=360 d Sugarcane)**

Examples

$$\text{Duty} = \frac{8.64\ B}{\Delta}$$

Where,

D= duty in Ha/ Cumec

Δ =Delta in m

B=Base Period in days.

1) Jowar

Area under Jowar 150 Ha; Δ =45 cm= 0.45 m

$$\text{Duty} = \frac{8.64\ B}{\Delta} = \frac{8.64 \times 120}{0.45} = \mathbf{2304\ ha/cumec}$$

Examples

Consider Transit Losses duty = $\frac{2304 \times 80}{100}$ =**1843.2ha/cumec**

Sugarcane: Perennial Crop =360 Days

Area under Sugarcane 70 ha Δ =180 cm

Duty = $\frac{360 \times 8.64}{1.8}$ =**1728 ha/ cumec**

Considering 40 %losses

Duty= $\frac{1728 \times 60}{100}$ = **1036.80 ha/ cumec**

Example

A Channel is to be designed for Irrigating 5000 ha in kharif crop and 4000 ha in Rabi crop. The water requirement for kharif and rabi are 60 cm and 25 cm respectively. The crop period for kharif crop is 21 days and for rabi crops 28 days. Determine the discharge of the channel for which it is to be designed.

Example

Using the relation.

$$\text{Duty} = \frac{8.64\,B}{\Delta}$$

Where,

D= duty in ha/ Cumec

Δ = Delta in m

Discharge for kharif crop

Here Δ = 60 cm = 0.60 m, B= 21 Days

$$\text{Duty} = \frac{8.64 \times 21}{0.60} = 302.4$$

Area to be irrigated= 5000ha

$$\text{Required discharge of channel} = \frac{5000}{302.4} = \mathbf{16.53\ cumec}$$

Example

Discharge for Rabi Crop

Here, Δ =25 cm =0.25 m

B=28 days

Therefore, Duty= $\dfrac{8.64 \times 28}{0.25}$ =**967.68 ha/Cumec**

Area to be irrigated =**4000 ha**

Required discharge of channel= $\dfrac{4000}{967.68}$ =4.13

= **4.13 cumecs**

Case Study

- **NARMADA- The lifeline of Gujarat**

Case Study- The Narmada River Development - Gujarat Water Delivery and Drainage Project

- **The Narmada River Development - Gujarat Water Delivery and Drainage Project** is part of an inter-state program for the development of multi-purpose hydropower and irrigation dams on the Narmada River and their associated irrigation canal networks. The program has been designed to: (a) further the progress of India's long-term power plan; (b) bring potentially valuable agricultural land in Gujarat and Rajasthan under irrigation; and (c) supply domestic, municipal and industrial water for Gujarat.

Case Study- The Narmada River Development - Gujarat Water Delivery and Drainage Project

- The project consists of the first three year time slice of construction of a large main canal extending for about 440 km through Gujarat to Rajasthan and an extensive canal network. A separate, parallel operation supported by the Bank Group will finance construction of a dam and power complex, including a storage reservoir extending about 210 kms upstream of the dam in Gujarat, into Maharashtra and Madhya Pradesh. The projects will install 1,450 MW of hydroelectric generating capacity and associated transmission facilities. They will further irrigate about 1.9 million ha in Gujarat and create the potential for the irrigation of about 70,000 ha in Rajasthan. Finally, the projects will supply about 1,300 million cubic meters per annum of municipal and industrial water.

Case Study

- Web links
- http://www.sardarsarovardam.org
- http://web.worldbank.org/external/projects/

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