# AGRICULTURE

# CHAPTER

# IRRIGATION MANAGEMENT

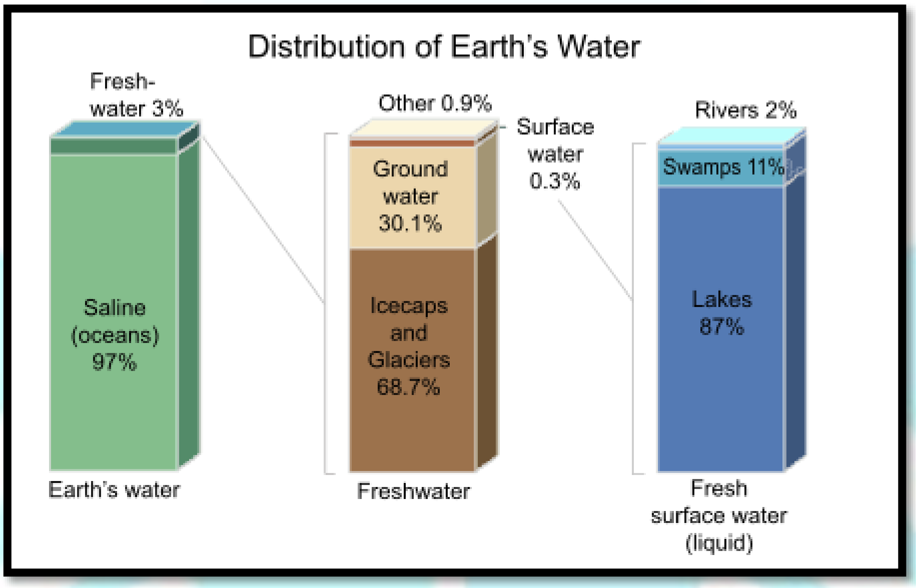
# SUMMARY SHEET

# For NABARD Grade A/B 2019

# Contents

## 1 Distribution of water resources on the planet Earth:

First, we shall begin this chapter by having an understanding regarding the **distribution of water resources on the planet Earth**: (The figures given below are approximate values)



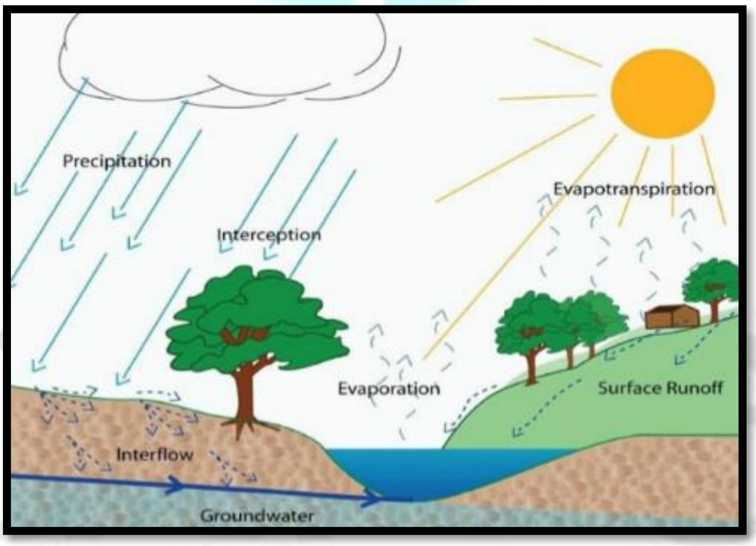

***Credit: Timothy Bralower***

Now, let us have a brief look at the **hydrologic cycle:**

## 2 Hydrologic Cycle:

The hydrologic cycle consists of **4 key components:**

- ✓ Precipitation
- ✓ Runoff
- ✓ Storage
- ✓ Evapotranspiration




**The 4 stages of Hydrologic cycle:**

## 2.1 Precipitation:

- Precipitation occurs when **atmospheric moisture** becomes **too great to remain suspended in clouds.**
- It denotes **all forms of water that reach the earth from the atmosphere**, the usual forms being rainfall, snowfall, hail, frost and dew.
- Once it reaches the earth's surface, precipitation can become surface water runoff, surface water storage, glacial ice, water for plants, groundwater, or may evaporate and return immediately to the atmosphere. Ocean evaporation is the greatest source (about 90%) of precipitation.

## 2.2 Runoff:

- Runoff is the water that flows across the land surface after a storm event.
- As the flow bears down, it notches out rills and gullies which combine to form channels. These combine further to form streams and rivers.
- The geographical area which contributes to the flow of a river is called a river or a watershed.

## 2.3 Storage:

- **Portion of the precipitation falling on land surface** which **does not flow out** as **runoff** gets **stored as either as surface water bodies** like Lakes, Reservoirs and Wetlands or as **sub-surface water body**, usually called **Ground water**.
- Ground water storage is the water infiltrating through the soil cover of a land surface and traveling further to reach the huge body of water underground.
- **The amount of ground water storage is much greater than that of lakes and rivers.**

## 2.4 Evapotranspiration:

- Evapotranspiration is actually **the combination of two terms – evaporation and transpiration.**
- The first of these, that is, **evaporation is the process of liquid converting into vapour,** through wind action and solar radiation and returning to the atmosphere.
- Evaporation is the cause of loss of water from open bodies of water, such as lakes, rivers, the oceans and the land surface.
- **Transpiration is the process by which water molecules leaves the body of a living plant and escapes to the atmosphere.**
- Evapotranspiration, therefore, includes all evaporation from water and land surfaces, as well as transpiration from plants.

# 3 Classification of Water Resources:

The water resources can be divided into **two equal parts**: Surface Water Resources and Sub Surface Water Resources.

## 3.1 Surface Water Resources:

- **Surface water** is **water on the surface of the planet** such as in a **river, lake, stream, reservoirs, wetland, or ocean.**

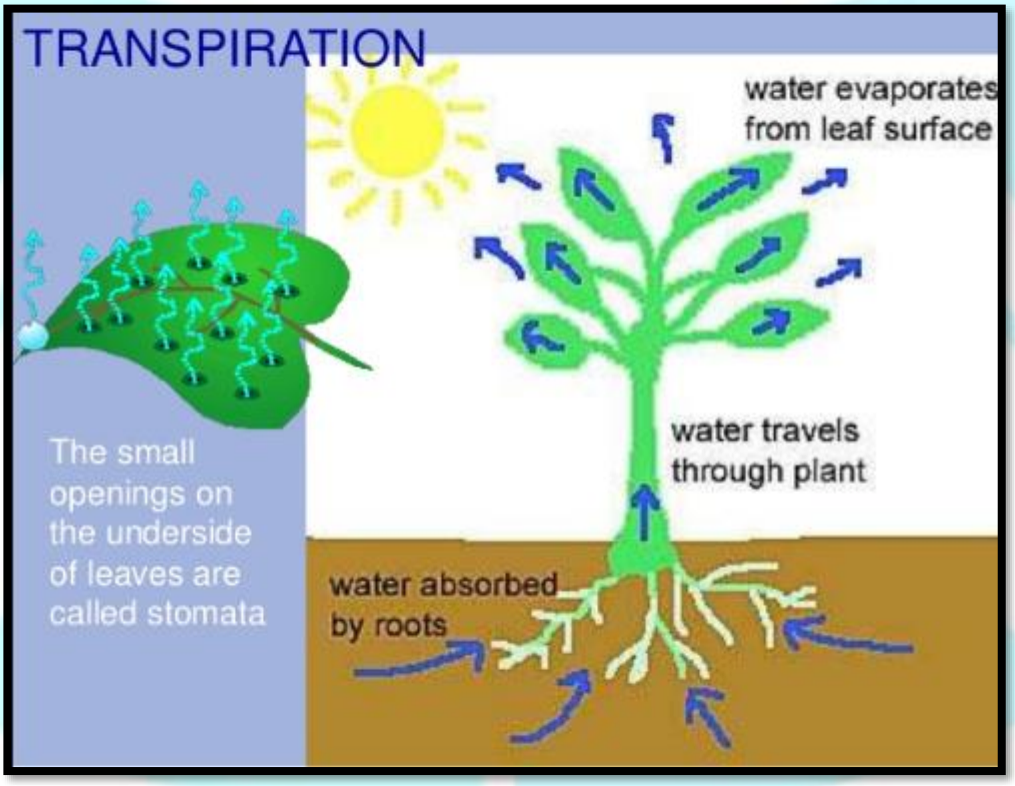
- It can be contrasted with groundwater and atmospheric water.
- The main uses of surface water include drinking-water and other public uses, irrigation uses, and for use by the thermoelectric-power industry to cool electricity-generating equipment.

### 3.2 Sub-surface water resources:

It includes **groundwater**. Groundwater is an important part of the water cycle.

## 4 Functions of water in plants:

The following is the **function of water in plants:**




1. Water is **essential for the germination of seeds and growth of plants**.
2. Water forms **over 90% of the plant body** by green or fresh weight basis.
3. During the process of photosynthesis, plants synthesize carbohydrates from carbon dioxide and water. Therefore, water is one of the essential components for the plant.
4. Water acts as a **solvent for fertilizers and other minerals**, which are taken up by the plant roots in the form of solution. Thus, water serves as the medium in which plants absorb soluble nutrients from the soil.
5. Water serves as **medium for transport of chemicals to and from cells**.
6. Water pressure in plant cells provides the firmness to the plants.
7. **Aquatic life is possible in water only**.
8. Water helps in the transpiration, which is very essential for maintaining the absorption of nutrient from the soil.
9. Water regulates the temperature and cools the plant.

**So we can see how indispensable is water for the plants.**

The water is applied externally, if availability seems limited through soil, not sufficient to meet the requirement due to drought or excess losses. We call the external application of water to the soil to supplement the requirement as `**Irrigation**'.

## 5 What is Irrigation?

Irrigation is defined as the **artificial application of water to the soil for the purpose of crop growth or crop production** in supplement to rainfall and ground water contribution.

## 6 What is Irrigation Management?

- Irrigation water management is the **act of timing and regulating irrigation water applications** in a way that will **satisfy the water requirement of the crop** without the waste of water, soil, plant nutrients, or energy.
- It means **applying water according to crop needs** in amounts that can be held in the soil available to crops and at rates consistent with the intake characteristics of the soil and the erosion hazard of the site.

**In order to carry out the Irrigation Management effectively, we have to do a study regarding the following:**

The **physical and chemical properties of soil are:**

- ✓ Biology of crop plants
- ✓ Quantity of water available
- ✓ Time of application of water

**The management of all the above said factors is known as Irrigation Agronomy.**

## 7 Seasons of rainfall in India:

| | |
|---|---|
| Winter (Cold dry period) | January – February |
| Summer (Hot weather period) | March – May |
| Kharif (South-West monsoon) *70% of the rainfall | June – September |
| Rabi (North-East monsoon) *Tamil Nadu receives its 60% of rainfall from NEM | October – December |

**Elaborating further on the amount of water that is available in India, let us have a look at India's Water Budget:**

## 8 What is Water Budget?

- Water budget can be defined as the **relationship between the inflow and outflow** of water through a **specified region or a country.**

- It gives a **comparison between the supply and demand of water**, making it possible to identify periods of excess and deficit precipitation.

## 8.1 India's Water Budget:

| | | |
|---|---|---|
| Total geographical area | 328M.ha. | |
| Average annual rainfall | 1190mm | |
| In million hectare metre | 1190 x 328 | 390 M ha m |
| Contribution from snowfall | | 8M ha m |
| **TOTAL** | | **398 (400 M ha m approx.)** |

- ✓ The rainfall below 2.5 mm is not considered for water budgeting, since it will immediately evaporate from surface soil without any contribution to surface water or ground water.
- ✓ There are on an average 130 rainy days in a year in the country out of which the rain during 75 days considered as effective rain. The remaining 55 days are very light and shallow which evaporates immediately without any contribution to surface or ground water recharge.
- ✓ Considering all these factors it is estimated that out of 400 million hectare meter of annual rainfall 70 million hectare meter is lost to atmosphere through evaporation and transpiration, about 115 million hectare meter flows as surface run-off and remaining 215 million hectare meter soaks or infiltrates into the soil profile.

**Total surface run-off has been estimated by Irrigation Commission of India in 1972 as follows:**

| | |
|---|---|
| Rain fall contribution | 115 |
| Contribution from outside the country through streams and rivers | 20 |
| Contribution from regeneration from ground water in Stream and rivers | 45 |
| **Total Surface Run-off** | **180** |

# 9 Important Irrigation Terminologies:

## 9.1 Matric Potential:

The total water potential that is attributed to the solid colloidal matrix of the soil system.

## 9.2 Capillary Potential:

The energy with which water is held by soil is defined in terms of capillary potential.

## 9.3 Seepage:

- It is the **horizontal flow of water channel**.
- **Water loss** from the **irrigation channel or canal** is mainly due to seepage.

## 9.4 Infiltration:

- **Entry of water** from the **upper layer of the soil is called infiltration**.
- It occurs in **unsaturated soil.**

- It is a process which is also used to measure the speed with which water enters the soil in case of rain or when water is supplied to the ground through human made means.

## 9.5 Percolation:

- Downward movement of water through saturated or nearly saturated soil in response to the gravity or we can put it as the descending motion of infiltered water through soil and rock layers.
- Thus, the Percolation process represents the **flow of water** from **unsaturated zone to the saturated zone.**

**Difference between Infiltration and Percolation:**

Infiltration occurs **closer to the surface of the soil**. Infiltration delivers water from the surface into the soil and plant rooting zone while **Percolation moves it through the soil profile** to **replenish ground water supplies** or become part of sub-surface run-off process.

## 9.6 Leaching:

Downward movement of nutrients and salts from the root zone with the water is called leaching.

## 9.7 Saturation capacity:

This is the **maximum water holding capacity of the soil** where all the soil pores (Macropores and Micropores) are completely filled with water.

## 9.8 Field capacity (FC):

- The soil moisture content after 2-3 days of irrigation and after drainage of gravitational water has become very slow and soil moisture content has become relatively stable.
- At the field capacity, the large pores are filled with air and the micro pores are filled with water.
- It is considered as the **upper limit of water availability to plants**.

## 9.9 Permanent Wilting Point (PWP):

- The **concept of PWP was proposed by Briggs and Shantz** in 1912.
- They utilized **dwarf sunflower as an indicator plant**.
- It is the soil moisture content at which plants can no longer obtain enough moisture to meet their requirement and remain wilted unless water is added to the soil.
- It is the **lower limit of available water to the plant.**
- In this case, though the plants are not dead, they are in a permanently wilted condition and would die if water is not added.

## 9.10 Wilting coefficient:

The percentage of moisture in root zone at the permanent wilting of plants is called wilting coefficient or critical moisture point.

## 9.11 Available water:

- This concept was given by Veihmayer and Hendrickson in 1981.

- It is the **moisture available for maximum plant use**.
- It is arrived at by subtracting the water at Field Capacity and water at the Permanent Wilting Point (PWP).

## 9.12 Ultimate Wilting Point (UWP):

- The moisture content at which the wilting is complete, and the plants die is called UWP.
- At UWP, the soil moisture tension is as high as -60 bars.

## 9.13 Soil Moisture Tension:

Soil moisture tension is a **measure of the tenacity with which water is retained in the soil** and shows the **force per unit area that must be exerted to remove water from a soil**.

## 9.14 Soil Water Potential:

- An **indication** of the tendency of **soil water to move** is expressed by the soil water potential ($\Psi$).
- $\Psi$ is defined as the **work water can do as it moves from its present state** to the **reference state**. The **reference state** is the **energy of a pool of pure water** at an elevation defined to be **zero**.

**There are three important factors affecting total soil water potential:**

This includes soil water potentials of
$\Psi_g$ Gravitational
$\Psi_o$ Osmotic
$\Psi_m$ Matric

The general relationship between total soil water potential ($\Psi_t$) and the various factors is expressed as

$$\Psi_t = \Psi_g + \Psi_o + \Psi_m$$

**Note**: Matric and Osmotic potentials are negative and reduce the free energy level of the soil water. These negative potentials are referred as suction or tension. The force of gravity is always positive.

### 9.14.1 Methods of expressing suctions:

There are **two units to express differences in energy levels of water:**

**pF Scale:**

The concept of the pF curve for expressing the relation between the amount of water in a soil and the force with which it is held there was introduced by **Schofield.**

- The **free energy** is measured in terms of the **height of a column of water** required to **produce necessary suction** or pressure difference at a particular soil moisture level.
- The pF, therefore, represents the **logarithm of the height of water column (cm)** to give the necessary suction.

**Atmospheric pressure or Bars:**

- It is another common mean of expressing suction.
- Atmosphere is the average air pressure at sea level.
- If the suction is very low as occurs in the case of a wet soil containing the maximum amount of water that it can hold, the pressure difference is of the order of about 0.01 atmospheres or 1 PF equivalent to a column of water 10 cm in height.

### 9.14.2 Soil condition and the corresponding pF value and Pressure:

**The tabular column below gives the list of soil condition and the corresponding pF values and Pressure (atm/bars):**

| Soil Condition | pF values | Pressure (atm/bars) |
|---|---|---|
| **Saturated Soil (filled with water completely)** | 0 | 0.001 |
| **Field Capacity** | 2.53 | 1/3 |
| **Permanent Wilting Point (PWP)** | 4.18 | 15 |
| **Hygroscopic point** | 4.50 | 31 |
| **Oven Dry Soil** | 7.0 | 10000 |

## 9.15 Moisture Equivalent:

Moisture equivalent is defined as the **amount of water retained by a sample of initially saturated soil material after being subjected to a centrifugal force of 1000 times** that of gravity for a definite period of time, usually half an hour.

## 9.16 Pudling:

Irrigation before sowing of crops to reduce percolation of water

## 9.17 Duty of water:

Volume or **quantity of water** required for **irrigation** to **bring a crop to maturity**.

Duty of water= 8.64 * Base period/Delta

**Gross Duty of Water:**

Area commanded by the flow of water as measured at the source of supply; It includes wastage in channel in addition to what is used for measuring crops.

**Net Duty of Water:**

Area commanded by water delivered at field. It includes the losses of water in the field.

**The difference between gross and net duty of water gives efficiency of distributaries.**

### 9.18 Base period:

The period (days) during which irrigation water is supplied to the crop.

### 9.19 Delta:

Delta is the total depth of water (cm) required by a crop during its duration in the field.

### 9.20 Kor watering:

Crop water requirement is nor uniform all through base period. The first watering is known as Kor watering.

### 9.21 Rostering/ water regulation:

The process of distribution of irrigation water.

### 9.22 Palco

Palco is the **first irrigation before sowing the crop** for **seed germination** and seedling establishment.

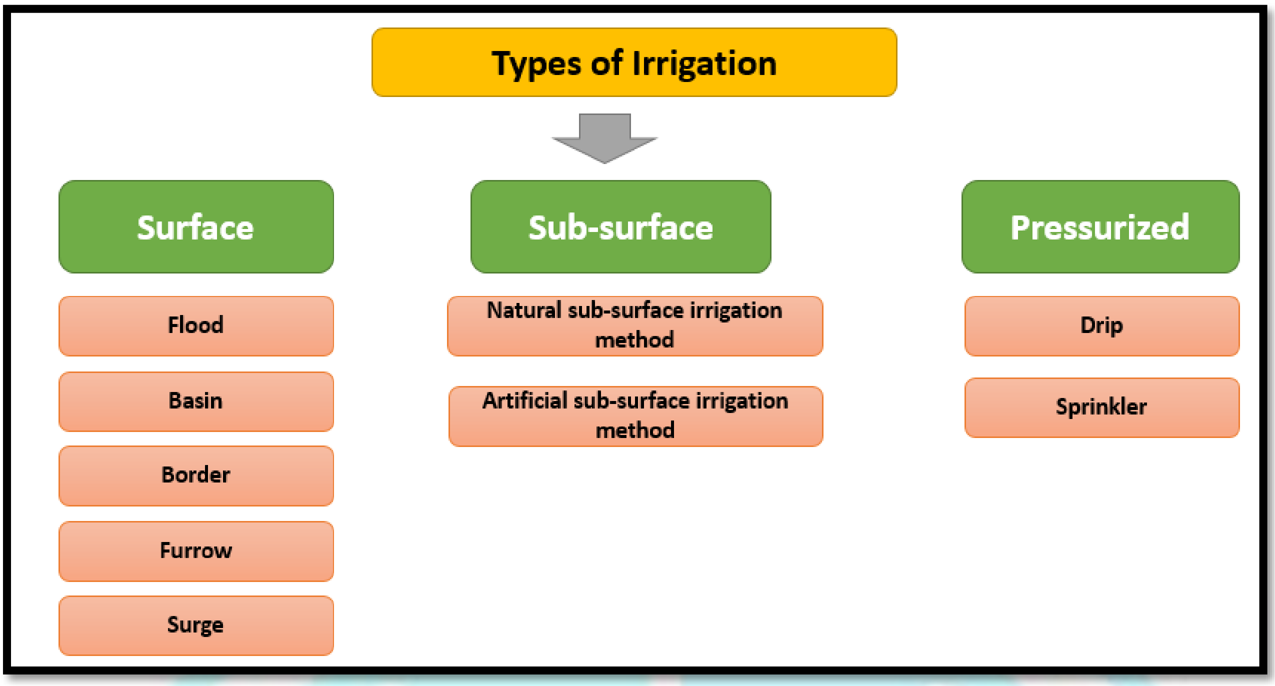
### 9.23 Moisture Regime:

The percentage of moisture in the soil at atmospheric pressure is known as moisture regime.

## 10 Classification of Irrigation Projects / Works

| | |
|---|---|
| **Major** | more than 50 million Rupees: It covers cultural command area of more than 10,000 hectares |
| **Medium** | 2.5 million to 50 million Rupees: It covers cultural command area of 2000 – 10,000 hectares |
| **Minor** | less than 2.5 million Rupees: It covers cultural command area of 2,000 hectares. |

## 11 Types of Irrigation:




### 11.1 Surface Irrigation:

The following methods are used under Surface Irrigation:

#### 11.1.1Flood Irrigation:

- Used for **lowland rice and other crops**.
- Water is allowed from the channel into the field without much control on either side of the flow.
- It covers the **entire field and move almost unguided.**
- The height of bunds around the field should be 15 cm for effective use of rainfall.

#### 11.1.2 Basin Irrigation:

- Basins are **flat areas of land surrounded by low bunds.**
- The **bunds prevent the water** from flowing to the adjacent fields.
- The basins are filled to desired depth and the water is retained until it infiltrates into the soil. Water may be maintained for considerable periods of time.

**Basin method may be divided into two types: Check Basin method and Ring Basin method.**

**Check Basin method:**

- In this method, **the land to be irrigated is divided into small plots or basins** surrounded by checks, levees (low bunds).
- **Each plot or basin** has a **nearly level surface**. The irrigation water is **applied by filling the plots with water up to the desired depth** without overtopping the levees and the water retained there is allowed to infiltrate into the soil. The levees may be constructed for temporary use or may be semi-permanent for repeated use as for paddy cultivation. The size of the levees depends on the depths of water to be impounded as on the stability of the soil when wet.
- **Basin irrigation is suitable for many field crops**. Paddy rice grows best when its roots are submerged in water and so basin irrigation is the best method for use with the crop. Also it is suitable for closely spaced crops like maize, pearl millet, groundnut etc.
- **Not suitable for crops which are sensitive to wet soil conditions around the stem.**

**Ring Basin method of Irrigation**

- The other form of basin irrigation is the ring basin method which is used for **growing trees in orchards**.
- In this method, generally for each tree, a separate basin is made which is usually circular in shape.
- Sometimes, basin sizes are made larger to include two more trees in one basin.
- Water to the basins is supplied from a supply channel through small field channels.

## 11.1.3Border Irrigation:

- The land is **divided into number of long parallel strips called borders**.
- These borders are **separated by low ridges**.
- The border strip has a **uniform gentle slope in the direction of irrigation**.

**Suitability:**

- To soils having **moderately low to moderately high infiltration rates**. It is **not used in coarse sandy soils that have very high infiltration rates** and also in heavy soils having very low infiltration rate.
- **Suitable to irrigate all close growing crops like wheat, barley, fodder crops and legumes and not suitable for rice.**

**Width of border strip**: It varies from 3-15 m.
Border length varies according to topography i.e Slope

| Slope | Soil | Length |
|---|---|---|
| 0.25 - 0.60% | Sandy and sandy loam | 60-120 m |
| 0.20 - 0.40% | Medium loam soil | 100-180 m |
| 0.05 – 0.20% | Clay loam and clay soil | 150-300 m |

## 11.1.4Furrow Irrigation:

- Furrows are **small channels, which carry water down the land slope** between the **crop rows.**
- Water infiltrates into the soil as it moves along the slope.
- The **crop** is usually **grown on ridges between the furrows.**
- This method is suitable for all row crops and for crops that cannot stand water for long periods, like 12 to 24 hours, as is generally encountered in the border or basin methods of irrigation.

**Types of furrow irrigation**

- **Based on alignment of furrows**

1. Straight furrows

2. Contour furrows

- **Based on size and spacing:**

1. Deep furrows
2. Corrugations: Small and shallow furrow are known as corrugation, suitable for close growing crops like wheat, ground nut etc.

## 11.1.5 Surge Irrigation:

Intermittent application of water to the field surface under gravity flow which results in a series of ''ON and OFF'' modes of constant or variable time spans.

## 11.2 Sub-Surface Irrigation:

- The application of water to fields in this type of irrigation system is **below the ground surface** so that it is **supplied directly to the root zone of the plants.**
- In sub-surface or sub-irrigation water is **applied beneath the ground by creating** and **maintaining an artificial water table at some depth**, usually 30 to 75 cm, below the ground surface.
- **Moisture moves upwards** towards the land surface through capillary action to meet requirements of the crops in plant roots.
- Water is applied through underground distribution system consisting of a properly designed main field ditches, laterals, laid 15 to 30 m apart.
- **Water may be obtained from wells, streams, lakes etc.**

**There may be two ways by which irrigation water may be applied below ground and these are termed as:**

- ✓ Natural sub-surface irrigation method
- ✓ Artificial sub-surface irrigation method

## 11.3 Pressurized Irrigation System/Micro-Irrigation:

### 11.3.1 Sprinkler Irrigation:

- Water is **applied with pressure to the surface of any crop or soil** in the form of a **thin spray**, somewhat **resembling rainfall**.
- This system consists of **sprinkler heads or nozzles**, which are mounted on risers in lateral lines taken from main line, which is further connected to a pumping unit.
- The **rate of spray of water** can be **regulated** and **natural rainfall can be simulated**.
- Sprinkler irrigation can be used for all crops, (except rice and jute) and on most soils (except heavy clay soils).
- It is **especially suited for field with steep slopes or irregular topography**.
- If soil erosion is a hazard, it can be used in conjunction with contour bunding, terracing, mulching and strip cropping.

**Advantages of sprinkler irrigation:**

- Suitable for undulating topography and sandy soils.
- Saving of water from 25-50% for different crops.
- Discharge rate is more than 1000 lit/hr.
- Sprinkler pressure 2.5-4.5 kg/cm$^2$
- Water use efficiency can be as high as 60% much higher to surface method of irrigation.
- Increase 40% in irrigated area with same amount of water as compared with surface method of irrigation
- About 40-60% saving in labour compared with surface.
- It can be used to protect crops against frost and high temperatures.

### 11.3.2 Drip Irrigation:

- Introduced from **Israel**. Usage of a plastic emitter in drip irrigation was developed in Israel by Simcha Blass and his son Yeshayahu.
- Drip or trickle irrigation is one of the **latest methods of irrigation** which is becoming **increasingly popular in areas** with **water scarcity and salt problems**.
- **Maximum area covered under Drip irrigation Rajasthan>Maharashtra>Andhra Pradesh.**
- This irrigation is defined as the **precise but slow application of water** as discrete drops or continuous drops through mechanical devices, called emitters located at selected points along water delivering lines.
- This system involves the **slow application of water**, **drop by drop to the root zone** of a crop.
- In this method **water is used very economically**, since losses due to deep percolation and surface evaporation are reducing to the minimum.

- Drip irrigation is best suited in water scarcity area where water quality is marginal, topography is undulating or steep, soil depth is restricted, labour is expensive and crop value is high.

**Advantages of drip irrigation:**

- Suitable for water scarcity area water saving 50-70% as compare to surface.
- Fertilizer or other chemical amendment can be efficiently applied to individual or separate plants.
- Discharge rate of water per dripper is generally 1-8 lit/hr. at 1.5-2.5 kg/cm$^2$ pressure.
- Most suitable for widely spaced crops, orchard trees and in green houses (protected cultivation of vegetables & flowers).

## 12 Comparative study between sprinkler and drip irrigation

| S. NO | Particulars | Sprinkler irrigation | Drip irrigation |
|---|---|---|---|
| 1 | Form of water | Spray or rain | Drop |
| 2 | Rate of delivery | >1000 litre/hrs | 1-4 litre/hr |
| 3 | Water saving | 25-50 per cent | 60-70 per cent |
| 4 | Land saving | 10-16 per cent | - |
| 5 | Uniformity | Uniform application of water (up to 10m) | Root zone application |
| 6 | Suitable for | Undulating land, sandy soils, areas where water and labour scarcity is common, saline soil | Wider spaced crop, orchard and vegetable garden, areas where acute water shortage |

## 13 Irrigation Methods Suitable for Different Crops

| S.No | Irrigation Method | Crops |
|---|---|---|
| 1 | Flooding | Rice and jute |
| 2 | Check basin | Groundnut, pulses, finger millet |
| 3 | Border strip | Close growing crops |
| 4 | Furrow | Cotton, maize, tobacco, potato, sorghum, sugarcane, vegetables |
| 5 | Surge | Maize, sorghum |
| 6 | Corrugation (shallow and small furrow) | Wheat, groundnut, setaria sp. |
| 7 | Drip | Sugarcane |
| 8 | Sprinkler | Vegetable and fruit crop |

## 14 Crop Water Requirement:

Water requirements of a crop is the **quantity of water needed for normal crop growth** and **yield in a period of time** to a place and may be supplied by precipitation or by irrigation or by both.

Water is needed mainly to meet the demand of evaporation (E), transpiration (T) and metabolic activity of plant together known as Consumptive Use (C.U).

**So, water requirement = IW + ER + S**

| |
|---|
| IW - Irrigation Water, in cm;<br>ER – Effective Rainfall, in cm;<br>S – Soil profile contribution |

**Let us have a look at the water requirement of different crops:**

## 15 Water Requirement of different crops:

### 15.1 RICE

**Total water requirement is 1100-1250**

- The **daily consumptive use of rice varies from 6-10 mm and total water is ranges from 1100 to 1250 mm depending upon the agro climatic situation.**
- Of the total water required for the crop, **3% or 40 mm is used for the nursery, 16% or 200 mm for the land preparation i.e. puddling and 81% or 1000 mm for field irrigation of the crop**.
- The growth of rice plant in relation to water management can be divided into **four periods viz., Seedling, vegetative, reproductive and ripening.**

### 15.2 Ground Nut

- Total water requirement **500-550 mm**.
- **Evapotranspiration is low during the first 35 days after sowing and last 35 days before harvest** and reaches a peak requirement between peg penetration and pod development stages.
- After the sowing irrigation the second irrigation can be scheduled 25 days after sowing i.e. 4 or 6 days after first hand hoeing and thereafter irrigation interval of 15 days is maintained upto peak flowering.
- During the critical stages the interval may be 7 or 10 days depending upon the soil and climate. During maturity period the interval is 15 days.

### 15.3 Finger Millet / Ragi

- Total **water requirement: 350 mm**
- Finger millet is a **drought tolerant crop**. Pre-planting irrigation at 7 or 8 cm is given.
- Third day after transplantation life irrigation with small quantity of water is sufficient for uniform establishment.

- Water is then withheld for 10-15 days after the establishment of seedling for healthy and vigorous growth.
- Subsequently three irrigations are essential at primordial initiation, flowering and grain filling stages.

## 15.4 Sugarcane

- Total water requirement: **1800-2200 mm**
- **Formative phase (120 days from planting) is the critical period for water demand**.
- To ensure uniform emergence and optimum number of tillers per unit area lesser quantity of water at more frequencies is preferable.
- The response for applied water is more during this critical phase during which the crop needs higher quantity of water comparing, the other two phases.
- **Water requirement, number of irrigations etc., are higher during this period.**

## 15.5 Maize

- Total water requirement: **500 – 600 mm**
- The water requirement of **maize is higher, but it is very efficient in water use.**
- **Growth stages of maize crop are sowing, four leaf stage, knee high, grand growth, tasseling, silking early dough and late dough stages.**
- Crop uniformly requires water in all these stages. Of this, **tasseling, silking and early dough stages are critical periods.**

## 15.6 Cotton

- Total water requirement: **550 – 600 mm**
- Cotton is **sensitive to soil moisture conditions.**
- Little water is used by plant with early part of the season and more water is lost through evaporation than transpiration.
- As the plant grows, **the use of water increases from 3 mm / day reaching a peak of 10 mm a day when the plant is loaded with flowers and boll.**
- **Water used during the emergence and early plant growth is only 10% of the total requirement**. Ample moisture during flowering and boll development stages is essential.
- In the **early stage as well as at the end the crop requires less water**.
- **Water requirement remains high till the boll development stage.**

## 15.7 Sorghum

Total water requirement: **350-500 mm**

## 15.8 Pulses

- Total water requirement: **200-450 mm**
- Mostly the pulses are grown under rainfed condition.
- Some pulse crops like Redgram, Blackgram, Greengram are grown in summer season as irrigated crop which need 3 to 4 irrigation at critical stags like germination, flowering and pod formation.

## 16 Critical stages of crops for irrigation:

| S.No | Cereals | Critical stages of crops for irrigation |
|---|---|---|
| 1 | Rice | Tillering, panicle, initiation, heading and flowering |
| 2 | Wheat | CRI, Tillering, Late joining, flowering, milking and dough |
| 3 | Maize | Tasseling and silking to dough stage |
| 4 | Sorghum | Booting, blooming, milking and dough stage |
| 5 | Pearl millet | Heading and flowering |
| 6 | Finger millet | Primordial initiation and flowering |
| **Pulses:** | | |
| 1 | Chickpea | Late vegetative phase and pod development |
| 2 | Pea | Flowering and early pod formation |
| 3 | Blackgram | Flowering and pod setting |
| 4 | Greengram | Flowering and pod setting |
| 5 | Lucern | After cutting and flowering |
| 6 | Beans | Flowering and pod settings |
| **Oilseed:** | | |
| 1 | Groundnut | Flowering, peg formation and pod development |
| 2 | Soybean | Blooming and seed formation |
| 3 | Sunflower | Buttoning, knee high, flowering and early seed formation |
| 4 | Sesamum | Blooming to maturity |

**Now in the section below we shall have a look at the important irrigation terminologies:**

## 17 Important Irrigation Terminologies:

- ✓ Water Use Efficiency
- ✓ Consumptive Water Use Efficiency
- ✓ Water Storage Efficiency
- ✓ Field Water Use Efficiency
- ✓ Crop Water Use Efficiency
- ✓ Water Conveyance Efficiency
- ✓ Irrigation Efficiency

### 17.1 Water Use Efficiency (WUE):

It is the **yield of a marketable crop** produced **per unit of water** used in evapo-transpiration or it is the **dry matter produced per unit of water** used and it is expressed as kg/ha-mm(cm).

**Water Use Efficiency is of two types:**

#### 17.1.1Field Water Use Efficiency:

**Field WUE = Crop Yield (kg/ha)/ (ET + S + D)**

Where ET: Evapotranspiration loss of water;

S: Ground water contribution;

D: Deep Percolation losses;

### 17.1.2 Crop Water Use Efficiency:

**Crop WUE = Crop Yield (kg/ha)/ (E + T + G)**

E: Evaporation loss;

T: Transpiration loss;

G: Metabolic use of plant;

### 17.1.3 Water use efficiency of major field crops:

| S.No | Crop | WUE (kg/ha mm) |
|---|---|---|
| 1 | Finger Millet | **13.4** |
| 2 | Wheat | 12.6 |
| 3 | Groundnut | 9.2 |
| 4 | Sorghum | 9.0 |
| 5 | Pearl millet, maize | 8.0 |
| 6 | Rice | **3.7 (lowest)** |

### 17.2 Consumptive Water Use Efficiency:

It is defined as the ratio of consumptive water use by the crop of irrigated farm or project and the irrigation water stored in the root zone of the soil on the farm or the project area.

$$Ecu = \frac{Wcu}{Wd} \times 100$$

where,

Ecu = consumptive use efficiency, per cent

Wcu = normal consumptive use of water

Wd = net amount of water depleted from root zone soil

### 17.2.1What is Consumptive Use of Water?

It is used to designate the losses due to evapotranspiration and the water used by the plant for its metabolic activities.

Since water used in the actual metabolic process is less than 1% of Evapotranspiration, it is insignificant and thus the term Consumptive Use = Evapotranspiration.

**CU = ET + water used in metabolic activities;**

## 17.3 Irrigation Efficiency:

It is **defined as the ratio of water output to the water input**, i.e., the ratio or percentage of the irrigation water consumed by the crop of an irrigated farm, field or project to the water delivered from the source.

$$E_i = \frac{W_c}{W_r} \times 100$$

where,

Ei = irrigation efficiency (%)

Wc = irrigation water consumed by crop during its growth period in an irrigation project.

Wr = water delivered from canals during the growth period of crops.

In most irrigation projects, the irrigation efficiency ranges between 12 to 34 %.

## 17.4 Water Storage Efficiency:

It is defined as the ratio of the water stored in the root depth by irrigation to the water needed in the root depth to bring it to the field capacity. Also termed as water storage factor.

$$E_s = \frac{W_s}{W_w} \times 100$$

where,

Es = water storage efficiency, per cent

Ws = water stored in the root zone during the irrigation

Ww = water needed in the root zone prior to irrigation, i.e., field capacity available

## 17.5 Water Conveyance Efficiency:

It is a **measure of efficiency of water conveyance system from canal network to watercourses and field channels**. It is the **ratio of water delivered infields at the outlet head to that diverted into the canal system from the river or reservoir**. Water losses occur in conveyance from the point of diversion till it reaches the farmer's fields which can be evaluated by water conveyance efficiency, as under:

$$E_c = \frac{W_t}{W_f} \times 100$$

where,

Ec = water conveyance efficiency, per cent

Wf= water delivered to the farm by conveyance system (at field supply channel)

Wt = water introduced into the conveyance system from the point of diversion

Water conveyance efficiency is generally low; about 21% losses occur in earthen watercourses only.

**Given below are some of the terms one should be aware of while studying schemes which are in place for Irrigation:**

## 17.6 Fertigation:

It is the **application of fertilizers** through the **irrigation system**.

***Fertilizers Suitable for Fertigation***

| Name | Chemical form | N-$P_2O_5$-$K_2O$ Content (%) | Solubility (g/l at $20^0$C) | Remarks |
|---|---|---|---|---|
| Ammonium Nitrate | $NH_4NO_3$ | 34-0-0 | 1830 | Incompatible with acids |
| Ammonium Sulfate | $(NH4)_2SO_4$ | 21-0-0 | 760 | Clogging with hard water |
| Urea | $CO(NH_2)_2$ | 46-0-0 | 1100 | |
| Diammonium Phosphate | $(NH4)_2HP_2O_5$ | 18-46-0 | 575 | Contains phosphorous at high solubility |
| Potassium Chloride | KCl | 0-0-60 | 347 | Chloride toxic for some crops, Cheapest K source |
| Potassium Nitrate | $KNO_3$ | 13-0-44 | 316 | Expensive, high |

# 18 Irrigation water quality:

- Irrigation water quality refers to the **kind and amount of salts** present in the **water** and **their effects on crop growth and development**.
- High salt concentrations influence osmotic pressure of the soil solution and affect the ability of plants to absorb water through their roots.
- However, an appropriate evaluation of the water quality prior to its use in irrigation will help in arresting any harmful effect on plant productivity and ground water recharge.
- The suitability of water for irrigation is determined in several ways including the degree of acidity or alkalinity (pH), EC (Electrical Conductivity), Residual Sodium Carbonate (RSC), Sodium Adsorption Ratio (SAR), Permeability Index (PI) and Total Hardness (TH) along with the effects of specific ions.
- The assessment of water quality criteria for irrigation is based on the consideration of the related aspects like the possible effects on the physico-chemical properties of the soil and the impact on crop yield.

## 18.1 Classification of Irrigation water quality:

**Let us have a look at the various standards for determining the Irrigation water quality:**

### 18.1.1Residual Sodium Carbonate:

- Carbonate associates quickly with Ca and Mg and form $CaCO_3$ and $MgCO_3$.
- The Na replaces Ca and Mg and synthesizes $Na_2CO_3$ which again causes sodium hazard (called as Residual Sodium Carbonate RSC).

| RSC in water (m.eq/l) | Suitability for irrigation | Remarks |
|---|---|---|
| >2.5 | Not suitable for irrigation | Needs gypsum |
| 1.25-2.5 | Marginal | Need gypsum |
| Less than 1.25 | Safe | - |

**Sodium Hazard of Irrigation Water:**

### 18.1.2Sodium Adsorption Ratio (SAR):

- SAR is commonly used as an index for evaluating the sodium hazard associated with an irrigation water supply.
- The SAR is defined as the square root of the ratio of the sodium (Na) to calcium + magnesium (Ca + Mg).

SAR= $[Na^+]/\sqrt{Ca + Mg}$

where all cation measurements are expressed in millimoles per liter (mmol/L). Alternatively, if the cation measurements are expressed in milliequivalents per liter (meq/L), then the SAR is defined to be:

SAR= $[Na^+]/\frac{\sqrt{[Ca2+]+[Mg2+]}}{2}$

Irrigation waters having **high SAR levels can lead to the build-up of high soil Na levels** over time, which in turn can adversely effect soil infiltration and poor aeration.

| Sodium hazard | Class | SAR |
|---|---|---|
| Low | $S_1$ | <10 |
| Medium | $S_2$ | 10-18 |
| High | $S_3$ | 18-26 |
| Very High | $S_4$ | 26-31 |

### 18.1.3 Boron Hazard of Irrigation water:

| Class | | Boron (ppm) | Suitability |
|---|---|---|---|
| Normal water | $C_1$ | <3 | Ideal for all crops on all soils |
| Low boron water | $C_2$ | 3-4 | All crops on heavy and medium soils |
| Medium boron water | $C_3$ | 4-5 | Can be used for most crops on heavy soils |

| | | | |
|---|---|---|---|
| Boron water | $C_4$ | 5-10 | Semi-tolerate and tolerate crops on heavy soils |
| High boron water | $C_5$ | >10 | Not suitable for irrigation |

### 18.1.4 Summary of various indicators:

**Classification of irrigation water quality**

| Quality of water | EC (m.mhos / cm) | pH | Na (%) | Cl (me/l) | SAR |
|---|---|---|---|---|---|
| Excellent | 0.5 | 6.5 – 7.5 | 30 | 2.5 | 1.0 |
| Good | 0.5 – 1.5 | 7.5 – 8.0 | 30 – 60 | 2.5 – 5.0 | 1.0 – 2.0 |
| Fair | 1.5 – 3.0 | 8.0 – 8.5 | 60 – 75 | 5.0 – 7.5 | 2.0 – 4.0 |
| Poor | 3.0 – 5.0 | 8.5 – 9.0 | 75 – 90 | 7.5 – 10. | 4.0 – 8.0 |
| Very poor | 5.0 – 6.0 | 9.0 – 10. | 80 – 90 | 10.0 – 12.5 | 8.0 – 15.0 |
| Unsuitable | >6.0 | > 10 | >90 | >12.5 | >15 |