Advances in Agronomy_ A Compilation of Research

(Volume - 1)

Editors

Ayush Baliyan

Mayur Bhatu Patil

Chennalwad Sharad Parashuram

Amol Rajkumar Pawar

Vasireddy Mani Chandana

Stella International ™ Publication

Contents

CHAPTER-17

WATER MANAGEMENT IN AGRICULTURE

B. Gouthami[1], Prajwal G. Dodewar[1], C Lokesh[2] and Jyothsna Kusukuntla[3]

[1]Ph. D Scholar, ICAR-Indian Agricultural Research Institute, New Delhi, India

[2]Water Technology Centre, Professor Jayashankar Telangana State Agricultural University.

[3]Ph.D Scholar GBPUAT, pantnagar, Uttarakhand, India.

Abstract

Effective water management in agriculture is essential for sustainable crop production, resource conservation, and environmental protection. Regular maintenance of soil moisture and irrigation levels in the field helps to prevent water loss and improves water retention, rainwater harvesting which enhances soil health conditions. In the context of agricultural water management, various irrigation terminologies like matric potential, capillary potential, seepage, infiltration, percolation, leaching, saturation capacity field capacity and permanent wilting point, wilting coefficient, soil moisture tension and soil water potential are used to describe systems, techniques, efficiencies, and practices. Understanding these terms is crucial for effective communication and implementation of irrigation strategies. Different irrigation methods and irrigation efficiencies play a crucial role in water management in agriculture by optimizing water use, enhancing crop yields, and conserving resources. Key strategies include in improving irrigation efficiency through advanced technologies like different irrigation methods *i.e.* drip and sprinkler systems, employing smart irrigation controllers based on real-time weather data, and utilizing soil moisture sensors to optimize watering schedules. Training and education for farmers are critical to implementing these practices, ensuring long-term water sustainability in agriculture.

Keywords: Irrigation Method, Irrigation Management, Ground Water and Surface Water

1. Introduction

Water is essential to the growth of the human race, the environment, and the economy. It is a critical endeavor aimed at efficiently utilizing water resources to sustainably support crop production while conserving natural ecosystems. As one of the primary users of freshwater globally, agriculture faces the dual challenge of increasing food production to meet growing global demand while minimizing water use and environmental impact. Improving food security, rural people' earnings, and quality of life all depend heavily on access to and security of water resources. For millions of impoverished farmers, especially those in rainfed regions but also those engaged in irrigated agriculture, dependable access to water continues to be a significant barrier. Many more farmers are in danger of losing water security and falling back into poverty as a result of climate change and the ensuing changes in rainfall patterns. Therefore, it is imperative that communities be better equipped to adopt and spread agricultural water management technology. Water utilised for animal production, inland fisheries, and crop production—both rainfed and irrigated—is managed as part of agricultural water management. An improved agricultural water management system in these fertile regions is the key to both global food security and poverty alleviation. Current food output has to quadruple in order to meet global food demands by 2050. This growth must come from both the extension and enhancement of already practiced irrigated agriculture as well as from places now using rainfed agriculture. The management of water and its effective use in agricultural crop production are the topics of this note.

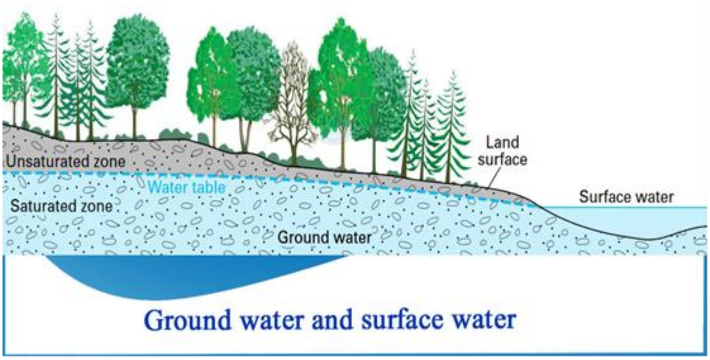


Fig1. Resources of water (groundwater and surface water)

2. Classification of Water Resources: Water resources are broadly classified into two main categories: Resources for Both Surface and Subsurface Waters.

Surface Water Resources Surface water refers to water that is found on the surface of the Earth, such as in rivers, lakes, streams, reservoirs, wetlands, and oceans. This type of water can be directly contrasted with groundwater, which is found beneath the surface, and atmospheric water, which exists in the atmosphere.

Uses of Surface Water:

- **Drinking-Water and Public Uses:** Surface water is a crucial source of drinking water for humans and is also used for various other public purposes.
- **Irrigation Uses:** It plays a significant role in agriculture, providing the necessary water for irrigation to cultivate crops.
- **Thermoelectric-Power Industry:** The thermoelectric power sector uses surface water to provide effective cooling for its electricity-generating machinery.
- **Sub-Surface Water Resources:** Sub-surface water resources primarily consist of groundwater. Groundwater is a critical component of the water cycle, stored in aquifers beneath the Earth's surface.

Uses of Sub-Surface Water:

- In situations where surface water is scarce, it is essential for providing water for various purposes.

Functions of Water in Plants

Water is indispensable for plant life, serving numerous essential functions that support their growth and survival. Here are the key roles of water in plants:

Germination and Growth: Water is crucial for the germination of seeds and the overall growth of plants. Without adequate water, seeds cannot sprout, and plants cannot thrive.

1. **Plant Composition:** Water constitutes over 90% of a plant's body by green or fresh weight, highlighting its importance in maintaining plant structure and function.

2. **Photosynthesis:** Plants use carbon dioxide and water to create carbohydrates during photosynthesis. Water is therefore a crucial element of this process, which allows plants to generate the energy required for growth.
3. **Nutrient Solvent:** Fertilisers and other minerals are dissolved by water. Water serves as a channel through which plants take up vital soluble elements from the soil because plant roots absorb these nutrients in solution form.
4. **Chemical Transport:** Water serves as a medium for transporting chemicals to and from plant cells, facilitating various physiological processes.
5. **Turgor Pressure:** Water pressure within plant cells provides turgor, which gives plants their firmness and structure.
6. **Aquatic Life Support:** Aquatic plants and organisms rely on water for their habitat, making it crucial for sustaining aquatic life.
7. **Transpiration:** Water plays a vital role in transpiration, a process essential for nutrient absorption from the soil. Transpiration helps maintain the flow of nutrients through the plant.
8. **Temperature Regulation:** Water regulates temperature and cools the plant, preventing overheating and ensuring optimal growth conditions.

The external application of water becomes necessary when natural availability through the soil is insufficient to meet plant requirements, particularly during drought conditions or periods of excess water loss.

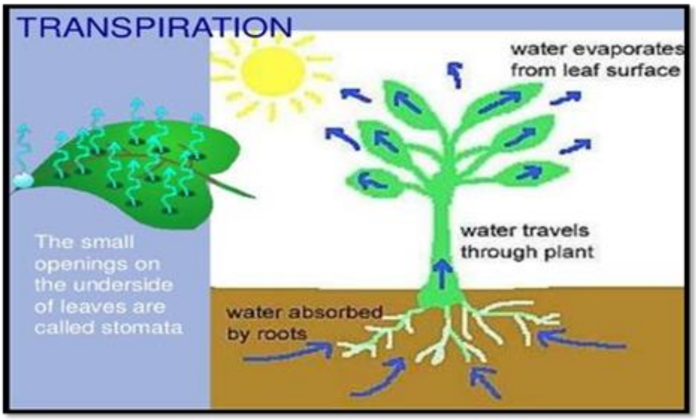


Fig 2. Water functions metabolism

This supplemental application of water to the soil to meet plant needs is known as irrigation. Irrigation is a critical practice to ensure that plants receive the water they need for optimal growth and productivity.

Irrigation and Irrigation Management

What is Irrigation?

Irrigation is defined as the artificial application of water to the soil to support crop growth or crop production. This is done to supplement natural sources of water such as rainfall and groundwater.

What is Irrigation Management?

Irrigation water management involves the strategic timing and regulation of water application to crops. The goal is to meet the water needs of crops efficiently, avoiding wastage of water, soil, plant nutrients, or energy.

Key Aspects of Irrigation Management:

- **Water Application:** Applying water in quantities that meet crop needs.
- **Soil Capacity:** Ensuring the soil can hold the applied water, making it available to crops.
- **Soil Characteristics:** Considering the soil's intake characteristics and the erosion risk of the site.

Factors to Study for Effective Irrigation Management:

To manage irrigation effectively, it is important to study several factors, including:

- **Physical and Chemical Properties of Soil:** Understanding soil texture, structure, and nutrient content.
- **Biology of Crop Plants:** Knowing the water requirements and growth stages of crops.
- **Quantity of Water Available:** Assessing the availability of water for irrigation.
- **Time of Application:** Determining the optimal timing for water application to maximize efficiency and crop benefit.

The management of these factors collectively is referred to as **Irrigation Agronomy**.

3. Important Irrigation Terminologies

1. Matric Potential

Definition: The total water potential attributed to the solid colloidal matrix of the soil system.

2. Capillary Potential

Definition: The energy with which water is held by soil, expressed in terms of capillary potential.

3. Seepage

Definition: The horizontal flow of water within a channel.

Note: Water loss from irrigation channels or canals is mainly due to seepage.

4. Infiltration

Definition: The entry of water from the soil surface into the upper layer.

Conditions: Occurs in unsaturated soil.

Function: Measures the speed at which water enters the soil during rainfall or irrigation.

5. Percolation

Definition: The downward movement of water through saturated or nearly saturated soil due to gravity.

Function: Represents the flow of water from the unsaturated zone to the saturated zone.

Difference Between Infiltration and Percolation:

Infiltration: Occurs near the soil surface, delivering water to the soil and plant rooting zone.

Percolation: Moves water through the soil profile, replenishing groundwater or contributing to subsurface runoff.

6. Leaching

Definition: The downward movement of nutrients and salts from the root zone with water.

7. Saturation Capacity

Definition: The maximum water-holding capacity of the soil where all soil pores (macropores and micropores) are completely filled with water.

8. Field Capacity (FC)

Definition: The soil moisture content 2-3 days after irrigation, once gravitational water has drained, and soil moisture becomes relatively stable.

Characteristics: Large pores are filled with air, and micropores are filled with water.

Importance: Considered the upper limit of water availability to plants.

9.Permanent Wilting Point (PWP)

Definition: The soil moisture content at which plants can no longer obtain sufficient water and remain wilted unless more water is added.

Origin: Concept proposed by Briggs and Shantz in 1912 using dwarf sunflower as an indicator plant.

Significance: Represents the lower limit of available water to the plant. Plants may die if water is not added.

10. Wilting Coefficient

Definition: The percentage of moisture in the root zone at the point of permanent wilting of plants, also known as the critical moisture point.

11. Available Water

Definition: The moisture available for maximum plant use, calculated by subtracting the water at Permanent Wilting Point (PWP) from the water at Field Capacity (FC).

Origin: Concept given by Veihmayer and Hendrickson in 1981.

12. Ultimate Wilting Point (UWP)

Definition: The moisture content at which wilting is complete, and plants die.

Condition: Soil moisture tension is as high as -60 bars at UWP.

13. Soil Moisture Tension

Definition: A measure of the tenacity with which water is retained in the soil, indicating the force per unit area required to remove water from the soil.

14. Soil Water Potential

Definition: An indication of the tendency of soil water to move, expressed by the soil water potential (Ψ). **Components:** Soil water potential is affected by:

Gravitational Potential (Ψg)

Osmotic Potential (Ψo)

Matric Potential (Ψm)

Relationship: The total soil water potential (Ψt) is the sum of Ψg, Ψo, and Ψm.

Note: Matric and Osmotic potentials are negative, reducing the free energy level of soil water. These negative potentials are referred to as suction or tension, while gravitational force is always positive.

4. Methods of irrigation

Irrigation method: How irrigation water is applied to the land, called a method of irrigation.

- ❖ **Surface irrigation:** Run the water over the soil surface and allow it to infiltrate, known as the surface irrigation method.
- ❖ **Sprinkler or overhead irrigation**: Spraying water into the air and allowing it to fall on the plants and soil as simulated rainfall is known as sprinkler irrigation.
- ❖ **Drip or trickle method**: Application of water directly to the root zone, known as drip or trickle method of irrigation.

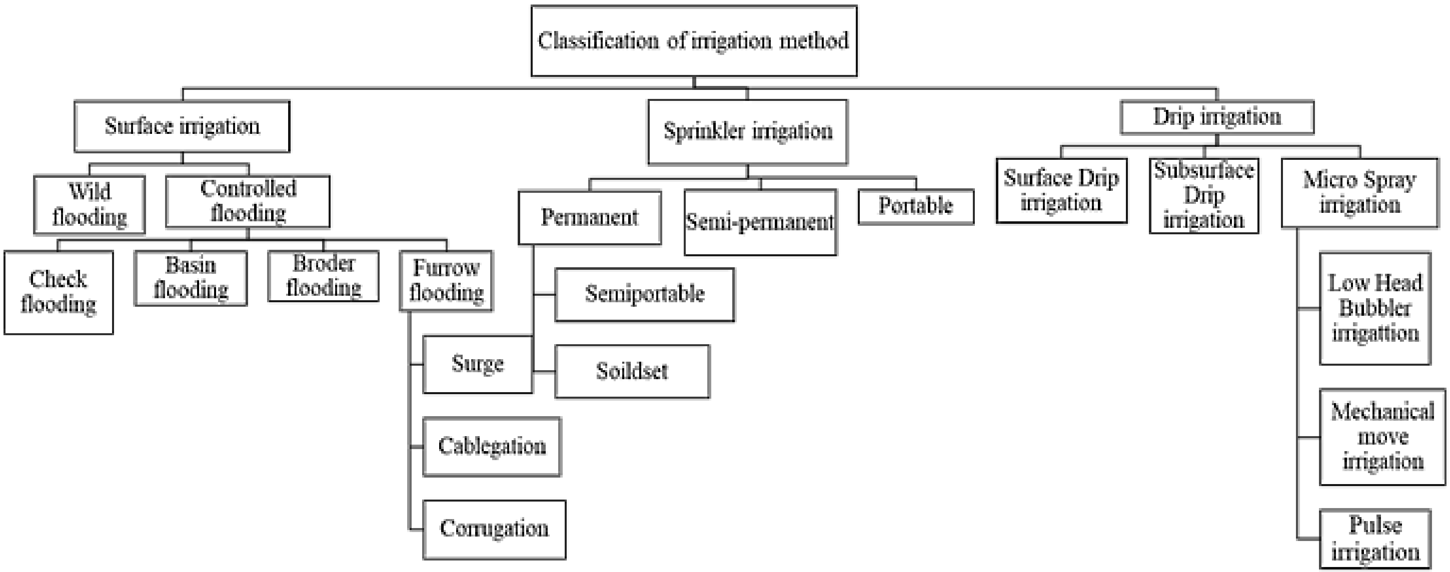
Surface Irrigation Methods

Wild flooding is a surface irrigation technique primarily used in saline soils where water is allowed to flow freely over the field. It includes three distinct sub-types:

1. **Spate Irrigation:** This method is employed in arid, hilly regions where intermittent streams or small rivers create spates. The sudden rush of water is diverted to fields for irrigation.
2. **Flood-Plain Irrigation:** Utilized in dry zones of large river plains, this method leverages the high discharge of rivers during brief periods. The floodwaters spread over the plains, providing essential moisture to the soil.
3. **Tidal Irrigation:** Common in coastal plains with levee soils, tidal irrigation uses river water influenced by tidal movements. This subsurface irrigation system benefits from the natural rise and fall of tides to distribute water efficiently.

Controlled Flooding

Controlled flooding is a more managed approach to surface irrigation, ensuring even distribution of water. Key methods include:


Classification of irrigation method
Surface irrigation
Sprinkler irrigation
Drip irrigation
Wild flooding
Controlled flooding
Check flooding
Basin flooding
Broder flooding
Furrow flooding
Surge
Cablegation
Corrugation
Permanent
Semi-permanent
Portable
Semiportable
Soildset
Surface Drip irrigation
Subsurface Drip irrigation
Micro Spray irrigation
Low Head Bubbler irrigattion
Mechanical move irrigation
Pulse irrigation

Check Basin:

- This is the most prevalent form of surface irrigation.
- Also known by various names such as check irrigation, flatbed irrigation, level border irrigation, or bed and channel irrigation.
- Water is distributed into small basins formed by earthen embankments, ensuring uniform application and reduced runoff.

Basin Flooding:

- Particularly effective for orchards.
- Basins, small circular or square plots enclosed by earthen dikes (checks), are created around individual trees or small groups of trees. Water is impounded within these basins for irrigation.

Border Strip Method

- Also referred to as **Bay Irrigation**, this method combines elements of level basin and furrow irrigation.
- It involves narrow strips of land oriented along the field's slope, facilitating the controlled flow of water down the length of each strip.
- This hybrid approach ensures efficient water distribution and is suitable for a variety of crops.

Furrow flooding

- In-furrow method of irrigation - 3/4th of furrow is wetted
- Compared with other surface irrigation methods, the furrow method exposes a smaller area of open water.
- Most efficient method of surface irrigation - Furrow irrigation (save up to 30% water)
- Border irrigation differs from furrow irrigation as in the border irrigation method the entire cropped area is ponded during irrigation and thus infiltration proceeds only downwards whereas, in the in-furrow method only half of the surface is ponded and thus movement of water from furrow is partly downward, partly sideward into the adjacent ridge and partly upwards within ridge.

Surge Irrigation: Surge irrigation is a technique that intermittently applies water to furrows, enhancing the uniformity of distribution along their length. This method leverages the natural properties of soil absorption to optimize irrigation efficiency. Here's how it works:

- **Principle of Operation** Surge irrigation is based on the observation that dry soil absorbs water more rapidly than wet soil. When soil becomes wet, the surface consolidates, creating a seal that reduces further absorption. This seal helps control the flow of water during subsequent irrigation cycles.
- **Wetting Front Dynamics** When water is reintroduced into a wet furrow, it moves quickly past the already wet zones and into the dry soil beyond. The dry soil then slows the progress of the water, creating a more uniform wetting front. This process reduces deep percolation and enhances application uniformity across the field.
- **Intermittent Water Application** In surge irrigation, water is delivered to long furrows in a controlled, cyclical manner, with predetermined ON, OFF periods. During the ON phase, water advances along the furrow, and during the OFF phase, it partially saturates the soil, reducing the infiltration rate in the wetted area. Subsequent ON cycles then benefit from this reduced intake rate, allowing water to advance quickly and uniformly to the furrow's end.
- **Efficiency and Benefits** This cyclical ON/OFF method results in significantly reduced deep percolation and runoff losses. The high uniformity of soil moisture distribution achieved throughout the furrow length leads to improved irrigation efficiencies of over 85% to 95%. Additionally, the design minimizes land loss, as the use of long furrows from a single head channel eliminates the need for multiple criss-cross ridges and feeder channels.

Advantages of Surge Irrigation

- **Cost-Effective:** By using less water and requiring less labour, surge irrigation can lower overall irrigation costs.
- **Water Conservation:** This method reduces the total amount of irrigation water needed, as well as excess water infiltration and runoff losses.
- **Sediment Control:** Surge irrigation helps reduce sediment loss from furrow-irrigated fields, preserving soil health and quality.

Disadvantages of Surge Irrigation

- **System Costs:** One significant drawback is the cost associated with switching to a surge irrigation system, including the expense of re-leveling fields and redesigning surface irrigation layouts.
- **Surge Valve Management:** Surge valves, which control the timing and duration of irrigation cycles, require careful management and investment. These valves allow growers to adjust irrigation oscillations to optimize water distribution across the field.

➢ **Cablegation:** is an innovative surface irrigation method developed in 1980 by the Soil and Water Management Research Unit of the USDA. Here are its key features:

- **Semi-Automated System:** Cab legation is designed to automate part of the irrigation process, reducing the need for constant manual intervention.
- **Gated Pipe System:** This method employs a gated pipe that both transmits and distributes water to furrows or border strips. The gated pipe system ensures that water is delivered evenly across the field.
- **Moveable Plug Mechanism:** The system includes a moveable plug controlled by a cable. The plug moves within the gated pipe, allowing precise control over the water distribution.

Corrugation: It is another surface irrigation technique that shares similarities with furrow irrigation. Here's how it works.

- **Small Channels:** Known as corrugations, these small channels guide water across the field. Unlike full-surface flooding, this method directs water through these defined pathways.
- **Partial Surface Flooding**: In corrugation irrigation, water does not cover the entire surface area of the field. Instead, it flows through the corrugations, making it a more controlled method of irrigation.
- **Soil Suitability:** This method is particularly effective for medium and heavy soils where soil crusting can occur post-irrigation. The channels help prevent crusting and ensure efficient water use.
- **Crop Suitability:** Corrugation is commonly used for crops like groundnut and small grains, particularly wheat. The method is

adaptable to these crops, providing adequate moisture while preventing waterlogging.

- **Channel Specifications:** Corrugations are typically 6-8 cm deep and spaced 40-75 cm apart. This spacing allows for optimal water distribution and soil absorption.

Sprinkler method of irrigation:

Fig 3. Portable Spray Sprinkler system installation

- Sprinkler irrigation evolved in -1946
- Also known as overhead irrigation.
- It is not used if wind velocity is higher than 15 km/hr.
- Sprinkler damage can occur to some crops, fruits, and vegetables owing to burning caused by the salt residue in the water.
- It is not ideal for crops sensitive to fungal disease.
- Conveyance losses with surface irrigation - 15-20% in good irrigation and 30-50% in canal irrigation.
- Sprinkler irrigation increases irrigable area by 1.5-2.0 times that of surface irrigation at the same amount of water.
- It saves 25-50% water.
- Water use efficiency can be increased 3-4 times with sprinkler over-irrigating sandy soil with flooding.
- The sprinkler is suited for steep slope or uneven slopes or undulating topography.
- Sprinkling water saves the crop from frost damage.

- Portable sprinkler system - The entire system can be moved.
- LEPA (Low Energy Precision Application) system is a modification of the sprinkler system in which water is directly applied in-furrow.
- Moderate pressure of sprinkler for orchards - 1.05 - 4.20 kg/cm^2
- Pressure of sprinkler for field crops - 3.5 - 7.0 kg/cm^2.
- Perforated pipe sprinkler pressure - 0.8 - 1.4 kg/cm^2
  - Sprinkler system includes four units -
    - Pump unit
    - Main and sub-main lines
    - Lateral line
    - Sprinkler
  - The average application rate of the sprinkler should be less than the basic infiltration rate.
  - The size of the drop should be between 0.5 to 4.0 mm.
  - Most commonly used sprinkler - Rotating hammerhead and spray nozzle type.

Drip irrigation system

Fig 4. Drip System Installation

- Modern drip technology was invented by Simcha Blass in Israel.
- Also known as trickle system.
- The act of slowly applying water in the form of discrete, continuous drips, tiny streams, or miniature sprays using mechanical devices called emitters or applicators that are

positioned at certain locations along water delivery pipes is known as a drip system.

- Pressure of drip irrigation -2.5 kg/cm^2,
- A drip system has the greatest potential where water is scarce or expensive.
- Somewhat brackish water (1000 mg/l salts) can be used for irrigation through this system. However, these salts accumulate near plants.
- Emitters are of two types - Line source and point source,
- An internal wetting pattern is formed by emitters of the line source type. Perfect for crops that grow closely together.
- Emitters of the point source type are connected to the lateral from the outside, often creating a circular deep wetting area. This works well for plants in orchards that are widely spaced. etc.
- The flow rate of emitters is expressed in - Gallons per minute (gpm)
- The discharge rate of emitters is - 0.2-2.0 gph (line source - 0.2-2.0 gph, point source - 0.5-2.0 gph)
- The fraction head loss in the main can be estimated by - Hazen-Williams formulae
- Drip irrigation can be scheduled at 60-100% pan evaporation.

Advantages of drip irrigation

- 40-70% saving of water.
- 25-100% increase in yield.
- 50% saving in energy by reducing pumping hours & friction losses.
- Drip is better for saline soils.

Bubbler irrigation system

- The process of applying water using a little stream or fountain to completely cover the soil surface. Compared to drip or subsurface emitters, point-source bubbler emitters have higher discharge rates.
- It reduces energy requirement.
- It applies water on per plant basis.
- Typical flow rate from bubbler emitters -2 to 20 gph

Micro/mini sprinkler/spray

- Micro-sprinklers are emitters commonly known as spray heads or sprinkler.
- This one is also referred to as mini-spray, micro-spray, jet or spinner.
- Sprinkler heads are connected to lateral pipes using spaghetti tubing.
- Flow rate of micro-sprinkler emitters - 3 to 30 gph
- Operating pressure - 0.8 to 4.0 bar
- Throw distance - 0.9 to 4.0 m
- Water discharge - 28-223 /hr

Pulse irrigation

- There are several irrigation time cycles in it, each having an operational phase (drainage of water) and a rest phase (no discharge). The typical operation intervals are five, ten, and fifteen minutes.

Microjet

- Application of water in the form of discrete drops, fan type, full circle, part circle, or quarter circle spray on the soil surface from a low height or low angle through the air around the crop. Operating pressure - 1 bar.Throw distance - 1 to 4 m. Water discharge - 5-160 /hr.

5. Crop Water Requirement

A crop water needs are the amount of water required at a specific location for typical crop development and output during a certain length of time. Irrigation, precipitation, or a mix of the two may provide this water. Water is mostly required for Transpiration (T), Evaporation (E), and plant metabolism, which are generally referred to as Consumptive Use (C.U.). So, here is the formula for water needed:

$$\boxed{\textbf{Water requirement=IW+ER+S}}$$

Water Requirement of Different Crops

1. Rice : 1100-1250 mm

The daily consumptive use of rice ranges from six-ten mm, with total water requirements varying between 1100 to 1250 mm depending on the agro-climatic conditions. The total water needed for rice: The growth of rice can be alienated into four periods concerning water management: seedling, vegetative, reproductive, and ripening stages.

- 3% (or 40 mm) is used for the nursery.
- 16% (or 200 mm) is used for land preparation, specifically puddling.
- 81% (or 1000 mm) is used for field irrigation.

2. Groundnut: 500-550 mm

Evapotranspiration is low during the first thirty-five days after sowing and the last thirty-five days before harvest, with peak water requirements occurring between the peg penetration and pod development stages. After the preliminary sowing irrigation, the second irrigation can be scheduled twenty-five days after sowing, typically four-six days after the first-hand hoeing. Succeeding irrigation intervals of fifteen days are sustained up to peak flowering. During critical stages, irrigation intervals may be seven-ten days depending on soil and climate conditions. During the maturity period, the interval is prolonged to fifteen days.

3. Finger Millet (Ragi): 350 mm

Finger millet is a drought-tolerant crop. Pre-planting irrigation at 7-8 cm is applied. Life irrigation with a small quantity of water is provided on the third day after transplantation for uniform establishment. Three subsequent irrigations are essential at primordial initiation, flowering, and grain filling stages.

4. Sugarcane: 1800-2200 mm

The important period for water need is the formative phase, which begins 120 days after planting. In order to achieve consistent emergence and the highest number of tillers per unit area, it is better to apply less water more often. Compared to previous growth phases, the reaction to applied water is greatest during this crucial period, requiring larger volumes and more frequent watering.

5. Maize: 500-600 mm

Although maize requires a lot of water, it uses it quite effectively. Corn goes through the following growth stages: sowing, four-leaf stage, knee-high, grand growth, tasseling, silking, early dough and late dough. All of these phases require a consistent water supply, but the tasseling, silking, and early dough stages are especially important.

6. Cotton: 550-600 mm

Cotton is susceptible to the moisture content of the soil. In the early part of the season, transpiration loses less water than evaporation does. Water consumption rises with plant growth, peaking at 10 mm/day when the plant is densely bloomed and producing bolls. During emergence and early development, just 10% of the entire amount of water is needed. Sufficient moisture is essential for the growth of bolls and for blooming. The crop uses less water in the early and late phases, and up until the point of boll formation, it still needs a lot of water.

7. Sorghum:350-500 mm

8. Pulses: 200-450 mm

Most pulses are cultivated in rainfed environments. Certain pulse crops, like as green, black, and red grammes, are watered during the summer and require three to four irrigations during crucial phases like germination, blooming, and pod production.

6. 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

7. Concepts of Water Use Efficiency

Water Use Efficiency (WUE):

It is represented as kg/ha-mm (cm) and represents the yield of a marketable crop generated per unit of water used in evapo-transpiration, or it represents the dry matter produced per unit of water utilised. Two categories of water use efficiency exist:

1.Field Water Use Efficiency:

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

2.Crop Water Use Efficiency:

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

WUE of different 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)**

8. Efficient Management Practices for Improving WUE

I. Efficient water management practices

- ✓ Localised irrigation methods
- ✓ Irrigation scheduling
- ✓ Deficit irrigation practices
- ✓ Improving the irrigation efficiency
- ✓ Conjunctive use of water resources

- ✓ Irrigation water pricing

II. Efficient crop management (agronomic) practices

- ✓ Selection of crops and cropping systems
- ✓ Tillage
- ✓ Fertilizer use
- ✓ Weed management
- ✓ Mulching and Antitranspirants
- ✓ Amelioration of problem soils
- ✓ Interaction with other inputs

9. Irrigation Efficiencies

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 deliveredfrom the source.

$$\text{Ei} = \frac{Wc}{Wr}100$$

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 %.

1. Water Application Efficiency:

Water application efficiency (WAE) is a measure of how effectively an irrigation system applies water to the target area, minimizing losses due to runoff, evaporation, deep percolation, and wind drift. It is defined as the percentage of the water that is beneficially used by the plants compared to the total amount of water applied.

$$\textbf{WAE}\ (\%) = \frac{Volume\ of\ water\ beneficially\ used\ by\ the\ plants}{Total\ volume\ of\ water\ applied} x100$$

2. Water Storage Efficiency:

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

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

$$\mathrm{Es} = \frac{Ws}{Ww} 100$$

3. Water Conveyance Efficiency:

It gauges the effectiveness of the system for moving water from the canal network to field channels and watercourses. It is the proportion of water that is diverted from a river or reservoir into the canal system and supplied to the infields at the outflow head. Water conveyance efficiency measures the amount of water lost during the conveyance process from the place of diversion to the farmer's fields. These losses can be expressed as follows:

$$\mathrm{Ec} = \frac{Wt}{Wf} 100$$

Wf= water delivered to the farm by conveyance system (field supply channel)
Wt = water introduced into the conveyance system from point of diversion

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

4. Water Distribution Efficiency (WDE)

measures how uniformly water is distributed over an irrigated area. High water distribution efficiency ensures that all parts of the field receive an equal amount of water, reducing areas of over- or under-irrigation.

$$100\ \mathrm{WDE}(\%) = \frac{n(1 - \ Average\ deviation\ from\ the\ mean\ water\ depth)}{Mean\ water\ depth\ applied} X100$$

5. Project Irrigation Efficiency (PIE)

It refers to the overall effectiveness of an irrigation project in delivering water to crops, taking into account all water losses from the source to the point of use. It encompasses the efficiency of water conveyance, distribution, and application.

PIE(%)=Conveyance Efficiency×Field Application Efficiency

10. Efficient Management Practices for Improving Irrigation Efficiency

1. **Regular Maintenance and Inspection**:
   - **Check for Leaks and Blockages**: Regularly inspect irrigation systems for leaks, clogs, and wear and tear.
   - **Clean Emitters and Filters**: Ensure that all emitters and filters are clean and functioning correctly.
2. **Efficient Irrigation Techniques**:
   - **Drip Irrigation**: Use drip irrigation systems to deliver water directly to the root zone, reducing evaporation and runoff.
   - **Sprinkler Systems**: Optimize sprinkler systems to minimize water loss due to wind drift and evaporation. Use low-angle and low-flow nozzles.
3. **Soil Moisture Monitoring**:
   - **Soil Moisture Sensors**: Install soil moisture sensors to monitor the water content in the soil and irrigate based on actual needs.
   - **Tensiometers**: Use tensiometers to measure soil water tension and determine when to irrigate.
4. **Smart Irrigation Controllers**:
   - **Weather-Based Controllers**: Use smart controllers that adjust irrigation schedules based on weather conditions and forecasts.
   - **Time-Based Controllers**: Ensure that time-based controllers are set to irrigate during cooler parts of the day to minimize evaporation.
5. **Irrigation Scheduling**:
   - **Crop Water Requirements**: Base irrigation schedules on the specific water requirements of different crops.
   - **Seasonal Adjustments**: Adjust irrigation schedules based on seasonal changes in temperature and rainfall.
6. **Soil Health Management**:
   - **Soil Structure Improvement**: Improve soil structure by adding organic matter to enhance water retention.
   - **Mulching**: Use mulch to reduce evaporation and maintain soil moisture

7. **Water-Efficient Crops**:
   - **Drought-Resistant Varieties**: Plant drought-resistant crop varieties that require less water.
   - **Crop Rotation**: Implement crop rotation practices to improve soil health and water efficiency.
8. **Training and Education**:
   - **Farmer Training Programs**: Provide training on efficient irrigation practices and technologies.
   - **Extension Services**: Utilize agricultural extension services to disseminate information on irrigation efficiency.
9. **Rainwater Harvesting**:
   - **Capture and Store Rainwater**: Implement rainwater harvesting systems to supplement irrigation needs.
10. **Reuse and Recycle Water**:
    - **Treated Wastewater**: Use treated wastewater for irrigation where appropriate and safe. Implementing these strategies can significantly improve irrigation efficiency, leading to better water management and sustainable agricultural practices.
11. **Conclusion:**

In conclusion, efficient water management in agriculture is critical for sustainable food production and environmental stewardship. By implementing advanced irrigation techniques like drip and sprinkler systems, optimizing crop selection based on local water availability, improving soil health through conservation practices, and promoting water recycling and reuse, agricultural sectors can significantly enhance water use efficiency. Furthermore, embracing technology such as remote sensing and AI for real-time monitoring and decision-making empowers farmers to optimize water application and reduce wastage. Integrated water management approaches that consider the nexus between water, energy, and food systems are essential for balancing competing water demands and ensuring equitable access. Global cooperation and supportive policies are also pivotal in addressing water challenges. Governments and international organizations must collaborate to develop robust frameworks that promote sustainable water use, invest in infrastructure for water storage and distribution, and support research and innovation in water-efficient technologies.

12. References:

------2013. Water for Prosperity: Investment Guideline for Smallholder Agricultural Water Management. Available at: http://imawesa.info/wp-content/uploads/2013/06/Water-for-prosperity_Douglas-J-Merrey2.pdf.

-----2014. Water Conservation and Management: Evaluation Synthesis. Rome: IFAD, Independent Office of Evaluation. Available at: http://www.ifad.org/evaluation/public_html/eksyst/doc/syn/2014/water/WATER%20ES%20-%20Full%20Report%20for%20web.pdf.

Comprehensive book of Principles of Agronomy by SR Reddy. Kalyani publishers 2022.

Hartmann, A.H. 2012a. Ethiopia: Scaling Up of IFAD Programs. 2012b. Challenges and Opportunities for Agricultural Water Management in West and Central Africa: Lessons from IFAD Experience. Field Experiences No. 3. Rome: IFAD. Available at: http://www.ifad.org/pub/pa/field/3.pdf.

ICID (International Commission on Irrigation and Drainage). 2004. Irrigation and Drainange Services: Some Principles and Issues Towards Sustainability. ICID Position Paper. New Delhi: ICID. Available at: http://www.icid.org/tf3_paper.pdf.

IFAD. 2009. Coping with Complexity: Innovative Approaches to an Emerging Issue in Agricultural Water Management. Rome: IFAD. Available at: http://www.ifad.org/english/water/innowat/strategic/complexity_web.pdf.

IWMI (International Water Management Institute). 2007. Water for Food, Water for Life: A comprehensive Assessment of Water Management in Agriculture. London: Earthscan; and Colombo, Sri Lanka: IWMI. Available at: http://www.iwmi.cgiar.org/assessment/Publications/books.htm.

SWADE (Swaziland Water and Agriculture Development Enterprises). 2013. Draft Lower Usuthu Smallholder Irrigation Project. Project Completion Report.