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System, principles and Mehod of irrigation

Dr. RS Sidar

Abstract
This Book Chapter provides information of "System, Principles and Method of irrigation". There are many old and new techniques are now available for irrigation, which includes modern technology and automation i.e. the use of sensors, valves, indicators n pipes. On the earth good quality water is available in fewer amounts so it's become necessary to use this water carefully, so that irrigation is important. Depend on used modern or smart technology it helps to conserve the water. Irrigation mainly used in agricultural crops. The aim of this paper is to provide various method used in irrigation, its importance and benefits.

Keywords: irrigation, sprinkler, drip, water

Introduction
Irrigation is the process of applying water to soil, primarily to meet the water needs of growing plants. Water from rivers, reservoirs, lakes, or aquifers is pumped or flows by gravity through pipes, canals, ditches or even natural streams. Applying water to fields enhances the magnitude, quality and reliability of crop production. According to the Food and Agriculture Organization of the United Nations, irrigation contributes to about 40% of the world's food production on 20% of the world's crop production land. Various irrigation methods have been developed over time to meet the irrigation needs of certain crops in specific areas. The three main methods of irrigation are surface, sprinkler and drip/micro. Water flows over the soil by gravity for surface irrigation. Sprinkler irrigation applies water to soil by sprinkling or spraying water droplets from fixed or moving systems. Microirrigation applies frequent, small applications by dripping, bubbling or spraying, and usually only wets a portion of the soil surface in the field. A fourth, and minor, irrigation method is subirrigation where the water table is raised to or held near the plant root zone using ditches or subsurface drains to supply the water. According to the International Commission on Irrigation and Drainage, surface irrigation is used on about 85% of the 299 Mha of irrigated crop land in the world.

Micro Irrigation Systems
Installation and management of micro irrigation systems (Sprinkler and Drip irrigation)
The micro irrigation has been introduced long back in India has gained attention during recent decades which has potential increase in crop yield and decrease the use of water, fertilizer as well as labor requirements for irrigation. The most common micro irrigation systems are drip and sprinkler irrigation system.

Drip irrigation systems are those that supply the water through dripper to plant material at a slow application rate. Drip irrigation is also called as trickle irrigation which involves discharge of water onto the soil at very low rates (2-20 litres/hour) through dripper. These drippers were fitted continuously on a small plastic pipes called as laterals.

In this method water is applied at the root zone so as to ensure the water availability near the root zone which involves wetting the whole soil profile. In drip irrigation system, applications of irrigation water are more frequent (usually every 1-3 days) than with other methods and hence that provides a very favourable moisture condition in the soil in which plants can nourish.

In the case of sprinkler irrigation, water is sprayed into the air and allowed to fall on the ground surface which is resembling like rainfall. In this system, the spray is developed by the flow of water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping. Hence, careful selection of nozzle sizes, operating pressure as well as sprinkler spacing for the amount of irrigation water required to refill the crop root zone in uniform condition is most essential criteria in sprinkler irrigation system.

The concept of micro irrigation system is application of water to crop by drop by drop (drip) or at small quantity (sprinkler).

A. Drip irrigation system

Choice of drip irrigation

Drip irrigation is most suitable for crops like vegetables, fruit trees and vine crops which is grown as row crops. This method is suitable for any soils. However, on clay soils, water must be applied slowly to avoid stagnation, and on sandy soils, higher emitter discharge rates will be preferred to ensure adequate lateral wetting of the soil.

The blocking of emitters is common problem in drip irrigation. Thus it is essential for irrigation water to be free of sediments. Otherwise, filtration of the irrigation water will be adopted with different filtering mechanisms. It may also occur as a result of algae, fertilizer deposits and dissolved soluble salts which are precipitated such as calcium and iron and deposited in the lines and emitters. Hence, filtration may remove these materials.

Major component of drip System systems

A typical drip irrigation system (Fig 5) is consists of the following components which includes,

- Pump unit
- Control head
- Main and submain lines
- Laterals
- Emitters or drippers

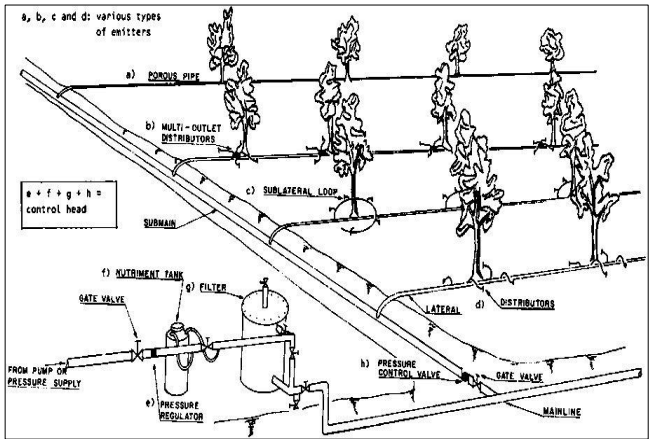

Fig 1: Drip irrigation system

- **Pump unit**

The pump unit used for pumping the water from the source and provides the right pressure fordelivery into the pipe system.

1. Control head

The control head includes valves to control the discharge and pressure in the entire system. It may also have filters to clear the water. The sand filters / media filters are used to remove organic matter and inorganic contaminants from water sources like rivers, tanks and open wells. The hydro Cyclone Filters or sand separators are used to remove particles of the size of 75 micron (200 mesh) which have a higher density than water, hydro cyclone filters / sand separators have been introduced.

- **Main, submain lines and laterals**

The main lines, submains and laterals supply water from the control head into the fields whichare usually made from materials such as either PVC or polyethylene pipes. These main and submains pipes usually buried below ground so as to avoid the damage as caused by the direct incidence of solar radiation. Then, the lateral pipes are usually 13-32 mm diameter where the drippers were filled at a specific interval based on the plant spacing.

- **Emitters or drippers**

The emitters or drippers are devices which is used to control the discharge rate of water from the lateral to the plants. The water discharge rates may vary from soil and or crop to crop. In general, it is ranged from very low rates of 2 to 20 litres per hour through dripper.

Drippers are usually spaced one or more emitters used for a single plant such as a tree. In the case of row crops, more closely spaced emitters may be used to wet a strip of soil. Many different emitter designs have been produced in recent years (eg. online and inline dripper).

1. Sprinkler irrigation system Choice of sprinkler irrigation system

Sprinkler irrigation is mostly suited for crops that are planted in rows as well as tree crops where the water can be sprayed over or under the crop canopy. Sprinklers are best suited to sandy soils with high infiltration rates although they are adaptable to most soils. The average application rate from the sprinklers (in mm/hour) is always chosen to be less than the basic infiltration rate of the soil so that surface ponding and runoff may be avoided. However, the sprinklers are not suitable for soils which easily form a crust.

Sprinkler systems are classified into the following two major types on the basis of the arrangement for spraying irrigation water.

1. Rotating head or revolving sprinkler system.
2. Perforated pipe system.

1. Rotating head

Small size nozzles are placed on riser pipes fixed at uniform intervals along the length of the lateral pipe and the lateral pipes are usually laid on the ground surface. They may also be mounted on posts above the crop height and rotated through 90^{o}, to irrigate a rectangular strip.

2. Perforated pipe system

This method consists of drilled holes or nozzles along their length through which water is sprayed under pressure. This system is usually designed for relatively low pressure (1kg/cm^2). The application rate ranges from 1.25 to 5 cm per hour for various pressure and spacing.

The sprinkler systems are further classified into the following types based on the portability which includes,

- **Portable system:** A portable system has portable main lines, laterals and pumping plant.
- **Semi portable system:** A semi portable system is similar to a portable system except that the location of water source and pumping plant is fixed.
- **Semi permanent system:** A semi permanent system has portable lateral lines, permanent main lines and sub mains and a stationery water source and pumping plant.
- **Solid set system:** A solid set system has enough laterals to eliminate their movement. The laterals are positions in the field early in the crop season and remain for the season.
- **Permanent system:** A fully permanent system consists of permanently laid mains, sub mains and laterals and a stationery water source and pumping plant.

Components of sprinkler irrigation system

The typical sprinkler system includes the following components (Fig 2).

- Pump unit
- Mainline, sublines and lateralsSprinklers (Sprinkler head)

1. Pumping Unit

The water is pumped under pressure to the fields. The pressure forces the water through sprinklers or through perforations or nozzles in pipelines and then forms a spray. A high speed centrifugal or turbine pump can be used for operating sprinkler irrigation for individual fields. Centrifugal pump is used when the distance from the pump inlet to the water surface is less than eight meters. In case of pumping water from deep wells or more than eight meters, a turbine pump is also suggested.

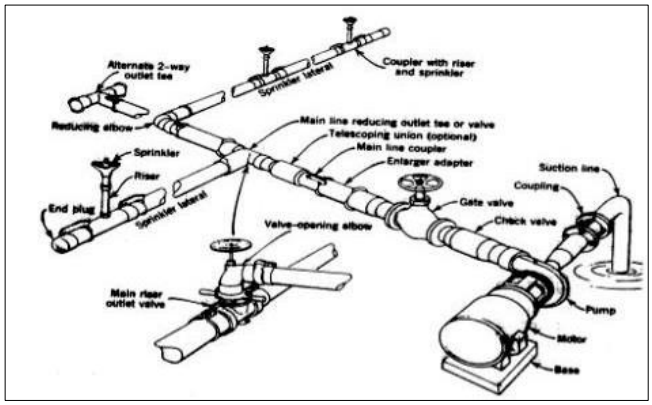

Fig 2: Component of a portable sprinkler irrigation system

Mains/ submains and laterals

The entire tube lines consist of mainline, submains and laterals. Main line conveys water from the source and distributes it to the submains. The submains convey water to the laterals which in turn supply water to the sprinklers. Aluminum or PVC pipes are generally used for portable systems, while steel pipes are usually used for center-pivot laterals.

1. Sprinkler Head

Sprinkler head distribute water uniformly over the field without runoff or excessive loss due to deep percolation (Fig 3). The different types of sprinklers are available such as rotating or fixed type. The rotating type can be adapted for a wide range of application rates and spacing. They are effective with pressure of about 10 to 70 m head at the sprinkler. The pressures ranging from 16 to 40 m head are considered the most practical for most farmers.

Fig 3: Sprinkler head

Fixed head sprinklers are commonly used to irrigate small lawns and gardens. Perforated lateral lines are sometimes used as sprinklers. They require less pressure than rotating sprinklers. They release more water per unit area than rotating sprinklers. Hence fixed head sprinklers are adaptable for soils with high intake rate.

Fertilizer applicator: Soluble chemical fertilizers can be injected into the either drip or sprinkler system and applied to the crop. These fertilizer either water soluble grade fertilizer or fertilizer which are soluble in water. Hence, these fertilizers can be applied to the crop root zone (drip) or sprayed over the crops (sprinkler). A venturi type injector can be arranged in the main line, which creates the differential pressure suction and allows the fertilizer solution to flow in the main water line.

Merits and demerits of drip and sprinkler irrigation

The merits and demerits of the drip and sprinkler irrigation is given below

Drip irrigation

Merits

- High water use efficiency (80-90%).
- Minimised fertilizer or nutrient loss due to localised application and reduced leaching
- Ability to irrigate undulating land
- Moisture within the root zone can be maintained at field capacity minimised soil erosion
- Uniform distribution of water
- Usually operated at lower pressure

Demerits

- Expensive initial cost
- Clogging of emitters is possible as a result of poor quality water use.
- Systems require careful maintenance toavoid any water loss or uniform distribution of water.
- Reinstallation is difficult for next crop

Sprinkler

Merits

- Mostly suitable for oil seeds and other cereal and vegetable crops
- Mobility of system is allowable
- Useful undulating area also
- Influences conducive micro-climate through water sprinkler
- Possibility of using soluble ertilizers and chemical to some extent.
- Problem of clogging is less in sprinkler nozzles

Demerit

- Expensive initial cost
- High pressure is required as compared to drip to maintain uniform sprinkling of water.
- It requires careful maintenance

Basic Principles in irrigation

Irrigation water is applied to ensure the sufficient moisture availability in the soil to meet crop water requirement. Plants require adequate water to complete their life cycle which can be either supplied by rainfall or substituted with irrigation. When water supplied through rainfall is not sufficient, plants must be irrigated by using different methods based on the

water requirement of crops. The main source of irrigation to several crops in India mainly supplied through lakes, rivers and wells.

The commonly used methods are surface irrigation, sprinkler irrigation and drip irrigation. The surface irrigation can be further classified in to basin, furrow and border irrigation. Hence, a reliable and suitable irrigation method of water supply may result in improvement in agricultural production. To supply the adequate water and selection of irrigation method needs complete understanding of principles of irrigation. In this chapter, basic principles of irrigation and method of irrigation are discussed in detail.

The main driving force in determining the water requirement of crops in a specific growth periods may differ with crops and growth stages which can be determined by weather, soil, water and requirement of water during its different growth stages. The water cycled from different water bodies to the atmosphere as result of evaporation and transpiration and it is transformed as rain and return to the earth. In the present scenario of climate change, the irrigation cycle was typically changed due to change in rainfall pattern. Thus change in rainfall pattern leads to failure of crops especially in dry land and rainfed areas. Sometimes excess rainfall also damage the crop.

The irrigation requirement of crops mainly influenced by the following factors that includes,

- Soil
- Climate
- Topography
- Water Source
- Crops

Soil

The suitability of a particular land type (eg. black soil, red soil, alluvial soil) for irrigated agriculture may depends on soil characteristics, soil profile, and soil texture (sand, silt and clay).

The yield of a crop may determined by the following factors such as, Adequate moisture holding capacity of a soil which may avoid either excess of loss of water through deep percolation or evaporation. It can be useful in nutrient mobilization and optimum plant growth etc.

Crop require adequate drainage through the root zone for proper aeration. Suitable soil texture and structure to ensure the easy field operation such as ploughing, weeding and other intercultural operations. Soil should not fall under extreme soil conditions such as acidity, sodicity, salinity, or any other toxic elements.

In addition, soil depth, water holding capacity, bulk density also determine the water availability after the irrigation which influence the irrigation interval period from one irrigation to other.

Climate

The climate of a particular location will remain constant and accordingly selection of crops may be based on the location. In addition, each crop has their own requirement of weather during its various growth stages.

The major weather or climatic elements important for agriculture are solar radiation, rainfall, temperature (maximum and minimum), humidity (morning and evening), sunshine duration, photoperiod and wind speed. The weather is the set of all external phenomena in a given atmosphere at a given time where as climate is the over the periods. The crops have their critical and optimum climatic requirements in its growth periods. The rainfall distribution in space and time determines the strategy for planning of crop production. Besides, rainfall amount, intensity, distribution as well as length of growing periods are also important factor in determining the crops and or cultivar.

Topography

The topography largely determined the irrigation methods in crop production practices. The topography also affects the effectiveness of labour work force. Similarly, topography also influences the efficiency of irrigation, drainage, erosion, size and shape of fields or plots, selection of crops, and land configuration methods. The agricultural field has to be leveled according the topography which helps in increasing the water use efficiency.

Source

The main water source in India is monsoon rain which contributed major food grain production. Besides, canal irrigation through catchment like lakes, rivers are vogue in ancient time periods from 2000 BC. In addition, wells, bore wells are also considerably used for various crops and plantation trees. The source of irrigation water may be selected according to the need of the farm. The use of rain water also followed in most of the area wherein other sources are limited. It can be either small catchment, farm ponds etc. The main factors to be consider for the source of water is irrigation water quality which includes pH (optimum is 6.0–8.5), electrical conductivity (EC), toxic element load (Boron, Nitrate, Chloride, Iron etc), dissolved metals (Arsenic, Lead, Cadmium). The main soluble constituents are calcium, magnesium, sodium as cations and chloride, sulphate, biocarbonate as anions. The other ions are present in minute quantities are boron, selenium, molybdenum and fluorine which are harmful to animals fed on plants grown with excess concentration of these ions. The source of water must meet the quality standards of irrigation water category for various crop uses.

Crops

The crops or cultivar can be selected based on the location and climate. Each crop has its own duration to attain the maturity. Hence, growth period of a particular crop requires periodical application water. Certainly, the rate or amount of water requirement may vary according the different growth phases. The each crop has unique critical period in its life cycle which compulsorily require irrigation to meet the moisture demand of the soil. These period is called critical period of irrigation (Table 1).

Table 1: Critical period for irrigation in different crops

Crops	Critical Stages
Rice	Initial tillering, flowering
Wheat	Crown root initiation and booting, flowering, milk and dough stages
Wheat	Boot stage; dough stage
Pulses	Flowering and pod maturation.
Peas	Flowering stage.
Berseem	After each cutting.
Gram	Pre flowering and flowering.
Pigeonpea	Flower initiation, pod filling.
Sorghum	Initial seedling, flowering, grain formation.
Barley	Boot stage, dough stage
Maize	Early vegetative, taselling and silking stage.

The selection of crops will be done based on the water availability in a particular season. The cultivar selection also played major role in determining the water requirement (eg. short duration, drought tolerant varieties etc) (Table 2).

Table 2: Water requirements of different crops in surface irrigation methods

Crop	Duration (days)	Total Water Requirement (mm)
Rice	110-140	1250
Sugarcane	360	2200
Groundnut	105-115	510
Sorghum	105	500
Maize	100-115	500
Ragi	95-105	310
Cotton	165	600
Blackgram	65-75	280
Soybean	85-95	320
Sesame	85	150
Sunflower	90-110	450

In addition with above, there are other factors are also determine the irrigation methods which includes, availability of energy sources and capital investment.

Field Water Balance

The field water balance is an account of water (rainfall and irrigation) added to the soil, subtracted from the soil (through evaporation, transpiration and percolation losses), and stored within a given volume of soil during a given period of time in a given field. The water stored in the soil can be influenced by the different matric potential such as osmotic potential, capillary, gravitational potential and potential due to external gas pressure.

The total water inflow, stored, outflow can be calculated in any of the field condition on the farm size and or regional size which may determine the irrigation water requirement. The inflow water either can be calculated based in the occurrence of rainfall and supply of irrigation water. The loss of water can be quantified based on the measuring the amount of surface run-off and deep percolation loss. Similarly, the water stored in the soil can be studied based on the soil moisture status. The major factor controlling the evaporation and transpiration are crop, weather, soil and agronomical management practices.

Methods of Irrigation and Water use Efficiency

a. Methods of irrigation:

There are three commonly used methods: surface irrigation, sprinkler irrigation and drip irrigation (Fig 1).

1. Surface irrigation (a. Basin irrigation; b. Furrow irrigation; and c. Border irrigation)
2. Sprinkler irrigation
3. Drip irrigation (a. Surface; and b. subsurface drip irrigation)

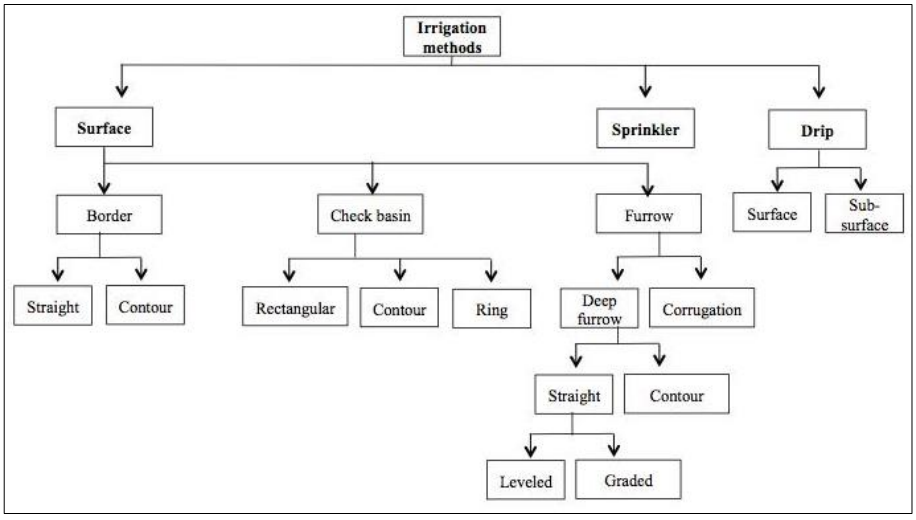

Fig 3: Irrigation methods

Surface irrigation

Surface irrigation is the application of water by gravity flow to the surface of the field. Either the entire field is flooded (basin irrigation) or the water is fed into small channels (furrows) or strips of land (borders).

a. Basin irrigation

Basins are flat areas of land, surrounded by low bunds (Fig 4). The bunds prevent the water from flowing to the adjacent fields. Basin irrigation is commonly used for rice grown on flat lands or in terraces on hillsides. Trees can also be grown in basins. The basin method are suitable for crops which are unaffected by standing in water for long periods.

Fig 4: Basin irrigation on the hillside and trees

b. Furrow irrigation

Furrows are small channels that carry water down the land slope between the crop rows. Water infiltrates into the soil as it moves along the slope and the crop is usually grown on the ridges between the furrows (Figure 5). This method is suitable for all row crops and for crops that cannot stand in water for long periods (eg. Maize, Sugarcane, Brinjal, Tomato, Bhendi).

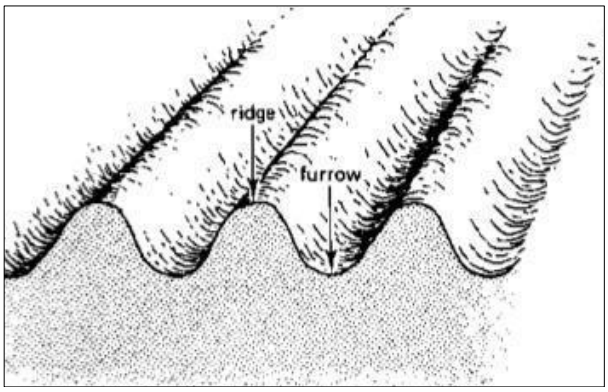

Fig 5: Furrow Irrigation

c. Border irrigation

Borders are long, sloping strips of land separated by bunds (Figure 6). They are sometimes called border strips. Irrigation water can be fed to the border in several ways: opening up the channel bank, using small outlets or gates or by means of siphons or spills. A sheet of water flows down the slope of the border, guided by the bunds on either side (eg. Groundnut, Finger millet, Sesame).

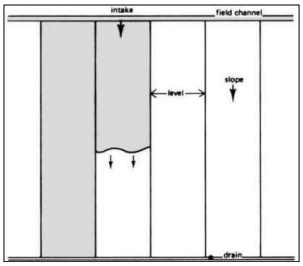

Fig 6: Border Irrigation

2. Sprinkler irrigation

Sprinkler irrigation is similar to natural rainfall. Water is pumped through a pipe system and then sprayed onto the crops through rotating sprinkler heads.

3. Drip irrigation

The water is conveyed under pressure through a pipe lines to the fields. In which, water can be discharged at a slow rate onto the soil through emitters or drippers which are located close to the plants. Hence, drip irrigation is considered to be effective irrigation in terms of water conservation as water soaked only the root zone. Drip irrigation is also called as trickle irrigation.

Water use efficiency

Water productivity (also termed as "water use efficiency" (WUE)) is defined as the ratio of yield to the consumptive water use, which can be derived from the formula,

$$E_{ET} = \frac{Y}{ET}$$

where, Y is the seed yield (t/ha), ET is the crop water use or evapotranspiration (cm), and EET is the Water use efficiency (WUE).

The efficiency of different irrigation method is given in Table 3.

Table 3: Irrigation efficiencies under different methods of irrigation (Per cent)

Irrigation efficiencies			Methods of irrigation		
			Surface	Sprinkler	Drip
Conveyance efficiency			40-50 (Canal); 60-70 (well)	100	100
Application efficiency			60-70	70-80	90
Surface	water	moisture	30-40	30-40	20-25
Overall efficiency			30-35	50-60	80-90

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