The application of water to soils for crop use is referred to as irrigation. Irrigation systems differ greatly depending on what they are going to be used for. They range from the simple hand watering method used in most home gardens and many nurseries to the huge flood and furrow irrigation systems found in large-scale production. Surface (gravity-driven surface irrigation), sprinkler, drip/micro, and subsurface are types of irrigation methods that are used by growers to irrigate various crops. Each system has its advantages and disadvantages. But with good design, they can be very successful for appropriate cases. Water losses from irrigation vary with the type of irrigation method. The water management decisions strongly influence how uniform water can be applied through different irrigation methods to provide optimal soil water conditions for crop growth and marketable yields. The most appropriate irrigation method for an area depends upon physical site conditions, the crops being grown, amount of water available, and management skill. This chapter gives some very broad guidance and indicates several important criteria in the selection of a suitable irrigation method.
2.1 General Perspectives of Water Application

Several decisions must be made before an irrigation system is installed in a field. Some determinations are technical in nature, some economic, and others involve a close scrutiny of the operation and crop to be irrigated.

Location, quantity, and quality of water should be determined before any type of irrigation system is selected. No assumptions should be made with the water supply. Make sure that the water source is large enough to meet the irrigation system’s demand by test pumping groundwater sources or measuring flow rate of streams. Securing of water rights on groundwater wells should be taken beforehand.

Numerous irrigation systems are on the market. Each system has advantages, disadvantages, and specific uses. A discussion of different systems, their roles, and capabilities in irrigated crop production are given in the next sections.

2.2 Classification of Water Application Methods

Water application methods can be classified based on different themes:

A Based on energy/pressure required
B Based on placement of irrigation water
C Based on wetted area by irrigation

Classification system – A
Based on energy/pressure requirement, irrigation methods can be grouped as

- gravity irrigation and
- pressurized irrigation

Again, gravity irrigation may be subdivided based on mode of application as

- border irrigation
- basin irrigation
- furrow irrigation

Pressure irrigation system may be subdivided based on mode of application as

- drip irrigation
- sprinkler irrigation

Classification system – B
Based on the placement of irrigation water (whether on, above, or below the soil surface), irrigation methods may be grouped as
2.2 Classification of Water Application Methods

- surface irrigation
- subsurface irrigation
- overhead irrigation

Surface irrigation system may be subdivided based on mode of water application as

- border irrigation
- basin irrigation
- furrow irrigation
- drip irrigation

Overhead irrigation includes sprinkler irrigation and hand watering.

**Classification system – C**

Based on wetted area of crop root zone by irrigation, irrigation methods can be grouped as

- flood irrigation
- drip (or trickle or localized) irrigation
- sprinkler irrigation

Flood irrigation can be further grouped as

- basin irrigation
- border irrigation
- furrow irrigation

Basin irrigation may be either “check basin” or “contour basin”.

The definition of different types of irrigation systems are outlined below:

*Gravity irrigation:* Irrigation in which the water is not pumped but flows and is distributed to the crop field by gravity.

*Pressurized irrigation:* Irrigation system in which water is pumped and flows to the crop field by pressure.

*Surface irrigation:* A form of irrigation where the soil surface is used as a conduit.

*Subsurface irrigation or subirrigation:* Applying irrigation water below the ground surface either by raising the water table within or near the root zone.

*Border irrigation:* Border irrigation is defined as the application of water to an area typically downslope and surrounded by two border ridges or dikes to the ends of the strip.

*Basin irrigation:* Basin irrigation is defined as the application of water to an area typically leveled to zero slope and surrounded by dikes or check banks to prevent runoff.
**Furrow irrigation:** A partial surface flooding method of irrigation in which water is applied in furrows (narrow channels dug between the rows of crops) or “rows of sufficient capacity” to contain the designed irrigation system, instead of distributing water throughout the whole field.

**Sprinkler irrigation:** A system in which water is applied by means of nozzle or perforated pipe that operates under pressure in the form of a spray pattern.

**Drip irrigation:** An irrigation system in which water is applied directly to the root zone of plants.

**Flood irrigation:** A system in which the entire soil surface of the field is covered by ponded water.

### 2.3 Description of Common Methods of Irrigation

#### 2.3.1 Border Irrigation

**2.3.1.1 Concept and Features**

Border irrigation is a modern method of surface irrigation. Border irrigation uses land formed into strips, bounded by ridges or borders (Fig. 2.1). Borders are generally prepared with zero side slope and a small but uniform longitudinal slope not exceeding 1%. The borders are divided by levees running down the slope at uniform spacing. The lower end of the border is opened to a drainage ditch or closed with a levee to create ponding on the end of the border. Levees are pulled across the end on steeper borders.

In this method, water is applied at the upper end of the border strip, and advances down the strip. Irrigation takes place by allowing the flow to advance and infiltrate along the border. After a time, the water is turned off, and a recession front, where standing water has soaked into the soil, moves down the strip. Smaller inflow discharges and longer time duration of application are utilized in graded fields to reduce

![Fig. 2.1 Schematic of border irrigation system](image-url)
2.3 Description of Common Methods of Irrigation

downstream losses, like for furrow irrigation. Larger inflow rates are utilized when the field slope is very small with management becoming similar to that of basins. Automated water control is often applied.

If it is possible, irrigate each block of border individually when irrigating. To maintain control with border irrigation, discharge the well into the top block until the desired application is achieved. The total well discharge then is moved to the second border and the first levee cut. Erosion control measures may be required if large stream sizes are used.

2.3.1.2 Suitability, Capabilities, and Limitations of Border Method

Crop Suitability

Border irrigation is best adapted to grain and forage crops where there are large areas of flat topography and water supplies are large. Border irrigation could be used on precision leveled rice fields, where beans or other grain crops are grown in rotation with rice.

Soil and Land Suitability

Border irrigation system performs better when soils are uniform, and the slope is mild. Undulating topography and shallow soils do not respond well to grading to a plane. Steep slopes and irregular topography increase the cost of land leveling and reduce border size. Deep cuts may expose areas of nonproductive soils, requiring special fertility management.

Economy and Financial Involvement

The major investment in border irrigation is that of land grading or leveling. The cost is directly related to the volume of earth that must be moved, the area to be finished, and the length and size of farm canals. Border irrigation is relatively inexpensive to operate after installation.

Attainable Irrigation Efficiency

Reasonable irrigation efficiency is possible with border irrigation method. Typical efficiencies for border strip irrigation ranges from 70 to 85%. With the border method, runoff return flow systems may be needed to achieve high water use efficiency.

The system designer and operator can control many of the factors affecting irrigation efficiency, but the potential uniformity of water application with surface irrigation is limited by the variability of soil properties (primarily infiltration rate) throughout the field. Results of field studies indicate that even for relatively uniform soils, there may be a distribution uniformity of infiltration rates of only about 80%.
Labor Requirement

Border systems may be automated to some degree to reduce labor requirements. It requires skilled irrigators to obtain high efficiencies. The labor skill needed for setting border flows can be decreased with equipment of higher cost. The setting of siphons or slide openings to obtain the desired flow rate requires skillness, but that one can learn.

Advantages and Disadvantages

Advantages

(i) Easy to construct and maintain
(ii) Operational system is simple and easy
(iii) High irrigation efficiencies are possible if properly designed, but rarely obtained in practice due to difficulty of balancing the advance and recession phases of water application
(iv) Natural drainage is facilitated through downward slope
(v) Comparatively less labor is required

Limitations

(i) Requires flat and smooth topography
(ii) Not suitable for sandy soils
(iii) Not suitable for crops which requires ponding water
(iv) Higher amount of water is required compared to sprinkler or drip irrigation.

2.3.2 Basin Irrigation

2.3.2.1 Concept and Characteristics

In this method, water is applied to leveled surface units (basins) which have complete perimeter dikes to prevent runoff and to allow infiltration after cutoff (Fig. 2.2). Basin irrigation is the simplest of the surface irrigation methods. Especially if the basins are small, they can be constructed by hand or animal traction. Their operation and maintenance are simple.

The best performance is obtained when advance time is minimized by using large non-erosive discharges, and the basin surface is precision leveled. This method is the most commonly practiced worldwide, both for rice and other field crops, including orchard tree crops. In general, basins are small and uneven and water application is manually controlled. Level basin irrigation using large laser-leveled units with automated or semiautomatic control is practiced in few areas in developed countries.

In this approach, water is applied to a completely level area enclosed by dikes or borders (called basins). This method of irrigation is used successfully for both field and row crops. The floor of the basin may be flat, ridged, or shaped into beds,
2.3 Description of Common Methods of Irrigation

**Fig. 2.2** Schematic layout of a basin irrigation system

Basin irrigation is suited to irrigate close growing crops (e.g., paddy). Paddy (rice) is always grown in basins. Many other crops can also be grown in basins: e.g., maize, sorghum, trees. Those crops that cannot stand a very wet soil for more than 12–24 h should not be grown in basins.

Basin and border strip irrigations flood the soil surface, and will cause some soils to form a crust, which may inhibit the sprouting of seeds.
Soil and Topography

For basin irrigation, basin size should be appropriate for soil texture and infiltration rate. Basin lengths should be limited to 100 meter (m) on very coarse textured soils, but may reach 400 m on other soils. Flat lands, with a slope of 0.1% or less, are best suited for basin irrigation: little land leveling will be required. If the slope is more than 1%, terraces can be constructed. However, the amount of land leveling can be considerable.

In areas of high intensity rainfall and low intake rate soils, surface drainage should be considered with basin irrigation, to reduce damage due to untimely inundation.

Water Quantity

It is important that irrigation stream size be properly matched to basin or border size for uniform irrigation. Basin systems are suitable for leaching of salts for soil reclamation, since the water can be held on the soil for any length of time. Under normal operating conditions, leaching fractions adequate for salinity control can be maintained with basin.

Required Depth of Irrigation Application

When the irrigation schedule is determined, it is known how much water (in mm depth) has to be given per irrigation application. It must be checked that this amount can indeed be given. Field experience has shown that the highest water can be applied per irrigation application when using basin irrigation. In practice, in small-scale irrigation projects, usually 40–70 mm of water is applied in basin irrigation.

Attainable Efficiencies

The system designer and operator can control many of the factors affecting irrigation efficiency. Properly designed and maintained basin systems are capable of obtaining moderately high efficiencies. Some basins are typically designed to pond the water on their surfaces and prevent tail water; they are usually the most efficient surface irrigation method. Design efficiencies should be on the order of 70–85%. With reasonable care and maintenance, field efficiencies in the range of 80–85% may be expected.

Labor and Energy Requirement

Basin irrigation requires accurate land leveling. Some labor and energy will be necessary for land grading and preparation. Basin irrigation involves the least labor of the surface methods, particularly if the system is automated. With surface irrigation, little or no energy is required to distribute the water throughout the field, but some energy may be needed to bring the water to the field, especially when water is
pumped from groundwater. In some instances, these energy costs can be substantial, particularly with low water use efficiencies.

Cost and Economic Factor

Basin irrigation is generally the most expensive surface irrigation configuration to develop and maintain but often the least expensive to operate and manage. Basin system’s costs can vary greatly, depending on crop and soil. A major cost in basin irrigation is that of land grading or leveling, if required. The cost is directly related to the volume of earth that must be moved. Typical operation and maintenance costs for basin irrigation systems vary greatly, depending on local circumstances and irrigation efficiencies achieved.

Advantage and Disadvantage

Advantages

(i) One of the major advantages of the basin method is its utility in irrigating fields with irregular shapes and small fields
(ii) Best suited for lands/crops where leaching is required to wash out salts from the root zone
(iii) Water application and distribution efficiencies are generally high

Limitations

(i) It requires accurate land leveling to achieve high application efficiency
(ii) Comparatively high labor intensive
(iii) Impedes surface drainage
(iv) Not suitable for crops which are sensitive to waterlogging
(v) Border ridges interfere with the free movement of farm machineries
(vi) Higher amount of water is required compared to sprinkler or drip irrigation.

2.3.3 Furrow Irrigation

2.3.3.1 Concepts and Features

Furrow irrigation is one of the oldest controlled irrigation methods. A furrow is a small, evenly spaced, shallow channel installed down or across the slope of the field to be irrigated parallel to row direction (Fig. 2.3). In this method, water is applied to furrows using small discharges to favor water infiltration while advancing down the field. Furrow irrigation can thus be defined as a partial surface flooding method of irrigation (normally used with clean-tilled crops), where water is applied in furrows or rows of sufficient capacity to obtain the designed irrigation system.
The furrow method is an efficient system if properly managed, but a most inefficient one if improperly managed. For this method, fields must have a mild slope and inflow discharge must be such that advance is not too fast and produce excessive runoff losses, nor too slow to induce excessive infiltration in the upper part of the field. Short blocked furrows with manually controlled water applications are practiced by traditional irrigators. Nowadays, long and precisely leveled furrows with automated or semi-automated control have become increasingly popular.

2.3.3.2 Suitability and Limitations

Crop Suitability

Furrow irrigation is best used for irrigating widely spaced row crops such as potato, maize, vegetables, and trees.

Soil and Topography

Loam soil is best suited for furrow irrigation. Sandy soils can cause excess infiltration at the upper end of the furrow, clay soils may need extra standing water to infiltrate.

Steeper land compared to basin or border (mild slopy topography, 0.5–2%) is needed to establish furrow irrigation. Undulated/zigzag topography is not suited for this method.

Water Quantity

Depending on surface conditions, stream size used should be as large as possible to move water through the field quickly without causing erosion.
Attainable Efficiencies

When using properly designed row slopes, row lengths, set times, stream sizes, and a reuse system, furrow irrigation efficiency can be high as 90%.

Labor and Energy Requirement

To establish the furrow, some labors are required. After that, the least labor required among the surface methods. If the system is automated, the labor requirement is reduces to minimum.

Required Depth of Irrigation Application

If only little water is to be applied per application, e.g., on sandy soils and a shallow rooting crop, furrow irrigation would be most appropriate (However, none of the surface irrigation methods can be used if the sand is very coarse, i.e., if the infiltration rate is more than 30 mm/h).

Cost and Economic Factor

Major initial cost in furrow system is the construction of furrows. The cost is directly related to the number of furrows (i.e. furrow spacing), volume of soil to be removed, and the unit labor/instrument charge.

Level of Technology

Furrow irrigation, with the possible exception of short, level furrows, requires accurate field grading. This is often done by machines. The maintenance – plowing and furrowing – is also often done by machines. This requires skill, organization, and frequently the use of foreign currency for fuel, equipment, and spare parts.

Advantages and Disadvantages

Advantages

(i) developed gradually as labor or economics allows
(ii) developed at a relatively low cost after necessary land-forming activities are accomplished
(iii) erosion is minimal
(iv) adaptable to a wide range of land slopes

Limitations

(i) Not suitable for high permeable soil where vertical infiltration is much higher than the lateral entry
(ii) Higher amount of water is required, compared to sprinkler or drip irrigation
(iii) Furrows should be closely arranged
2.3.4 Sprinkler Irrigation Systems

2.3.4.1 Concept and Features

In sprinkler irrigation, water is delivered through a pressurized pipe network to sprinklers, nozzles, or jets which spray the water into the air, to fall to the soil as an artificial “rain” (Fig. 2.4). Sprinkler irrigation can be defined as a pressurized system, where water is distributed through a network of pipe lines to and in the field and applied through selected sprinkler heads or water applicators.

The basic components of any sprinkler system are

- a water source
- a pump (to pressurize the water)
- a pipe network (to distribute the water throughout the field)
- sprinklers (to spray the water over the ground) and
- valves (to control the flow of water)

In addition, flow meters and pressure gauges are sometimes added to monitor system performance.

The sprinklers, when properly spaced, give a relatively uniform application of water over the irrigated area. Sprinkler systems are usually (there are some

Fig. 2.4 Sprinkler system
(a) view of a sprinkler and
(b) sprinklers irrigating a field
2.3 Description of Common Methods of Irrigation

exceptions) designed to apply water at a lower rate than the soil infiltration rate so that the amount of water infiltrated at any point depends upon the application rate and time of application but not the soil infiltration rate.

Sprinkler irrigation systems are normally used under more favorable operational conditions than surface systems because farmers may control the discharge rates, duration, and frequency. Many sprinkler systems have independent water supply or are connected to networks which may be operated on demand. However, the pressure from the hydrants or farm pumps is often not appropriate resulting in lower (or higher) discharges than those envisaged during the design phase. Pressure head (and discharge) variations at the hydrant should be identified by the user when appropriate equipment is available.

Sprinklers can be moved manually to ensure an even distribution of water over the ground, but a series of small fixed sprinklers are commonly used in an irrigation system. The “throw” of a sprinkler is the area of land which receives water from it, and sprinklers are placed “head to head,” meaning that they are placed sufficiently close together so that there are no gaps of dry land between them.

2.3.4.2 Types of Sprinkler Systems

Many types of sprinkler devices and sprinkler systems are available. Sprinkler irrigation systems exist in various shapes, sizes, costs, and capabilities. Descriptions of the more common types are given below.

Portable (or Hand-Move) Sprinkler System

These systems employ a lateral pipeline with sprinklers installed at regular intervals. The lateral pipe is often made of aluminum, with 20-, 30-, or 40-feet sections, and special quick-coupling connections at each pipe joint. The sprinkler is installed on a pipe riser so that it may operate above the crop being grown (in orchards, the riser may be short so that these types of sprinklers operate under the tree canopy). The risers are connected to the lateral at the pipe coupling, with the length of pipe section chosen to correspond to the desired sprinkler spacing. The sprinkler lateral is placed in one location and operated until the desired water application has been made. Then the lateral line is disassembled and moved to the next position to be irrigated. This type of sprinkler system has a low initial cost but a high labor requirement. It can be used on most crops, though with some, such as corn, the laterals become difficult to move as the crop reaches maturity.

Solid Set and Permanent Systems

Sprinklers irrigate at a fixed position. Solid set systems are similar in concept to the hand-move lateral sprinkler system, except that enough laterals are placed in the field so that it is not necessary to move the pipe during the season. The laterals are controlled by valves, which direct the water into the laterals irrigating at any particular moment. The pipe laterals for the solid set system are moved into the
field at the beginning of the season and are not removed until the end of the irrigation season. The solid set system utilizes labor at the beginning and ends of the irrigation season but minimizes labor needs during the irrigation season.

A permanent system is a solid set system where the main supply lines and the sprinkler laterals are buried (Fig. 2.5) and left in place permanently (this is usually done with PVC plastic pipe).

Side Roll System

The side roll sprinkler system is best suited for rectangular fields. The lateral line is mounted on wheels, with the pipe forming the axle (Fig. 2.6). The wheel height
is selected so that the axle clears the crop as it is moved. A drive unit (usually an air-cooled gasoline-powered engine located near the center of the lateral) is used to move the system from one irrigation position to another by rolling the wheels.

Traveling Gun System

This system utilizes a high volume, high pressure sprinkler (called “gun”) mounted on a trailer, with water being supplied through a flexible hose or from an open ditch along which the trailer passes (Fig. 2.7). The gun may be operated in a stationary position for the desired time and then moved to the next location. However, the most common use is as a continuous move system, where the gun sprinkles as it moves. The gun used is usually a part-circle sprinkler, operating through 80–90% of the circle for best uniformity and allowing the trailer to move ahead on dry ground. These systems can be used on most crops, though due to the large droplets and high application rates produced, they are best suited to coarse soils having high intake rates and to crops providing good ground cover.

Fig. 2.7 Traveling gun type sprinkler

Center Pivot and Linear Move Systems

The center pivot system consists of a single sprinkler lateral supported by a series of towers. The towers are self-propelled so that the lateral rotates around a pivot point in the center of the irrigated area (Fig. 2.8). The time for the system to revolve through one complete circle can range from a half a day to many days. The longer the lateral, the faster the end of the lateral travels and the larger the area irrigated by the end section. Thus, the water application rate must increase with distance from the pivot to deliver an even application amount. A variety of sprinkler products
have been developed specifically for use on these machines to better match water requirements, water application rates, and soil characteristics. Since the center pivot irrigates a circle, it leaves the corners of the field unirrigated (unless additions of special equipment are made to the system). Center pivots are capable of irrigating most field crops but have on occasion been used on tree and vine crops. Linear move systems are similar to center pivot systems in construction, except that neither end of the lateral pipeline is fixed. The whole line moves down the field in a direction perpendicular to the lateral.

Continuous Move Laterals
These systems are well adapted to apply to small and frequent irrigations.

LEPA Systems
Low Energy Precision Application (LEPA) systems are similar to linear move irrigation systems but are different enough to deserve separate mention of their own. The lateral line is equipped with drop tubes and very low pressure orifice emission devices discharging water just above the ground surface into furrows. This distribution system is often combined with micro-basin land preparation for improved runoff control (and to retain rainfall which might fall during the season). High-efficiency irrigation is possible but requires either very high soil intake rates or adequate surface storage in the furrow micro-basins to prevent runoff or nonuniformity along a furrow.

2.3.4.3 Capabilities and Limitations of Sprinkler System

Soil Type
Sprinklers adapt to a range of soil and topographic conditions. Light sandy soils are well suited to sprinkler irrigation systems. Most soils can be irrigated with the
sprinkler method, although soils with an intake rate below 0.2 in./h may require special measures. Sprinklers are applicable to soils that are too shallow to permit surface shaping or too variable for efficient surface irrigation.

Field Shape and Topography

In general, sprinklers can be used on any topography that can be farmed or cropped. Land leveling is not normally required. Odd-shaped fields cannot be easily irrigated with certain types of sprinkler systems such as center pivots.

Crops

Nearly all crops can be irrigated with some type of sprinkler system, though the characteristics of the crop, especially the height, must be considered in system selection. Sprinklers are sometimes used to germinate seed and establish ground cover for crops like lettuce, alfalfa, and sod. The light, frequent applications that are desirable for this purpose are easily achieved with some sprinkler systems.

Water Quantity and Quality

Leaching salts from the soil for reclamation can be done with sprinklers using much less water than is required by flooding methods (although a longer time is required to accomplish the reclamation). This is particularly important in areas with a high water table.

Efficiencies

Both the center pivot and the linear move systems are capable of very high efficiency water application.

Financial Involvement and Labor Requirement

Sprinkler irrigation requires high capital investment but has low irrigation labor requirements.

Advantages and Disadvantages

Advantages of sprinkler systems include the following: readily automatable, facilitates to chemigation and fertigation, reduced labor requirements needed for irrigation. LEPA type systems can deliver precise quantities of water in a highly efficient manner and are adaptable to a wide range of soil and topographic conditions.

A disadvantage of sprinkler irrigation is that many crops (citrus, for example) are sensitive to foliar damage when sprinkled with saline waters. Other disadvantages of sprinkler systems are the initially high installation cost and high maintenance cost thereafter (when needed).
2.3.4.4 Choosing a Sprinkler Type

When choosing a sprinkler type for irrigation, there are several considerations:

- Adaptability to crop, terrain, and field shape
- Labor availability and requirements
- Economics
- Automation facility
- Ability of the system to meet crop needs

2.3.5 Drip Irrigation

2.3.5.1 Concept and Features

Drip irrigation system is traditionally the application of a constant steady flow of water to soil at low pressure. In this system, water is applied directly to the root zone of plants by means of applicators (orifices, emitters, porous tubing, perforated pipe, etc.) operated under low pressure with the applicators being placed either on or below the surface of the ground (Fig. 2.9). Water loss is minimized through these measures, as there is very little splash owing to the low pressure and short distance to the ground.

Drip systems tend to be very efficient and can be totally automated. Of the irrigation systems available, drip is the most ideally suited to high-value crops such as the vegetables and fruits. Properly managed systems enable the production of maximum yields with a minimum quantity of water. These advantages often help justify the high costs and management requirements. A typical drip irrigation system is shown in Fig. 2.9. There are many types of drip products on the market designed to meet the demands for just about any application.
2.3 Description of Common Methods of Irrigation

2.3.5.2 Suitabilities, Capabilities, and Limitations

Crop Suitability

Drip irrigation is most suited to high-density orchards, tree crops, and high-value horticultural crops. Drip systems allow accurate amounts of water to be supplied regularly to a small area of the root zone. Such a system can be used to restrict the vegetative growth of the trees, an important part of management in high density planting.

Drip irrigation is more suited to areas where cooler climates and higher rainfall reduce the need for high volumes of water application.

Water Supply

Drip irrigation is not designed for applying water to large root systems. To obtain adequate water distribution and application rates, two to three dripper lines per row of trees are required. As only a small area of the total field is wetted, drip irrigation is especially suited for situations where the water supply is limited. Drip tubing is used frequently to supply water under plastic mulches.

Fertilizer Application

Applying nutrients (fertilizers) through the drip system is very effective and may reduce the total amount of fertilizer needed. Some chemical insecticides can also be efficiently applied (precision of amounts) via drip irrigation system. This can lead to significant savings in money and maintenance time of the garden and field. In this case, care must be taken to ensure that the product is suitable for this type of application and will not damage the irrigation system.

Utilities of Buried Drip System

Burying the drip system reduces water loss even further by preventing runoff across the surface, which can occur at very high rates on dry impervious ground. It also reduces the chance of damaging the system while weeding. The soil surface is also kept dry, which can reduce invasion by weeds.

Attainable Efficiency

It is the most efficient irrigation system as the water is supplied directly to the root system, an important consideration where water supplies are limited.

Advantages and Disadvantages

There are several disadvantages and potential problems with a drip irrigation system. Costs of the product and its installation can be relatively high compared to more simple alternatives, although these may eventually be outweighed by savings
in water bills. The systems are vulnerable to blockage by organic matter, either in the water supply or algal growth in the pipes themselves. Chemicals and filtering systems can be used to minimize these problems. In a wide spaced orchard, supplying large trees with sufficient water can pose problems with a drip system, particularly in the 4 weeks prior to harvest.

The advantages of drip irrigation are as follows:

- Highly efficient system
- Saves water
- Limited water sources can be used
- Correct volume of water can be applied in the root zone
- The system can be automated and easily adapted to chemigation and fertigation
- Reduces nutrient leaching, labor requirement, and operating cost
- Other field operations such as harvesting and spraying can be done while irrigating
- Each plant of the field receives nearly the same amount of water
- Lower pressures are required to operate systems resulting in a reduction in energy for pumping

The disadvantages/limitations of the drip system are as follows:

- High initial cost
- Technical skill is required to maintain and operate the system
- The closer the spacing, the higher the system cost per hectare
- Damage to drip tape may occur
- Cannot wet the soil volume quickly (to recover from moisture deficit) as other systems
- Facilitates shallow root zone
- Needs clean water

### 2.3.6 Other Forms of Irrigation

Besides the above-mentioned methods, other categories of water application methods include the following:

- Hand watering
- Capillary irrigation
- Localized irrigation
- Trickle irrigation
- Micro-irrigation
- Subsurface irrigation

**Hand Watering**

The hand watering method is probably the most basic or earliest type of irrigation method. Water is applied to the plant root zone (close to or directly at the root area)
by means of a container or bucket. In the present age of automation, people do not consider hand watering a viable alternative. However, many horticultural enterprises, such as nurseries and fruit trees, cannot use the automated fixed irrigation system efficiently due to the random location of the plants and therefore use hand watering.

Capillary Irrigation
Water is applied beneath the root zone in such a manner that it wets the root zone by capillary rise. Buried pipes or deep surface canals are used for this purpose.

Localized Irrigation
Water is applied around each plant or a group of plants so as to wet locally and the root zone only. The application rate is adjusted to meet evapotranspiration needs so that percolation losses are minimized.

Trickle Irrigation
The term trickle irrigation is general and includes several more specific methods. Trickle irrigation is the slow, frequent application of water to the soil through emitters placed along a water delivery line. It includes drip irrigation, subsurface irrigation, and bubbler irrigation.

Trickle irrigation is best suited for tree, vine, and row crops. The main limitation is the cost of the system, which can be quite high for closely spaced crops. Complete cover crops, such as grains or pasture cannot be economically irrigated with trickle systems. Trickle irrigation is suitable for most soils, with only the extremes causing any special concern. With proper design, using pressure compensating emitters and pressure regulators if required, trickle irrigation can be adapted to virtually any topography. In some areas, trickle irrigation is successfully practiced on such steep slopes that cultivation becomes the limiting factor.

Trickle irrigation uses a slower rate of water application over a longer period of time than other irrigation methods. The most economical design would have water flowing into the farm area throughout most of the day and every day during peak use periods. If water is not available on a continuous basis, on-farm water storage may be necessary. Trickle irrigation can be used successfully with waters of some salinity, although some special caution is needed. Salts will tend to concentrate at the perimeter of the wetted soil volume.

Subsurface Irrigation
Applying irrigation water below the ground surface either by raising the water table within or near the root zone or by using a buried perforated or porous pipe system that discharges directly into the root zone is termed subsurface irrigation.
2.4 Selection of Irrigation Method

Decision must be made regarding the type of irrigation method before an irrigation system is installed in a field. To choose an appropriate irrigation method, one must know the advantages and disadvantages of the various methods. He or she must know which method suits the local conditions best. Unfortunately, in many cases there is no single best solution, as all methods have their relative advantages and disadvantages. Trials of the various methods under the prevailing local conditions provide the best basis for a sound choice of irrigation method.

2.4.1 Factors Affecting Selection of an Irrigation Method

Factors determining irrigation method are some in technical nature, some economic, and others involve a close scrutiny of the operation and crop to be irrigated.

In selecting an irrigation method, the following factors should be considered:

- Soil type
- Field shape/geometry and topography
- Climate – evaporation rates, wind, and rainfall
- Water availability and its price
- Water quality
- The particular crop to be grown – physical requirements, crop layout, and water use characteristics
- Required depth and frequency of irrigation application
- Labor requirements and its availability
- Energy requirement
- Economic factor – cost–benefit ratio, initial investment
- Compatibility with existing farm equipments
- Attainable irrigation efficiency of the proposed system
- Relative advantages and disadvantages of the available systems
- Type/level of technology at the locality
- Cultural factor/previous experience with irrigation
- Automation capacity
- Fertigation capability
- Environmental conditions – impact and regulations
- Farm machinery and equipment requirements

Soil Type

Light sandy soils are not well suited to furrow or basin irrigation systems. Sandy soils have a low water storage capacity and a high infiltration rate. They therefore need frequent but small irrigation applications, in particular when the sandy soil is also shallow. Under these circumstances, sprinkler or drip irrigation are more suitable than surface irrigation. On loam or clay soils all three irrigation methods
can be used, but surface irrigation is more commonly used. Clay soils with low infiltration rates are ideally suited to surface irrigation.

When a variety of soil types exists within one irrigation scheme, sprinkler or drip irrigation is recommended as they will ensure a more even water distribution. Sprinkler or drip irrigation are preferred to surface irrigation on steeper or unevenly sloping lands, as they require little or no land leveling. An exception is rice grown on terraces on sloping lands.

Field Shape/Geometry and Topography

Topography of a field is a decision-making aid in the selection of the type of irrigation system, or in determination of size of the irrigation system to be installed. Sprinklers fit rolling topography, but surface irrigation systems require graded fields. Odd-shaped fields cannot be easily irrigated with certain types of sprinkler systems such as center pivots. Rolling topography prohibits the use of furrow or surface systems because water cannot run uphill. Basins can be adopted in irrigating fields with irregular shapes and small sizes.

Climate

Local climate greatly influences the choice of an irrigation system. In a very hot, dry climate, a significant amount of water is evaporated during irrigation through sprinklers. Strong wind can disturb the uniform distribution of water from sprinklers. Under very windy conditions, drip or surface irrigation methods are preferred. In areas of supplementary irrigation, sprinkler or drip irrigation may be more suitable than surface irrigation because of their flexibility and adaptability to varying irrigation demands on the farm.

Water Availability

An adequate water supply to meet crop demand is important for ease of operation and for management of an irrigation system. With low probability of rainfall, a water supply should be large enough to meet crop demand. Location of water source, quantity, and quality of water should be determined before any type of irrigation system is selected. No assumptions should be made with the water supply. The amount of water available and the cost of the water (due to pumping or direct purchase) will determine the type of system you should use. If the supply is sufficient, assured and low cost, labor and/or energy saving irrigation method may be employed. On the other hand, if the supply is scarce/limited and very expensive, then consider only the most efficient type of irrigation system (e.g., sprinkler, drip).

Water Quality

Surface irrigation is preferred if the irrigation water contains much sediment. The sediments may clog the drip or sprinkler irrigation systems. Water having high salt
content may cause foliar damage if sprayed directly on the plants (e.g., sprinkler irrigation). In this case, consider systems that deliver water directly on or below the surface such as drip, surface, or LEPA (low energy precision agriculture) systems. In these methods, less water is applied to the soil (and hence less salt) than with surface methods. Special consideration is also needed in the placement of drip tubing and emitters when irrigating with saline water.

Labor Requirement

The labor requirement and skill required for operation and maintenance varies greatly between systems. Labor availability and cost are prime considerations for a labor-intensive system. For example, studies have shown that about one-man-hour per acre is required for a hand-move sprinkler system. Mechanical move systems require 1/10 to 1/2 as such labor. Automated systems are more expensive but may be more profitable when the labor costs over the life of the system are considered.

Surface irrigation often requires a much higher labor input – for construction, operation, and maintenance – than sprinkler or drip irrigation. Surface irrigation requires accurate land leveling, regular maintenance, and a high level of farmers’ organization to operate the system. Sprinkler and drip irrigation require little land leveling; system operation and maintenance are also less labor intensive.

Energy Requirement

With surface irrigation, little or no energy is required to distribute the water throughout the field, but some energy may be needed to bring the water to the field, especially when water is pumped from the ground. In some instances, these energy costs can be substantial, particularly with low water use efficiencies. Some labor and energy will be necessary for land grading and preparation.

Economic Factors

Costs and Benefits

Before choosing an irrigation system, an estimate must be made of the costs and benefits of the available options. On the cost side, not only the construction and installation but also the operation and maintenance (per hectare) should be taken into account. These costs should then be compared with the expected benefits (price of yields). It is obvious that farmers will only be interested in implementing a certain method if they consider this economically attractive (higher benefit–cost ratio).

Initial Investment/Development Cost

Although a method is found to be economical, it cannot be implemented due to limitation of fund for initial development cost. Sprinkler and drip systems require higher initial costs. Among surface irrigation configurations, basin irrigation is generally expensive to develop and maintain.
Compatibility with Existing Farm Equipments

Choose a system that is compatible with your farming operations, equipment, field conditions, and crops and/or crop rotation plan.

Attainable Irrigation Efficiency of the System

Water application efficiency is generally higher with sprinkler and drip irrigation than surface irrigation, so these methods are preferred when water is in short supply. However, it must be remembered that efficiency is just as much a function of the irrigator as the method used.

Relative Advantage and Disadvantages of the Available Methods

Several irrigation systems are on the market. Each system has advantages and disadvantages. A discussion of suitability/capabilities of different systems has been explained earlier. These points should be taken into consideration.

Crop to Be Irrigated/Type of Crop

The crop type influences the selection of the irrigation method. Surface irrigation can be used for all types of crops. Sprinkler and drip irrigation, because of their high capital investment per hectare, are mostly used for high-value cash crops, such as vegetables and fruit trees. They are seldom used for the lower value staple crops. Widely spaced crops do not require total field soil volume to be wetted, and thus basin or border irrigation in this case is less useful. Instead, a mini-basin can be formed around each tree. Drip irrigation is suited to irrigating individual plants or trees or row crops. It is not suitable for close growing crops (e.g., paddy). Paddy (rice) is always grown in basins. Many other crops can also be grown in basins (e.g., maize, sorghum). If paddy is the major crop, basins will be the logical choice. Those crops that cannot stand a very wet soil for more than 12–24 h should not be grown in basins. Row crops such as maize, vegetables, and trees are best suited to furrow irrigation. Close growing crops such as wheat, mustard, and alfalfa are best suited to border irrigation.

Required Depth and Frequency of Irrigation Application

The depth of water (mm) required per irrigation and seasonal total water requirement influence the irrigation method. Field experience has shown that most water can be applied per irrigation application when using basin irrigation, less with border irrigation, and least with furrow irrigation. Usually 40–70 mm of water is applied in basin irrigation, 30–60 mm in border irrigation, and 20–50 mm in furrow irrigation (in large-scale irrigation projects, the amounts of water applied may be much higher). This means that if only little water is to be applied per application, e.g., on sandy soils and a shallow rooting crop, furrow irrigation would be most appropriate.
On the other hand, if a large amount of irrigation water is to be applied per application, e.g., on a clay soil and with a deep rooting crop, border or basin irrigation would be more appropriate.

Farm Machinery and Equipment Requirement

If an irrigation system requires heavy farm machinery and equipment to install and for maintenance, it will be less preferred by the irrigators having low- and medium-level technology.

Level of Technology at the Locality

The level of technology in the locality affects the choice of irrigation method. In general, drip and sprinkler irrigation are technically more complicated methods. The purchase of equipment requires high capital investment per hectare. To maintain the equipment a high level of “know-how” has to be available. Also, a regular supply of fuel and spare parts must be maintained which, together with the purchase of equipment, may require foreign currency.

Surface irrigation systems, in particular small-scale schemes, usually require less sophisticated equipment for both construction and maintenance (unless pumps are used). The equipment needed is often easier to maintain and less dependent on the availability of foreign currency.

Basin irrigation is the simplest of the surface irrigation methods. Especially if the basins are small, they can be constructed by hand or animal traction. Their operation and maintenance is simple. Furrow irrigation, with the possible exception of short, level furrows, requires accurate field grading. This is often done by machines. The maintenance – plowing and furrowing – is also often done by machines. This requires skill, organization, and frequently the use of foreign currency for fuel, equipment, and spare parts. All these factors affect the selection process of irrigation methods.

Tradition/Previous Experience with Irrigation

The choice of an irrigation method also depends on the irrigation tradition within the region or country. Introducing a previously unknown method may lead to unexpected complications. It is not certain that the farmers will accept the new method. Most irrigators tend to stay with practices that have been used previously in their area rather than take the risk associated with a new technology. The uncertainties with the new method include the following: the servicing of the equipment may be problematic and the costs may be high compared to the benefits. Often it is easier to improve the traditional irrigation method than to introduce a totally new method.

Personal Preference/Cultural Factor

Select a system that you can live with. If you do not like your system, chances are you will not operate or maintain it properly.
### Table 2.1 Comparison of irrigation systems in relation to site and situation factors

<table>
<thead>
<tr>
<th>Site and situation factors</th>
<th>Basin</th>
<th>Border</th>
<th>Furrow</th>
<th>Sprinkler</th>
<th>Drip</th>
<th>Sub-irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil</strong></td>
<td>Loam to heavy soil</td>
<td>Loam to heavy soil</td>
<td>Loam to heavy soil</td>
<td>Sandy soil</td>
<td>Sandy soil</td>
<td>Sandy soil</td>
</tr>
<tr>
<td><strong>Infiltration rate</strong></td>
<td>Moderate to low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate to high</td>
<td>Moderate to high</td>
<td>Moderate to high</td>
</tr>
<tr>
<td><strong>Topography</strong></td>
<td>Flat/nearly level ground</td>
<td>Flat-to- small slope</td>
<td>Flat-to- small slope</td>
<td>All category (flat to rolling)</td>
<td>Flat</td>
<td>Flat</td>
</tr>
<tr>
<td><strong>Crop</strong></td>
<td>Close growing crops, suited to standing water</td>
<td>Close growing crops, not suited to standing water</td>
<td>Widely spaced row crops</td>
<td>Generally short crops</td>
<td>Widely spaced row crops, generally high value crops</td>
<td>Row crops</td>
</tr>
<tr>
<td><strong>Water supply/stream size</strong></td>
<td>Large stream</td>
<td>Medium-to- large stream</td>
<td>Medium stream</td>
<td>Small stream</td>
<td>Small stream</td>
<td>Small stream</td>
</tr>
<tr>
<td><strong>Water quality</strong></td>
<td>All category</td>
<td>All category</td>
<td>All category</td>
<td>Clean water</td>
<td>Clean water</td>
<td>Clean water</td>
</tr>
<tr>
<td><strong>Windy climate</strong></td>
<td>No problem</td>
<td>No problem</td>
<td>No problem</td>
<td>Problem</td>
<td>No problem</td>
<td>No problem</td>
</tr>
<tr>
<td><strong>Attainable irrigation efficiency</strong></td>
<td>80–90%</td>
<td>70–85%</td>
<td>65–75%</td>
<td>85–95%</td>
<td>85–95%</td>
<td>85–95%</td>
</tr>
<tr>
<td><strong>Capital required/initial investment</strong></td>
<td>Medium cost for establishment of basin</td>
<td>Low cost</td>
<td>Medium cost</td>
<td>High initial cost</td>
<td>High initial cost</td>
<td>High initial cost</td>
</tr>
<tr>
<td><strong>Labor requirement</strong></td>
<td>High for establishment, but low for operation</td>
<td>Medium</td>
<td>Medium, low if automated</td>
<td>Medium, low if automated</td>
<td>Low</td>
<td>High for establishment, but low for operation</td>
</tr>
</tbody>
</table>
Table 2.1 (continued)

<table>
<thead>
<tr>
<th>Site and situation factors</th>
<th>Basin</th>
<th>Border</th>
<th>Furrow</th>
<th>Sprinkler</th>
<th>Drip</th>
<th>Sub-irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy requirement</td>
<td>No energy required (only if groundwater is to be supplied)</td>
<td>No energy required (only if groundwater is to be supplied)</td>
<td>No energy required (only if groundwater is to be supplied)</td>
<td>Energy required</td>
<td>Energy required</td>
<td>No energy required</td>
</tr>
<tr>
<td>Skill required</td>
<td>Skill required to establish basin</td>
<td>No skill required</td>
<td>Moderate skill required</td>
<td>High skill required</td>
<td>High skill required</td>
<td>High skill required</td>
</tr>
<tr>
<td>Epidemic diseases</td>
<td>No problem</td>
<td>No problem</td>
<td>No problem</td>
<td>Problem</td>
<td>No problem</td>
<td>No problem</td>
</tr>
<tr>
<td>Operation and maintenance</td>
<td>Easy; low operation and maintenance cost</td>
<td>Easy; low operation and maintenance cost</td>
<td>Easy; low operation and maintenance cost</td>
<td>Not easy, require skill; high operation and maintenance cost</td>
<td>Not easy, require skill; high operation and maintenance cost</td>
<td>Not easy, require skill; high operation and maintenance cost</td>
</tr>
</tbody>
</table>
Questions

2.4.2 Selection Procedure

To choose an irrigation method, the farmer must know the advantages and disadvantages of the various methods. He or she must know which method suits the local conditions best. Unfortunately, in many cases, there is no single best solution: all methods have their advantages and disadvantages. Testing of the various methods under the prevailing local conditions provides the best basis for a sound choice of irrigation method. Based on the local soil, climate, crop and water availability, and the suitability and limiting criteria of the methods (described in earlier sections, and also summarized in Table 2.1), the irrigation engineer will prescribe the appropriate method for the particular area.

Relevant Journals

– Irrigation Science
– Agricultural Water Management
– Irrigation and Drainage System
– Journal of Irrigation and Drainage Division, ASCE
– Transactions of the American Society of Agricultural Engineers
– ICID Bulletins
– Agronomy Journal

Questions

(1) What are the different methods of applying water to crops?
(2) Describe in brief the characteristic features, suitabilities, and limitations of the following irrigation methods: (a) Border, (b) Basin, (c) Furrow, (d) Sprinkler, (e) Drip, and (f) Trickle.
(3) Describe the factors influencing selection of an irrigation method.
(4) Compare different irrigation systems in relation to site and different situation factors.
(5) As an irrigation engineer, you are asked to advise regarding irrigation method in a new irrigable farming area. What points will you consider and what steps will you follow to materialize your job.
Practices of Irrigation & On-farm Water Management:
Volume 2
Ali, H.
2011, XXIII, 546 p., Hardcover