Chapter 3

# Irrigation of Sandy Soils, Basics and Scheduling

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Additional information is available at the end of the chapter

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## 1. Introduction

Irrigation of sandy soils must be considered carefully. In this chapter a review is made of the physical characteristics and water-soil relationships of sandy soils [1], as well as various irrigation methods. Recommendations are also given on proper water management at field level.

Dry land and irrigated agriculture depend on the management of two basic natural resources; soil and water. Soil is the supporting structure of plant life and water is essential to sustain plant life. The wise use of these resources requires a basic understanding of soil and water as well as the crop itself.

Irrigating sandy soils requires high attention to the timing and amount of irrigation water applied [2], which are crucial decisions for each operator. Applying too much water means increased pumping costs, reduced water efficiency, and increased potential for pollutant leaching below the rooting zone and into the ground water. Delaying irrigation until plant stress is evident can result in economic yield loss.

This chapter describes some "best" soil moisture management strategies and monitoring techniques that a farmer should consider in managing irrigation and maintaining soil moisture for optimum crop production and least possible degradation of ground water quality.

The main objective of this chapter is to investigate main soil physical and chemical properties that affect the irrigation water amount and to suggest possible irrigation strategies for sandy soil.

Drip irrigation is one of the most efficient irrigation methods to be developed [3]. Although it had been known for many years, some horticulturists and nursery gardeners mostly used it. Its application at the farm level became more common with the extensive use of polyethylene plastics, which has led to reduced cost and increased acceptability for some crops. Trickle irrigation really started in agriculture less than 10 years ago. The real success of this new method is based on a certain number of advantages which are claimed by the enthusiastic promoters of the method: water saving, higher yields, utilization of brackish waters, manual labor extremely reduced, reduction in diseases, weed control, etc. In fact highly qualified specialists have obtained most of these promising results in experimental conditions. Comparative field trials are still few to determine in what proportion these advantages are applicable to large scale irrigation. The method is still in its initial stages and many developments are expected in the near future.

A well designed irrigation scheme may not yield the expected returns if water is not managed in the proper way by farmers. This may be even more applicable in the case of sandy soils for which irrigation must be handled with special care. The human aspect is often unduly disregarded during the planning period whereas it plays a decisive part during the whole lifetime of a project. It is therefore necessary to provide farmers with the knowledge that they need. This of course can only be done through an intensive education program of demonstrations, advice, rewards, etc., carried out by a well organized extension service. In order to be efficient, the extension workers should receive special training on the irrigation of sandy soils based on a very good knowledge of the local soil conditions.

## 2. Basic soil characteristics affecting irrigation

Soil is composed of three major parts: air, water, and solids. The solid component forms the framework of the soil and consists of mineral and organic matter [4]. The mineral fraction is made up of sand, silt, and clay particles. The proportion of the soil occupied by water and air is referred to as the pore volume. The pore volume is generally constant for a given soil layer but may be altered by tillage and compaction. The ratio of air to water stored in the pores changes as water is added to or lost from the soil.

There are two main soil characteristics that affect irrigation:

- Soil physical characteristics [5] (soil depth, soil texture, soil infiltration, soil moisture content, bulk density and soil porosity). Summary of the physical characteristics of the main soil texture classes are listed in table 1.
- Soil chemical characteristics [6] (soil salinity and sodicity)

### 2.1. Soil depth

Soil depth refers to the thickness of the soil materials, which provide structural support, nutrients, and water for plants. Sandy lands are deep and contain low gravels at a depth of more than 50 centimeters. These lands are characterized by high quantities of calcium carbonate and found in some area of the gravel plain adjacent to the sandy desert. The depth of the soil layer of sand and gravel can affect irrigation management decisions. If the depth to this layer is less than 3 feet, the rooting depth and available soil water for plants is decreased. Soils with less available water for plants require more frequent irrigation.

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### 2.2. Texture

The distribution of the soil particles according to their size is called the texture. Sand is usually defined as particles having a diameter between 0.05 and 1.00 mm (Figure 1). If the amount of particles within this range is greater than 50 percent, the soil is said to be sandy. According to the exact percentages of sand and other particles contained in a sandy soil, its texture will vary from sandy-clay to coarse sand (Figure 2). The texture of sandy soils has a very important influence on the infiltration rate, the water holding capacity and consequently on its value for irrigation. Since generally the more loam and clay contained in the soil, the better it will be for irrigation, a mechanical analysis is a necessary tool for soil classification. Coarse soils are easily eroded by running water, which is one of the obstacles to successful surface irrigation. Two well known physical features of sandy soils are their coarse texture and their high rate of permeability. Other features that play an important part in irrigation are the pore space, the bulk density and the water content [7].

Since sand particles are most dominant in the soil of arid regions, their texture tends to be light (sandier). Moreover, clay particles are rarely found in some areas of the arid regions with coarse sand and large quantity of gravel. Thus fast leakage of nutritional elements occurs when water is added at short intervals. Adding organic substances is highly recommended to improve the soil water holding capacity.

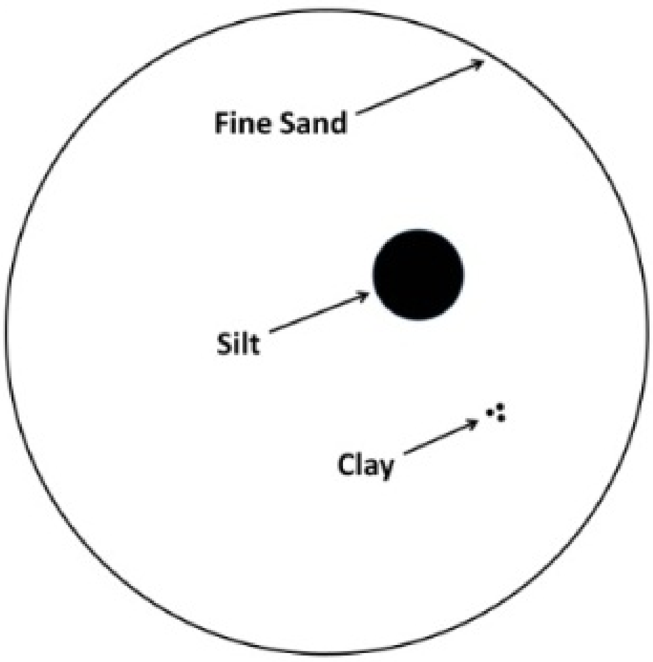


**Figure 1.** Comparative size of clay to fine sand. Clay is actually less than 0.002 mm with fine sand up to 0.25 mm [8].

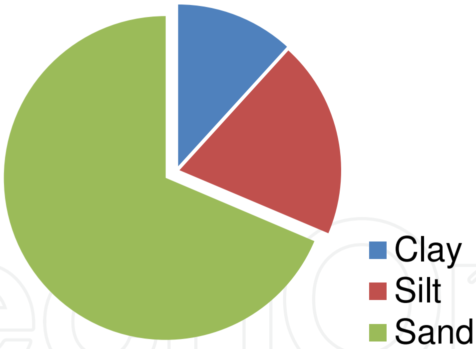


**Figure 2.** Percentages of sand and other particles contained in a sandy soil vary from sandy clay to coarse sand.

### 2.3. Soil infiltration

The infiltration rate is the velocity at which water percolates into a soil and usually decreases the longer water is in contact with the soil. It will reach a relatively steady value equal to the permeability or hydraulic conductivity of water through the soil. This variation of infiltration rate with time differs from one type of soil to another. In the case of sandy soils the final rate is reached rapidly and is usually high.

Sandy soils have high infiltration rates varying for sandy clay and sandy loam from 4 to 25 cm/h, but in very permeable sandy soils values as high as 100 to 400 cm/h are easily reached (Figure 3 & 4). High final infiltration rates are responsible for important water losses both in conveyance systems and in the field. Soils having a final infiltration rate of 10 cm/h and above are generally not recommended for surface irrigation systems. In other words, to keep the conveyance and application efficiencies at an acceptable level the length of the ditches and the size of the fields may be too small for proper cropping. A 30 l/s flow could irrigate no more than 1080 $m^2$ at any one time. The uniformity of application will be poor if the fields are large since upper parts would receive more water than the lower ones. High infiltration rates may be an important constraint to efficient surface irrigation schemes. High infiltration rates also have an action on the soil structure in that often the clay particles contained in the upper layers are conveyed to deeper layers where they accumulate and form a less permeable horizon. This horizon may impede the deep percolation of excess water coming from rain or over-irrigation and may form a perched water table, which will require field drainage.

Infiltration is the downward entry of water into the soil. The velocity at which water enters the soil is the infiltration rate. The infiltration rate is typically expressed in inches per hour. Water from rainfall or irrigation must first enter the soil to be valuable for the plant. This is important in irrigation since infiltration is considered as an indicator of the soil's ability to allow water movement into and through the soil profile. Soil temporarily stores water, making it available for root uptake, plant growth and habitat for soil organisms. When water is supplied at a rate that exceeds the soil's infiltration capacity, it moves down slope as runoff on sloping land or ponds on the surface of level land. When runoff occurs on bare or poorly vegetated soil, erosion takes place. Runoff carries nutrients, chemicals, and soil with it, resulting in decreased soil productivity, off-site sedimentation of water bodies and diminished

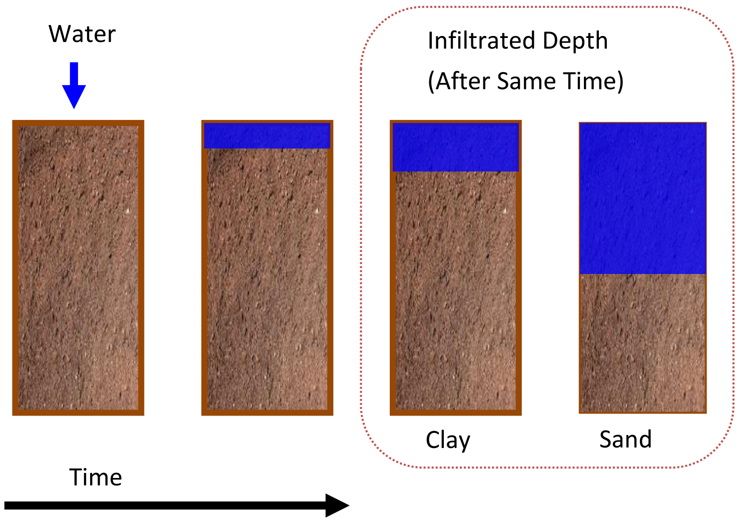


**Figure 3.** Comparison of water infiltrated depth over time between two soil textures.

water quality. Sedimentation decreases storage capacity of reservoirs and streams and can lead to flooding. Therefore, knowing of soil infiltration rate is important to select a good method of irrigation.

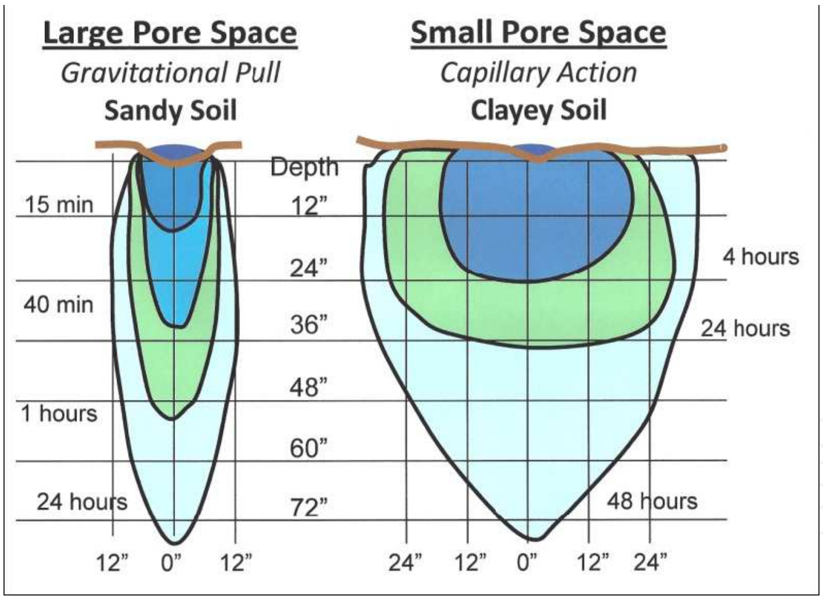


**Figure 4.** Comparative movement of water in sandy and clayey soils. In sandy soils, water readily moves downward due to the gravitational pull. In clay soils, water slowly moves in all direction by capillary action [8].

### 2.4. Soil moisture content

Soil moisture content is one of the most variable characteristics of soil. The soil acts as a reservoir for water, making it available for plants as it is needed. Soil water is very important to the entire soil system, not only because it is necessary for plant growth, but because the nutrients required for plant growth are also present in the soil solution. Most of the important soil reactions (weathering, cation exchange, organic matter decomposition, fertilization) take place in the context of the soil solution. Thus, soil moisture is a key property of the soil.

### 2.5. Bulk density and porosity

The porosity or pore space is that space between the soil particles, which is equal to the ratio of the volume of voids either filled with air or with water to the total volume of soil, including air and water. The porosity or pore space of sandy soils is less than for clay soils.

The apparent specific gravity or bulk density is the ratio of the weight of a given volume of dry soil (dry space included) to the weight of an equal volume of water. The apparent specific gravity varies with soil types as does the porosity. Mean and extreme values are indicated in table 2.

| Properties | Sandy | Loamy | Clay |
|---|---|---|---|
| Feeling | Coarse | Medium | Fine |
| Decomposition of O.M. | Rapid | Medium to high | High |
| Water Holding Capacity | Low | Medium to high | High |
| Drainage | Good | Medium | Poor |
| Aeration | Good | Medium | Poor |
| Infiltration rate | High | Medium | Low |
| Porosity | Low | Medium | High |

**Table 1.** Physical characteristics of main soil texture classes [4].

| Soil Texture | Apparent Specific Gravity | Pore Space |
|---|---|---|
| Sandy | | |
| Mean | 1.65 | 38 |
| Extremes | 1.55-1.80 | 32-42 |
| Sandy loam | | |
| Mean | 1.50 | 43 |
| Extremes | 1.40-1.60 | 40-47 |

**Table 2.** Bulk density and porosity of some sandy and sandy loam soil

### 2.6. Soil salinity and sodicity

Salinity in soil becomes a problem when the total amount of salts that accumulate in the root zone is high enough to negatively affect plant growth. Excess soluble salts in the root zone restrict plant roots from withdrawing water from the surrounding soil, effectively reducing the plant available water. Plant available water is at its maximum and soil salinity is at its lowest concentration immediately after irrigation. However, as plants use soil water, the force with which the remaining water is held in the soil increases, making it progressively more difficult to withdraw water. Also, as water is taken up by plants through transpiration or is lost to the atmosphere by evaporation, the salinity of the remaining water increases. This is due to the fact that the majority of the salts are left behind in both processes while the amount of water that the salt is dissolved in is progressively reduced. This effect becomes most pronounced during periods of high evapotranspiration (ET) demand, such as hot sunny summer days and during the peak of the growing season. It is widely accepted that the salinity of soil water is equal to approximately three times the salinity of irrigation water, assuming relatively little leaching is occurring [5]. In conditions of relatively high leaching fractions, the soil water solution and drainage water will have a salinity level slightly greater than the irrigation water. When considering salinity effects of the irrigation water, the plants and soil are actually subject to the salinity of the resultant soil solution, which is a function of the salinity of the applied water.

In much of the arid and semi-arid regions, most of the salts present in irrigation water and groundwater are either chlorides, sulfates, carbonates or bicarbonates of calcium, magnesium, sodium and potassium. Each of these salts has a unique solubility, which along with the composition of the mineral material through which water passes, dictates the salts present in the water. When these salts are dissolved in solution, they often ionize, breaking down (disassociating) into cations (positively-charged molecules) and anions (negatively-charged molecules) [6]. The most common cations in arid and semi-arid areas are calcium, magnesium and sodium. Each of these cations is base-forming, meaning that they contribute to an increased $OH^-$ concentration in the soil solution and a decrease in $H^+$ concentration. They typically dominate the exchange complex of soils, having replaced aluminum and hydrogen. Soils with exchange complexes saturated with calcium, magnesium and sodium have a high base saturation and typically high pH values

In addition to decreasing plant available water and being potentially toxic to plants, soil solution salinity can also affect soil physical properties. Salinity can have a flocculating affect on soils, causing fine particles to bind together into aggregates.

Assessment of the relationship between soil solution salinity and soil physical properties requires knowledge of the constituents of the dissolved salts, and especially the sodium concentration [9]. Sodium has the opposite effect on soils that salinity does. While elevated electrolyte concentration may enhance flocculation, sodium saturation may cause dispersion. Because of its relatively large size, single electrical charge and hydration status, adsorbed sodium tends to cause physical separation of soil particles.

The relationship between soil salinity and its flocculating effects, and soil ESP (exchangeable sodium percentage) and its dispersive effects, dictate whether or not a soil will stay aggregated or become dispersed under various salinity and sodicity combinations

Dispersed clay particles within the soil solution can clog soil pores when the particles settle out of solution. Additionally, when dispersed particles settle, they may form a nearly structureless cement-like soil. This pore plugging and cement-like structure make it difficult for plants to get established and grow. It also impedes water flow and water infiltration into the soil.

The disruption of soil hydraulic properties has two main consequences. Firstly, there is less water infiltrating into the soil, and therefore less plant available water, particularly at deeper depths. Secondly runoff, and therefore water loss and soil erosion, may be enhanced, and both affect the irrigation.

## 3. Levels of soil moisture content

There are four important levels of soil moisture content that reflect the availability of water in the soil (figure 5). These levels are commonly referred to as: 1) saturation, 2) field capacity, 3) wilting point and 4) oven dry [4]

*Saturated:* all of the soil pore spaces are filled with water. At this point the soil is at its maximum retentive capacity. Not all the water present in the soil is available for plant use. Some water drains past the rooting zone and is unavailable. Soil can be viewed as a sponge composed of air and solid particles when dry. This is an undesirable condition for the growth of most plants because the available dissolved oxygen is quickly depleted. Water at the saturation point in soils is held at a tension of 0 MPa (0 bars).

*Field capacity:* the maximum amount of water left in the soil after losses of water to the forces of gravity have ceased and before surface evaporation begins. It occurs when the soil contains the maximum amount of capillary water. Field capacity represents the amount of water remaining in the soil after the large pores have drained. Medium and small pores are still filled with water held against the force of gravity. Soil water at field capacity is readily available to plants and sufficient air is present for root and microbial respiration. The optimum water content for plant growth and soil microbial respiration is considered to be close to field capacity. Soils at field capacity are generally considered to be holding water at a tension of about 0.01-0.03 MPa (0.1-0.3 bars).

*Permanent wilting point (PWP):* If water is continually taken-up by plants and no additional water is added to the soil in the form of precipitation or irrigation water, the medium and small soil pores will be emptied of water. With time, the plant will eventually wilt when it cannot extract more water. The soil is said to be at the permanent wilting point when plants can no longer exert enough force to extract the remaining soil water. At the permanent wilting point, water is held in the soil at about 1.5 MPa (15 bars). At this point the plant can no longer obtain sufficient water from the soil to meet its transpiration needs. At this point the plant enters permanent wilt and dies.

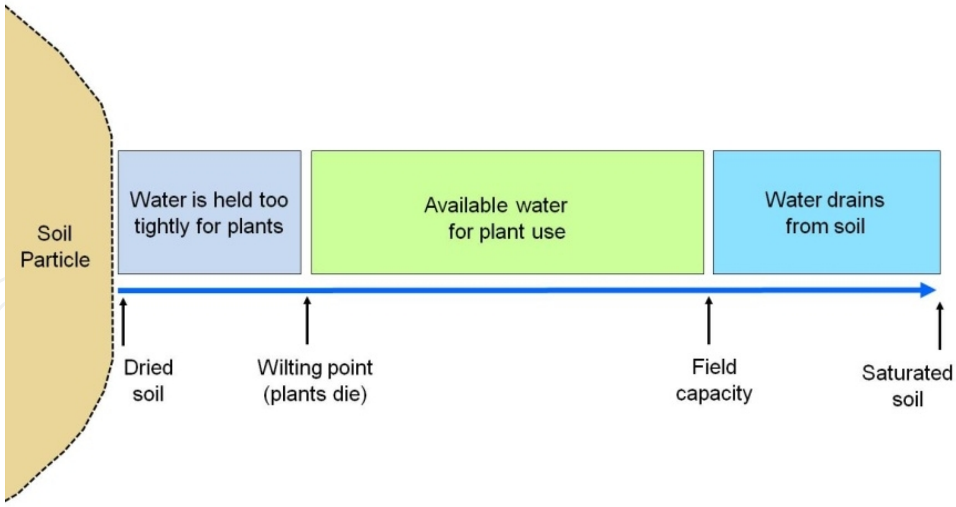


**Figure 5.** arrangement of soil water classes starting from the surface of the soil particle.

*Hygroscopic coefficient:* The hygroscopic coefficient is the boundary between moist-appearing and dry-appearing soil. This boundary is not sharp. Its arbitrary value is – 3100 kPa (-3.1 Mpa) soil matric potential.

*Oven-dry:* If soil is placed in an oven and dried at 105°C, additional water will be removed. The oven-dry condition is the reference state used as the basis for expressing most soil characteristics.

### 3.1. Classes of soil moisture

*Gravitational water:* The water that moves into, through, or out of the soil by gravity (0- 1/3 bar).

*Capillary water:* Water that is left in soil, along with hygroscopic moisture and water vapor, after the gravitational water has drained off. Capillary water is held by surface tension as a film of moisture on the surface of soil particles and peds, and as minute bodies of water filling part of the pore space between particles. Most, but not all, of this water is available for plant growth Capillary water is held in the soil against the pull of gravity forces acting on capillary water (1/3 to -31 bars)

*Hygroscopic water:* Water absorbed from the atmosphere and held very tightly by the soil particles, so that it is unavailable to plants in amounts sufficient for them to survive. It is the water lost from an air-dry soil when it is heated to 105°C (31-10,000 bar).

The water content of soil depends on the amount of water stored in the pore space. Since sandy soils do not have a very large total pore space, their water content will never be very high. The water content can be expressed either as a percentage on a dry weight basis or as a percentage on a volume basis. The moisture content on a dry weight basis is equal to the ratio of the weight of water contained by a soil at field capacity to the weight of this same soil after having been dried in an oven at a temperature of 105 °C. The moisture content on a volume basis is equal to the ratio of the volume occupied by the water stored in the pore space to the total volume of the soil.

This relation can be converted to a depth of water available in soil which is usable in determining quantitative water requirements of individual crops grown in specific soils and is called the readily available water.

In irrigation practice it is not recommended to wait for the soil water to reach the permanent wilting point before replenishing the soil reservoir. In this way the plants will not suffer from an eventual lack of water. In principle, water applications should never be greater than the readily available water as any excess will automatically be lost by deep percolation.

### 3.2. Available water for various sand soil textures

The more sandy a soil is the higher its apparent specific gravity and the lower its pore space. Thus sandy soils, which are often designated by farmers as "light soils" are in fact the ones that weigh the most per unit volume. The term "light" refers to their ease in working with agricultural implements.

Available soil water defined as the amount of water present in a soil, which can be moved by plants. It is designated as the difference between the field capacity and the wilting point. The available water for various sandy soil classes is listed in table 3.

| Soil Texture | Available Water (mm/m) |
|---|---|
| Coarse Sands | 20-65 |
| Fine Sands | 60-85 |
| Loamy Sands | 65-110 |
| Sandy Loams | 90-130 |
| Fine Sandy Loam | 100-170 |

**Table 3.** Available water for various sandy soil textures [10]

## 4. Irrigation of sandy soils

There are about 250 million irrigated hectares in the world, most of which have experienced moderate to high soil erosion due to the lack of experience [10]. Surface runoff and deep percolation decrease the irrigation efficiency; therefore selecting suitable irrigation method is needed in order to improve irrigation efficiency. More than 95% of irrigated land in the world is irrigated by surface method. Using surface irrigation method is not desirable on sandy soil due to the fact that it has high infiltration rate. On the other hand, sprinkle and drip irrigation methods are more desirable on the sandy soils because surface runoff and deep percolation do not occur frequently. In the drip irrigation system, water is applied more to the places of the plant root area. Compare to other irrigation methods, drip irrigation is more efficient and can be applied more frequently. The low irrigation rate of drip irrigation makes it most suitable for both sandy and clay soils. In addition, drip irrigation method has been successfully used with saline water.

## 5. Irrigation scheduling

As the demand for water increases, along with the need to protect aquatic habitats, water conservation practices for irrigation need to be effective and affordable. Precision irrigation will optimize irrigation by minimizing the waste of water, and energy, while maximizing crop yields [11].

The most effective method for determining the water demands of crops is based on the real time monitoring of soil moisture, and direct water application used in conjunction with the information about soil hydrological properties and evapotranspiration [12].

Good irrigation scheduling means applying the right amount of water at the right time. In other words, making sure water is available when the crop needs it. Scheduling maximizes irrigation efficiency by minimizing runoff and percolation losses. This often results in lower energy and water use and optimum crop yields, but it can result in increased energy and water use in situations where water isnot being managed properly.

The following factors influence an efficient irrigation schedule:

1. *Irrigation System Information:* A key piece of irrigation system information is the net amount of water applied by your system. Determining this requires measurements of system gross application rate and irrigation application efficiency. In addition to the application efficiency, it is very important to consider the uniformity efficiency especially in the case of sprinkler irrigation system in windy areas.
2. *Crop Information:* crop type, crop density, amount of vegetative cover or leaf area, crop health, and stage of growth
3. *Climatic conditions:* temperature, relative humidity, wind speed, day time hour, solar radiation
4. *Environmental Conditions:* Soil salinity [3], soil depth and layering, poor soil fertility
5. *Field Management Practices:* Fertility management, disease and pest control

Advantages of irrigation scheduling

Irrigation scheduling offers several advantages:

1. It enables the farmer to schedule water cycles among the various fields to minimize crop water stress and maximize yields.
2. It lowers fertilizer costs by holding surface runoff and deep percolation (leaching) to a minimum.
3. It increases net returns by increasing crop yields and crop quality.

**4.** It assists in controlling root zone salinity problems through controlled leaching.

**5.** It results in additional returns by using the "saved" water to irrigate non-cash crops that otherwise would not be irrigated during water-short periods.

### 5.1. Irrigation scheduling metchods

These methods can range from *qualitative 'feeling'* the need to apply water to prevent damaging crop stress to *quantitative soil water budgets* for individual fields at various levels of detail. Table (4) describes the main technologies to improve irrigation efficiency.

| Irrigation Scheduling Methods | Method Characteristics | Level of Complexity |
|---|---|---|
| Visual observations | • Crop is at a specific growth stage<br>• Crop is experiencing water stress<br>• Water is available to irrigate<br>• Neighbor is irrigating | Simple |
| Measure current moisture level | • Soil moisture sensors indicate water availability in the root zone e.g. gypsum blocks, granular matrix probes, tensiometers, capacitance probes,<br>• Sensors indicating the water status of the crop e.g. IR thermometer for canopy temperature [13] and [14] | Basic to Moderate Methods |
| Smart Irrigation:<br>Defined as controllers that reduce water use by monitoring and using information about site conditions (such as soil moisture, rain, wind, slope, soil, plant type, and more and applying the right amount of water based on those factors". Essentially, these irrigation controllers receive feedback from the irrigated system and schedule or adjust irrigation duration and/or frequency accordingly [15]. | Maintain soil water budget of the root zone (Weather-Based Irrigation Control System Principles)<br>• Daily measurement of the actual ET using lysometers<br>• Daily reference ET based on weather data<br>• Crop coefficients for actual ET<br>• Measure rainfall<br>• Forecast daily water use for next 1-2 weeks<br>• Compare computed with measured soil moisture | |
| | Automatic irrigations (Smart Irrigation System)<br>• measured soil moisture level in root zone<br>• water potential of the plant<br>• computed soil water depletions<br>• programmed time | |
| Infra red thermometer:<br>Canopy temperature is measured with infrared thermometer. It also simultaneously measures canopy temperature and air temperature and displays the difference. This difference can be used for scheduling irrigation. [16] | • If canopy temperature "/> Air Temperature: indicates stress irrigation is scheduled<br>• Canopy Temperature < Air Temperature: indicate the plants have sufficient amount of water | |
| Remote sensing:<br>In areas, where a single crop is grown [17] | Irrigation scheduling can be done with the help of remote sensing data. Reflectance of solar radiation by the plants with sufficient amount of water is different from that of stressed plants. This principle can be used for scheduling irrigation. | (Advance Method) Complex |

**Table 4.** main technologies to improve irrigation efficiency

The irrigation scheduling method can be classified over 5 levels as follows:

| Level | Irrigation Scheduling Method |
|---|---|
| 0 | "Feel Like It" Method (Guessing) |
| 1 | "Feel and See" Method |
| 2 | Use a Schedule (1/2" every 3 days) |
| 3 | Use a Soil Water Tension device |
| 4 | Use a Soil Water Tension device to apply water on a schedule |
| 5 | Adjust water based on crop need, utilizing Soil Water Tension device |

**Table 5.** classification of irrigation scheduling methods [18]

## 6. Irrigation water management

Irrigation Water Management is the process of determining and controlling the volume, frequency, and application rate of irrigation water in a planned [19], efficient manner. Irrigation water management is important for the following reasons

- Managing soil moisture to promote desired crop response.
- Optimizing the use of available water supplies.
- Preventing economic yield losses due to moisture stress.
- Maximizing efficiency of production inputs.
- Minimizing irrigation induced erosion.
- Minimizing leaching potential of nitrates and other agrichemicals below the rooting zone.
- Managing salts in the crop root zone.
- Managing air, soil or plant micro-climate.

Irrigation water management primarily aims to control the volume and frequency of irrigation water applied to crops, so as to meet crop needs while conserving water resources. This includes determining and controlling the rate, amount and timing of irrigation water in a planned and efficient manner. Obtaining high yield from irrigation requires appropriate management of all the inputs. This means efficient management of the amount of applied water. One of the most important aspects of irrigation management is deciding when to turn on the irrigation system and how much water to apply [20]. Fortunately, irrigation scheduling methods have been developed to help making those decisions. Using rational or scientific methods to schedule irrigations is essential for good irrigation management. Good irrigation management begins with accurate measurement of the rainfall received and knowing the soil moisture status in the field. Over the past few years, several attempts were conducted to develop irrigation scheduling methods [21]. Measurement of soil moisture levels is the most common method in determining irrigation scheduling, however more modern methods were developed that combine both crop water use and soil water estimate. The major factors influencing irrigation management in addition to the management levels will be discussed in this section.

Five essential elements for irrigation water management:

$$\left.\begin{array}{l}\text{1. Measurement of soil moisture}\\ \text{2. Measurement of irrigation water applied}\\ \text{3. Measurement crop consumptive use}\\ \text{4. Evaluation of the irrigation system efficiency}\\ \text{5. Measurement of the soil and irrigation water quality}\end{array}\right\}\text{Need all 5 items} \qquad (1)$$

Table 6 shows a comparison between the currently used smart irrigation technology and the traditional controller, which have been developed to address some elements of irrigation water management to improve irrigation efficiencies.

| **Features** | **Traditional controller** | **"Smart" controller** |
|---|---|---|
| Automated watering system | X | X |
| Does not require seasonal monitoring/changes | | X |
| Uses less water | | X |
| Fails to consider; Rainfall, Solar Radiation, Humidity, Temperature and Wind | X | |

**Table 6.** comparison between traditional controller and smart controller [18]

## 7. Irrigation using wireless sensors

Nowadays new technologies are being used to determine the actual crop water need through sensing soil moisture using wireless techniques (figure 6). These technologies have been used in precision agriculture to assist in precise irrigation where it can provide a potential solution to efficient water management through remotely sensing soil water conditions in the field and controlling irrigation systems on the site [22]. The network of these sensors consists of radio frequency transceivers, sensors, and microcontrollers. There are several types of wireless technologies, most of which depend on infrared light, point-to-point communications, wireless personal area network (WLAN), Bluetooth, ZigBee, multi-hop wireless local area network, and log-distance cellular phone systems such as GSM/GPRS and CDMA [23]. The technology of wireless sensors needs more development especially in the agricultural area. Since the late 1970s, a wide range of competing technologies has each been hailed as 'the answer' for sensing soil water. Several studies were conducted to evaluate these technologies [24], [25], [26] and [27]. A new wireless irrigation system was developed that communicates to boost irrigation through Bluetooth and wireless network of small soil moisture and temperature sensors. It has the ability to continuously detect accurate plant water needs [24]. Chávez et al. [25] used a new system with Single Board Computer (SBC) using Linux operating system to control solenoids connected to an individual or group of nozzles. The control box was connected to a sensor network radio, GPS unit, and Ethernet radio. For efficient irrigation water management, Kim and Evans [27] designed a Bluetooth wireless communication in-field sensor and control software using four major design factors that provide real-time monitoring and control of both field data and sprinkler controls. The system successfully enabled real-time remote access to the field conditions and site-specific irrigation. Their recommendation was to simply use and manage the software by growers. Smart sensor array for cotton irrigation scheduling was developed by Vellidis et al. [28]. Damas et al [24] developed and evaluated a remotely controlled automatic irrigation system for an area of 1500 ha using WLAN network. They were able to save 30-60% of water usage. In addition, they develop a mobile field data acquisition system to collect information for crop management and spatial-variability studies including available soil water and plant water status and other field data. Evans and Bergman [29] assisted irrigation scheduling using wireless sensors in three irrigation systems (e.g. self-propelled, linear-move and center-pivot) combined with an on-site weather station, remote sensing data and farmer preferences.

Since wireless sensors and networks have just started in the agricultural field, there is great potential for the implementation of wireless sensors in the irrigation of sandy soil, in which greater water use efficiency will be achieved. The main advantage of these technologies is to save water use in agriculture sector.

**Figure 6.** wireless sensor in the field that detects soil water status at various depths.

## 8. Conclusion

Sandy soils have a low pore space and a high infiltration rate. The consequences of these two features on irrigation systems and methods are of paramount importance. The low pore space is responsible for a low water holding capacity. Consequently the frequency of irrigation and the labor requirements are high regardless of the irrigation method used. Labor requirements can be reduced but the initial cost of equipment is then considerably increased. The high infiltration rates make surface irrigation very difficult, as an important task is to avoid losses when applying water to the fields. The adaptation of surface irrigation, when possible, requires higher investment costs for increased length and size of canals, canal lining, large number of small plots and eventually special on-farm equipment.

On the contrary high infiltration rates have little influence on sprinkler irrigation. This method can therefore be considered as the best for sandy soils. It will lead to acceptable efficiencies if properly designed and managed.

Drip irrigation is a promising method but its cost is still quite high. It is recommended to set up field trials before embarking on large scale developments with drip irrigation.

Wireless sensors and networks have just started in agriculture to assist in precise irrigation where it can provide a potential solution to efficient water management through remotely sensing soil water conditions in the field and controlling irrigation systems in the site. The implementation of wireless sensors in the irrigation of sandy soil has a great potential, in which more water use efficiency will be achieved. More development of such technology is needed specifically for the agricultural area.

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