Irrigation Systems

Lecture 1

Lecturer: Dr Aram Ali

1

Broad Course Aims

- Educate students in the theory of irrigation across the broad themes of
  – The irrigation industry in local/world
  – Irrigation equipment and performance
  – Irrigation management
  – Irrigation scheduling
- Educate students in the practice of irrigation
- Enhance the ability to critically evaluate existing irrigation systems and decision making.

2

Background information

Improving irrigation water use efficiency is decisive to satisfy the increased world demand for food and other agricultural products.

❑ **Irrigation method**

❑ **Irrigation schedule** (**how often or when** water is given, and **how much** irrigation water has to be given to the crop)

is the key issue for

- conserving water,
- improving irrigation performance
- sustainability of irrigated agriculture.

3

Irrigation

Definition: under the term "***irrigation***" as applied to agriculture, *is included all of the operations or practises in artificially applying water to the soil for the production of the crops.*

Irrigation Application Methods

- **Surface irrigation** (including bay and furrow irrigation, flexible and rigid gated pipe);
- **Sprinkler irrigation**, including hand shift and solid set systems, travelling irrigators, and lateral move and centre pivot machines;
- **Micro-irrigation**; including pipes, emitters and pressurised pumps to deliver water to all individual plants.

4

Irrigation Delivery Systems

- Pumps and pressure tanks may be used to increase or stabilize the hydraulic pressure
- All irrigation systems consist of tubing and/or pipe to transport the irrigation water from the source to the individual plants or to a group of plants
- Injectors are used to inject various nutrients into the water (if fertilizer applied (**Fertigation**).
- Mixing or blending tanks assure that the dissolved materials are distributed uniformly within the water
- Filters are placed to remove insoluble materials.

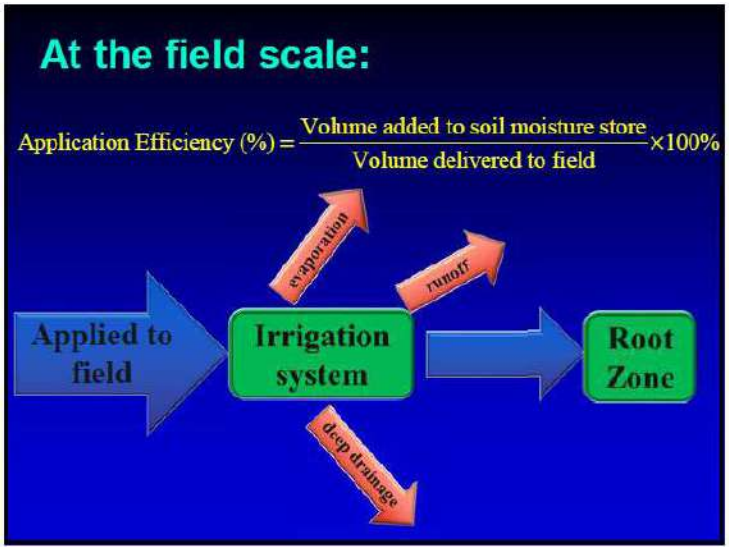
5

- **Minimizing the pressure drop within the system, and especially the variation in pressure among the emitters, maximizes irrigation uniformity.** It is important to design of irrigation systems properly so that all of the parts (main lines, valves, pressure regulators, laterals and emitters) are correctly sized to deliver water at the desired pressure and flow rate.

- **Well-designed and well-maintained irrigation system having with high uniformity (q var ≤ 10%) should be kept**.

6

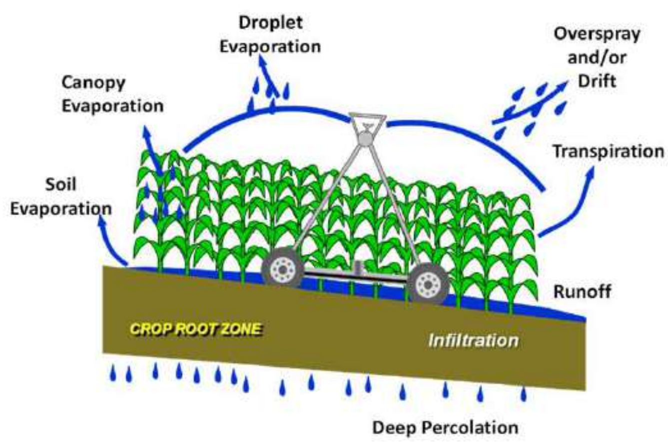
Irrigation application efficiency



7

Endpoint of applied water
What is a loss?

- Crop water use
- Runoff
- Deep drainage
- Evaporation
- Channel losses
- Canopy interception.



Paths of water loss from a center pivot

8

Types of Irrigation

- **Surface Irrigation**

Just flooding water. About 90% of the irrigated areas in the world are by this method

1-Flooding (wild) **2-basin**

3-Border **4-furrow**

B-Subsurface Irrigation

Applying water underground and allowing it to come up by capillarity to crop roots.

C-Automated Irrigation (mechanical)

1-Drip/trickle
Applying water slowly to the soil ideally at the same rate with crop consumption
2-Sprinkler
Applying water under pressure. This system is progressively increasing globally

9

Furrow irrigation.

Furrow irrigation is used extensively for row crops such as cotton, sugar and maize. The furrows run down the slope of the land, between individual rows of plants, at spacings typically 0.75 to 1.5 m. As in border irrigation the flow is let in at the top of the field and runs down the slope.

Border irrigation.

The field is subdivided into strips 10 to 100 m wide and 200 to 1000 m long, running down the direction of the predominant slope. The flows down adjacent strips (or bays) are separated by low earth banks known as check banks. There is no lateral slope across the strips between these banks. Alternatively called border check or bay irrigation, this method is most commonly used for irrigation of pasture.

10

Furrow Irrigation

Border Irrigation

1. Level basin.

Similar to border irrigation except that here there is no longitudinal slope on the field and the length may be shorter. Water may be let into and drained off the basin from one or both ends. This method is claimed to give higher application efficiencies and is being adopted widely in the USA. The contour bay system used for irrigation of rice.

We have some similarities with level basin, but here the water is held on the surface for much longer.

Sprinkler Irrigation

Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The pump supply system, sprinklers and operating conditions must be designed to enable a uniform application of water.

13

Micro-irrigation

Drip and micro-irrigation systems are the water saving champions of the irrigation world. They apply water, either by dripping or spraying, directly to individual plants or small areas of the plants.

Drip: these systems use small emitters installed in water lines to drip water at slow, constant rate directly at the base of a plant. Because the water is delivered directly to the surface of the soil, it does not evaporate and soil beyond the drip area stays dry. The ability to withhold water from certain areas of the land scape is an advantage because dry soil prevents weed seeds from germinating.

14

Micro-irrigation:

Micro-irrigation systems use miniaturized sprinklers installed in small water lines to apply water the aboveground spray results in some evaporation, but these systems are nearly as efficient as drip systems and have a broader range of application.

Drip and micro systems are usually installed on the surface, so no digging is necessary.

This makes them easy to install, so you can adapt to changing plant layouts.

15

Furrow Irrigation

- More crops can be irrigated by the furrow or corrugation method except those grows in ponded water, such as rice

- Is not particularly suitable for irrigating crops subject to injury if water covers the crown or stem of the plants, as the crops may be planted on beds between furrows.

- This irrigation method is best suited to medium moderately fine texture soils of relatively high available water holding capacity & conductivities which allow significant water movement in both the horizontal & vertical directions

16

Types of furrow Irrigation

1-Normal furrow

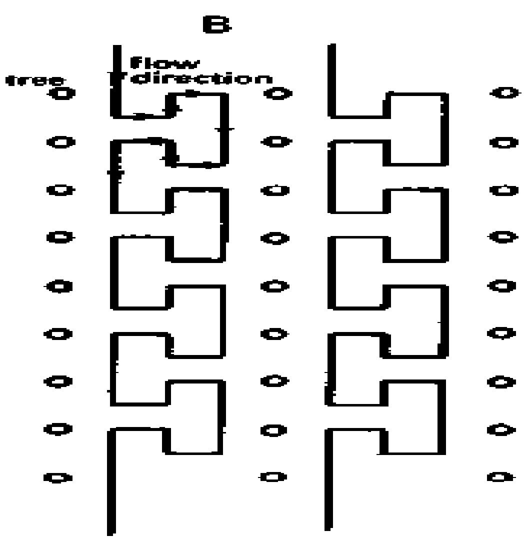
2-Zig –Zag furrow

3-Contour furrow

4-Corrugation furrow

Normal furrow

17



Zig-zag furrows pattern for furrow irrigation on fairly flat slopes (under 0.5%)

Contour furrows can be used for irrigation

18

Design of furrow Irrigation

1-Furrow width:-Must be suitable for selective crop, agriculture machine water move for lateral in the soil and relative with vertical and horizontal intake. In general, the furrow width must be from 30-180cm depends on the crop type and soil for example cotton and potato must be furrow width 60-90cm , also lettuce and onion must be 30-40cm .

2-Furrow length:-Must be suitable for operating and cost to obtain the best yield and economically and sampling agriculture procedures .It has influence on the water application efficiency ,it limited by area and shape of field it may be equal to (1/2) or (1/3) or (1/4) of field length

3- Shape of furrow :-The shape of the furrow has a significant effect on infiltration and irrigation efficiency on the alluvial soils of the delta area. The two furrow shapes in common usage within the field are the broad based "U" shape and the narrow based "V" shape.

19

4- maximum discharge:- Selective suitable discharge is important factor in the optimum design in furrow system. In general average suitable discharge depend on the intake characteristics in the soil , furrow length, slop, furrow spacing and net depth of applied water .

q_{max}=0.6/slope

20

Advantages and disadvantages of Furrow irrigation systems

Advantages:

1. Large areas can be irrigated at a time.
2. It saves labour since once the furrow is filled; it is not necessary to give water a second time.
3. It is a comparatively cheaper method.
4. Plants receive adequate quantity of water by this method.

Disadvantages:

1. Due to imbalance in flow of water, wastage of water is caused in it.
2. It is not suitable in all types of crops.
3. Making challenges for drains requires more labour information.
4. Due to filling of excess water, there is risk of underground salts coming up to the surface layer.

21

Infiltration and Opportunity Time

If it is required to apply a given depth of water (Z_{req}) in a particular irrigation then the time that the water must be present on the soil surface can be determined from the cumulative infiltration curve for the particular soil. This time is known as the infiltration opportunity time or simply the opportunity time.

Advance and Recession

An individual irrigation bay or furrow is essential an open channel. Water is let in at the top end and flows down the slope. A wetting front will advance down the field.

22

This wetting front advances at a decreasing rate, as an increasing proportion of the flow infiltrates into the soil in that part of the field covered by the flow. At any time the depth infiltrated will vary from zero at the wetting front to a maximum at the upstream end of the field, reflecting the different times water has been present on the surface.

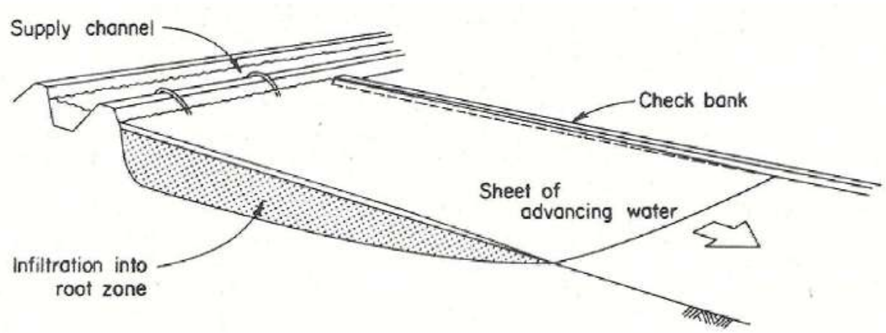


Figure 1: Section showing surface flow and infiltration in an irrigation border.

23

At some suitable time the inflow to the field is cut-off and a draining front will recede down the field (Figure 2). At the time of cut-off the advance may have reached the lower end of the field and water may be running off the field or the advance may still be in progress. Infiltration at any point will cease as the draining front passes that point.

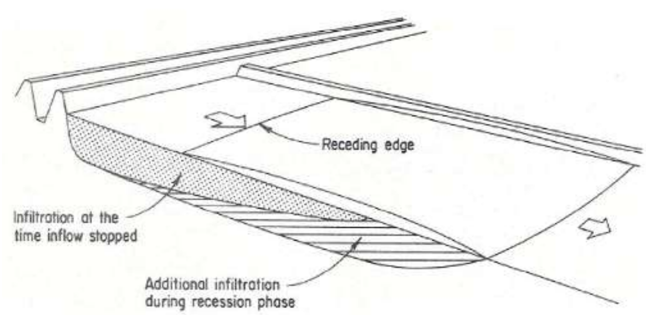
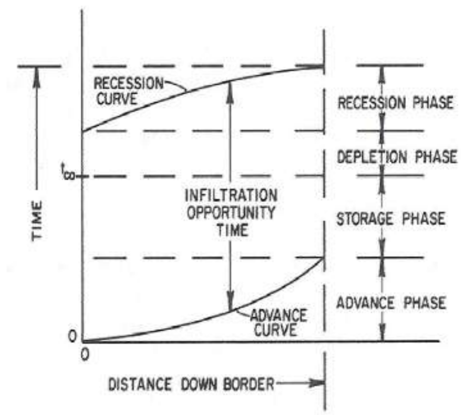


Figure 2: Infiltration during the recession phase in surface irrigation.

24

- Both the advance and the recession trajectories are best visualised as plots of distance down the field versus time. This figure also shows the other two phases in the surface irrigation process, the storage and depletion phases. The advance phase ends when the wetting front reaches the lower end of the field.



25

The infiltration opportunity time at any location, x, along the length-of-run, $T_{opp}(x)$, is defined as the time between advance, $t_A(x)$, and recession, $t_R(x)$ or

$$\mathbf{t_{opp}\ (x) = Inflow\ time + t_R(x) - t_A(x)}$$

At the head end of the field (x = L), the opportunity time is equal to the recession time, or

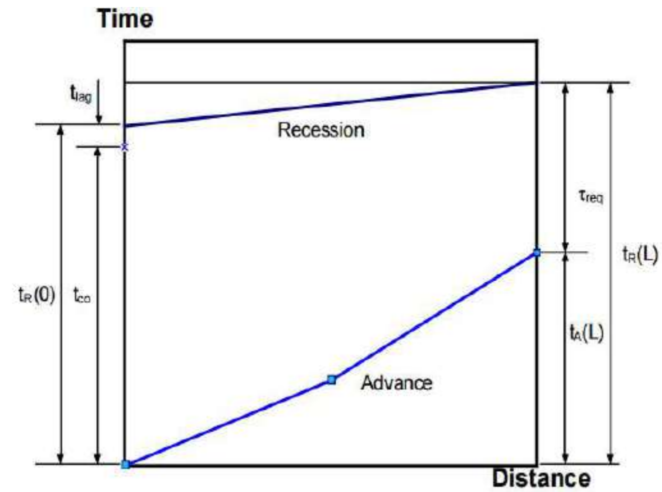
$$\mathbf{t_{opp}\ (0) = t_R\ (0) = t_{co} + t_{lag}}$$

Where $\mathbf{t_{co}}$ is the time of cut-off or application time and $\mathbf{t_{lag}}$ is the recession lag time, or the time required for the water depth at the upstream end to drop to zero after cut-off.

With the minimum depth at the downstream end of the field, furthest from the water source, advance and recession curves must be computed. Estimating the appropriate inflow rate and time required to achieve t_{req} at the downstream end is more difficult.

tR(x) = tA(x) + treq

26



Advance and recession curves and definitions for design satisfying the target depth at the downstream end (x=L).

27

Example:

Estimate the time required to achieve water at downstream end of a furrow (t_{req}) if you know, the recession time $t_R(x)$ is 2 hours and $t_A(x)$ is 45 minutes.

Solution:

$t_R(x)$= 2 hours

$t_A(x)$= 45 minutes = 45/60 = 0.75 hour

$\mathbf{t_R(x) = t_A(x) + t_{req}}$

2 hr = 0.75+ t_{req}

t_{req}= 2-0.75= **1.25**hrs or 75 minutes

28

Irrigation Systems

Drip Irrigation

Lecturer: Dr Aram Ali

1

What is Drip Irrigation?

- Drip irrigation, also known as trickle irrigation or micro irrigation or localized irrigation, is an irrigation method that saves water and fertilizer by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters.

- It is done through narrow tubes that deliver water directly to the base of the plant.

2

Why should I use drip irrigation?

- Drip irrigation saves water because little is lost to runoff or evaporation.
- This watering method also promotes healthy plant growth, controls weed growth, and reduces pest problems.

3

Advantages of Drip Irrigation

- Reduced water use
- Joint management of irrigation and Fertilization
- Reduced pest problems
- Simplicity
- Low pumping needs
- Automation
- Adaptation
- Production advantages

4

Disadvantages of Drip Irrigation

- Drip irrigation requires an economic Investment (high initial cost)
- Drip irrigation requires maintenance and high-quality water
- Water-application pattern must match planting pattern
- Safety
- Leak repair
- It may not be applicable to all farms.
- Salt accumulation risks

5

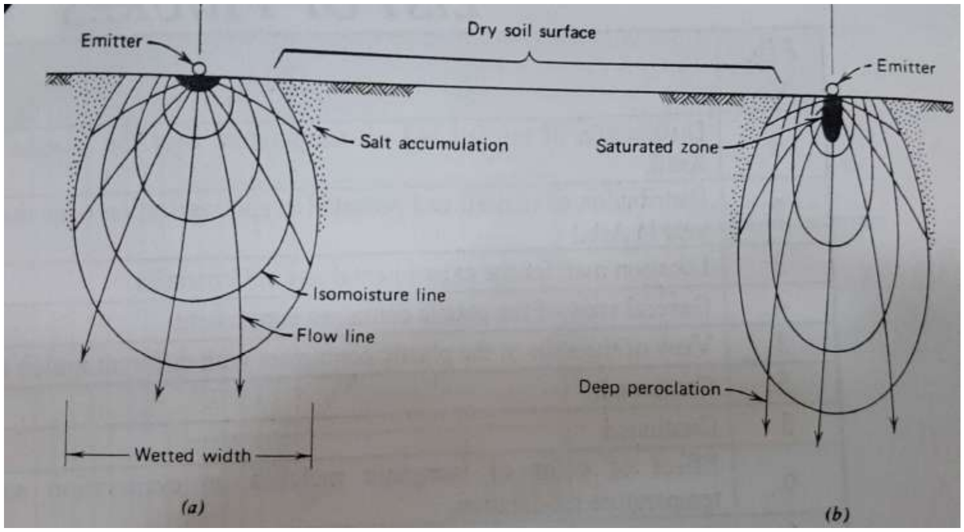
Drip irrigation is useful for crop

- **Fruit crops :**
- Banana, Grapes, Citrus, Pomegranate ,Papaya, Pineapple, Watermelon, Sweet lime, Mango etc.

- **Vegetable crops** :
- Cabbage, Cauliflower, Okra, Tomato, Potato, Onion, Chillis, Radish, Capsicum, Beans, Carrots, Cucumber etc.

- **Commercial crops** :
- Sugarcane, Cotton, Ground nut, chickpeas.

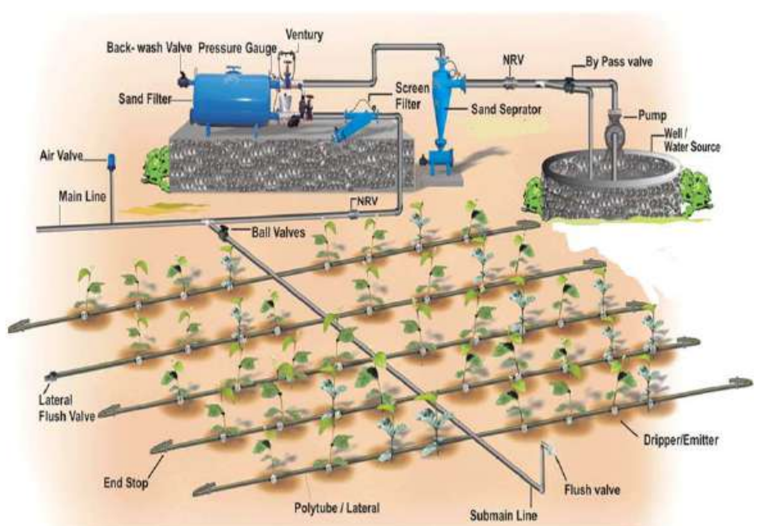
6



7

Components of Drip Irrigation:

Water reservoir
Pumping set
Filters
Mainlines
Sub-main lines
Laterals
Emitters



8

Crop water requirement

- Estimating the daily crop water requirement for localised irrigation (drip irrigation)
- **ETcrop_loc = ETc * [0.1(GC)$^{0.5}$]**
- ETc= Traditional estimated crop evapotranspiration (mm/day)
- GC= Percentage of ground cover%.

Example: The daily water requirement for cabbage is estimated to be 5.4 mm/day where 80% of the farm is covered with cabbage. Calculate crop water requirement for cabbage with drip irrigation system implemented.

Answer:

ETcrop_loc = 5.4 * [0.1(80)$^{0.5}$] = 4.83 mm/day

9

Irrigation efficiency (IE)

$$\mathbf{IE} = \frac{\textbf{Average water stored in root zone}}{\textbf{average water applied to the farm}} \times \mathbf{IU}$$

IE = Irrigation efficiency

IU = Coefficient of uniformity of application

The IU varies the emitter characteristics and recommends that the design of IU should not be less than 0.9.

10

Sprinkler Irrigation

Lecture 3

Lecturer: Dr Aram Ali

1

Sprinkler Irrigation

Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is distributed through a system of pipes usually by pumping.

It is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The pump supply system, sprinklers and operating conditions must be designed to enable a uniform application of water.

2

* Sprinkler irrigation is suited for most crops

* Sprinkler systems can have unique uses such as seeding germination, Frost protection and fertigation.

* It is approved that 50% of irrigated water is actually used by plants & the remaining water resources are wasted.

* Sprinklers irrigation system saves up to 50% compared to surface irrigation method.

* Sprinkler irrigation is the method of irrigation by which water is spread on the land surface in the form of artificial rain.

* To create the precipitation, water under pressure is ejected through the nozzle of a device called sprinkler.

* Wind speed should be considered during sprinkler spacing design to over the irrigating of water distribution by making overlapping.

* The philosophy of the sprinkler irrigation is the soil surface don't use for conveying the irrigation water, and the application rate should be less than basic infiltration rate $\mathbf{A_r \leq Infil}$

3

Factors to consider when selecting Sprinkler Systems

- **Slopes**: Sprinkler irrigation is adaptable to any farmable slope,(uniform or undulating).
- **Soils**: Sprinklers are best suited to coarse textured soils with high infiltration rates although they are adaptable to most soils.
- **Water**: Clean supply of water, free of suspended sediments/heavy metals, is required to avoid problems of sprinkler nozzle blockage and corrosion.

4

Advantages & Disadvantages of sprinkler irrigation

ADVANTAGES

- High suitability to various slopes
- Micro-climate modification
- Low labor input (comparable to surface)
- Easily automated
- High uniformity (compared to surface irrigation)

DISADVANTAGES

- High initial cost (compared to surface irrigation)
- High operation cost (e.g., due to pumping)
- Not suitable for some crops (e.g., those do not require repeated wetting of leaves or with flowers that can be dislodged)
- Canopy interception
- Wind effect is considerable
- Sometimes the pipes may obstacle the agricultural machineries.

5

Choice of Sprinkler System

- **Consider:**
- Application rate or precipitation rate
- Uniformity of Application
- Drop Size Distribution and
- Cost

6

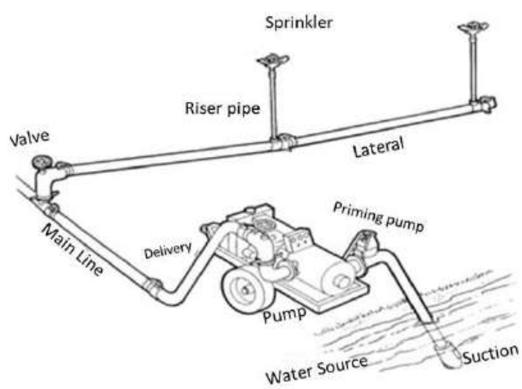
Technical aspects need to be considered for sprinkler irrigation system

- Map of the area
- Type of crops
- Soil
- Available water
- Climate
- Depth of irrigation
- Irrigation interval
- Well capacity for pumping
- Water quality

7

Components of the sprinkler irrigation system

1) Pump unit
2) Tubing - main/ sub main and laterals.
3) Couplers
4) Sprinkler head
5) Other accessories such as valves, bends, plugs and risers.



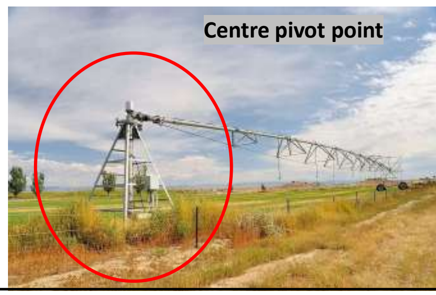
Sprinklers are usually located on pipes called laterals.

Water is discharged into the air and then infiltrates into soil (Evaporation is also possible).

8

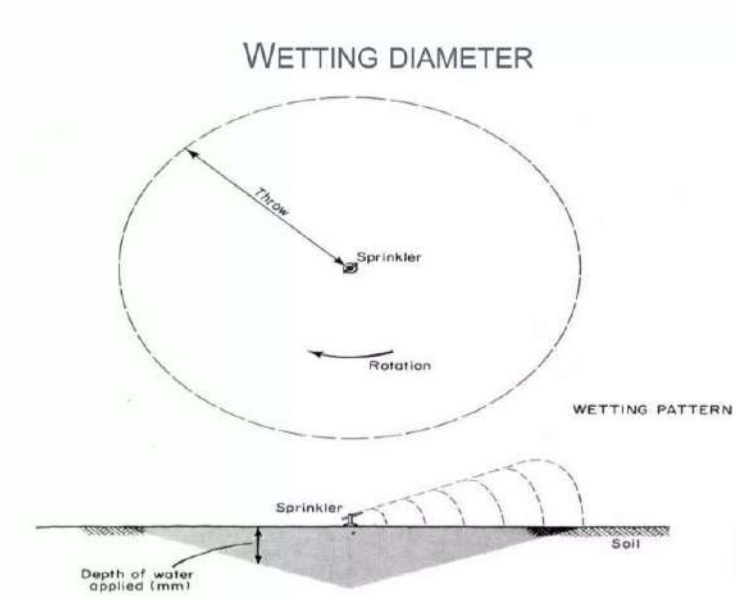
Types of Sprinkler irrigation systems for Agriculture

- Center pivot,
- Linear move,
- Traveling gun,
- Permanent set,
- Solid set



9

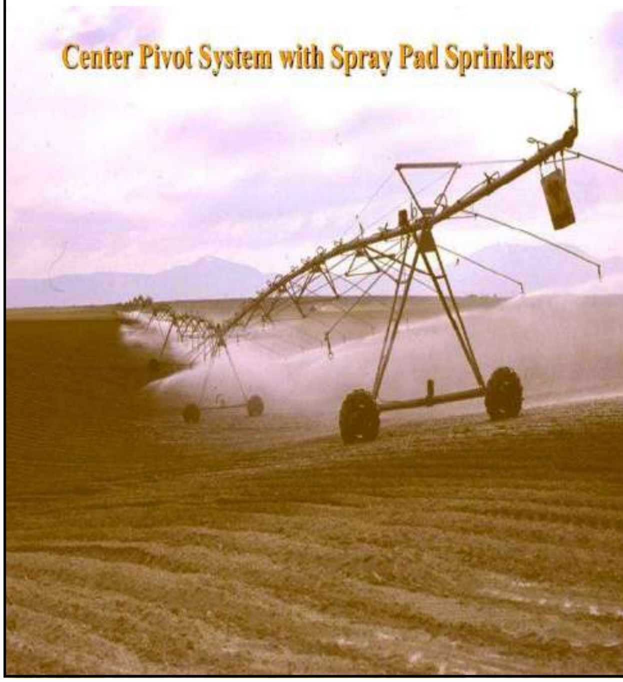
10

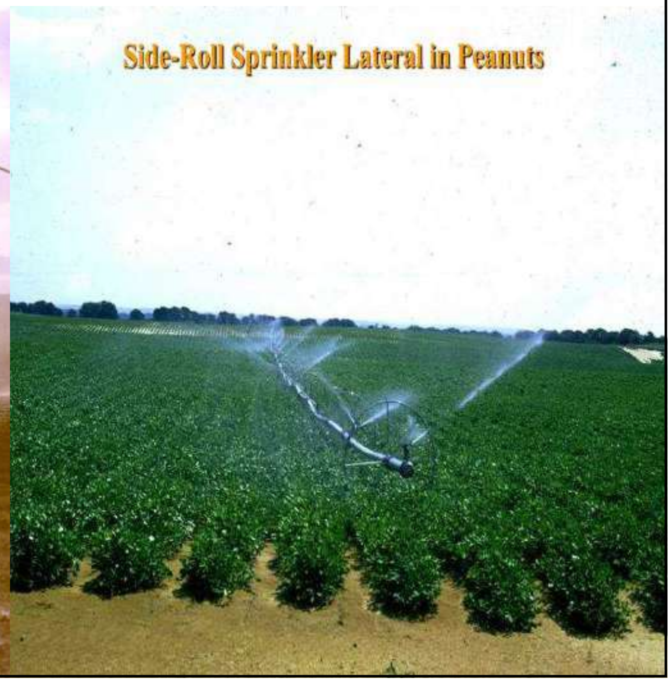

WETTING DIAMETER
Throw
Sprinkler
Rotation
WETTING PATTERN
Sprinkler
Soil
Depth of water applied (mm)

11


Portable Solid-Set Sprinkler System

12





13

Example: Assess whether the following spacing 8 X 7m under the following conditions is appropriate to apply irrigation water with 1.2 m^3/hr. Soil infiltration rate is 12 mm/hr.

Solution: A_r =(Q / Sp* Sl) 1000

=1200/56

= 21.43 mm/hr

Because Basic infiltration 12 mm/hr

Thereby $A_r > I_{nfil}$

The application rate is more than the basic infiltration rate, this sprinkler pattern is not suitable, because it will cause either runoff or ponding of water on the surface of the soil. Therefore, lower application rate (Q) needs to be performed.

14

Christiansen Uniformity Coefficient (CU)

$$CU = 100\left(1 - \frac{m}{\bar{x}}\right)$$

where **m** is the mean absolute deviation of the applied depths and x_i is given by:

$$m = \frac{\sum|x_i - \bar{x}|}{n}$$

$\bar{x}$ is the mean applied depth, and **n** is the number of depth measurements. The Christiansen coefficient was originally developed for sprinkler irrigation and remains the most widely used uniformity measure for that purpose.

15

Example:

Assume that a catch can trial, using 8 cans arranged in a grid pattern, was conducted on a sprinkler irrigation system and the following can readings (volumes from same size cans) were measured.

Can Readings (ml): 8, 13, 11, 9, 6.8, 9, 4.5 and 10.

Calculate **Christiansen Uniformity Coefficient (CU).**

Answer:

$$m = \frac{\sum|8-8.91|+|13-8.91|+|11-8.91|\ldots\ldots}{8} = 1.86$$

$$CU = 100\left(1 - \frac{1.86}{8.91}\right) = \mathbf{79.14\%}$$

16

Irrigation Systems

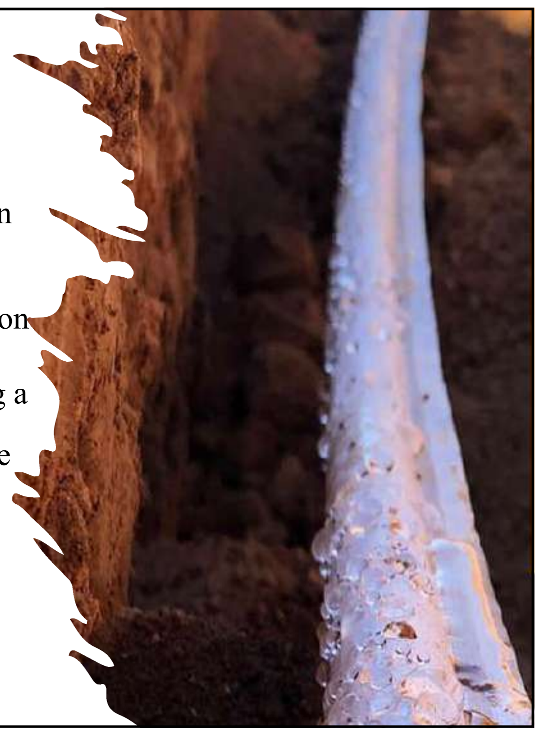
Lecture 4- Responsive Drip Irrigation (RDI)

Lecturer: Dr Aram Ali

1

Responsive Drip Irrigation (RDI)

- RDI is an only plant- responsive water and nutrient delivery, and the smartest most water efficient irrigation system.
- The system is based on organic chemistry, interacting directly with plants roots to deliver water and nutrients on demand.
- The system operates at constant low pressure, providing a reservoir that plants can access when needed, by means water and nutrients delivery fluctuates in response to the plant.
- All plants emit root signals to uptake moisture and nutrients from the surrounding soil.
- The pipe has a smooth interior surface that has been infused with **hydrophilic polymer** creates a chemical bond to keep water molecules inside the tube.

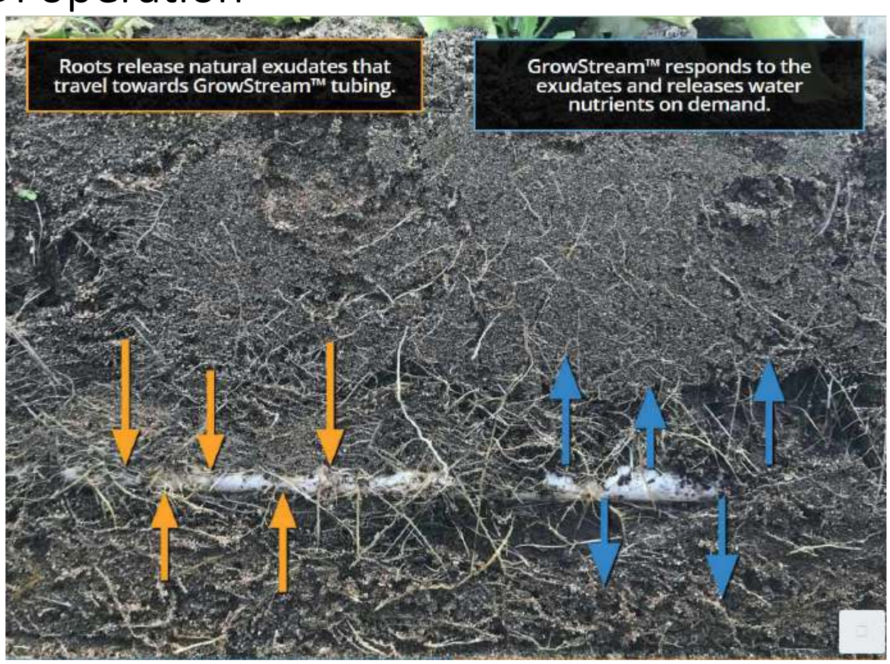


2

- Microspores in the tube will enable the movement of water molecules and water-soluble fertilizer/nutrients if there is a force from the outside (plant roots) to release it.
- When natural chemical exudates are released from the plant roots, their affinity for water breaks the molecular bond of the water from the hydrophilic polymer and triggers the flow of water from the inside of the tube.
- Plant variety, stages of growth, development, and weather conditions contribute to how much water and nutrients each plant root demands.
- RDI acts like an underground reservoir

3

Processes of RDI operation



4

5

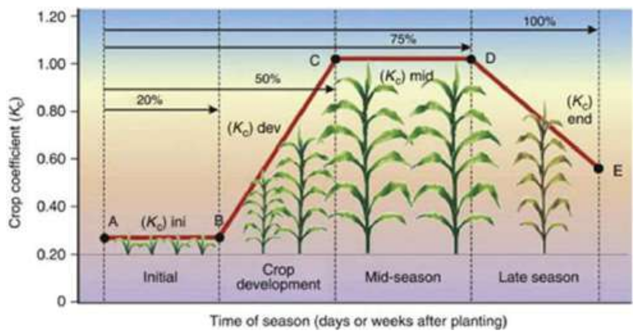
Advantages of RDI

- The system dose not need controller, valves, and sensors.
- Saves 30-50% of water compared to standard drip irrigation
- Reduces 40-90% of energy requirement
- The system needs a very low pressure 2psi (~0.14 bar).
- Low cost and the system lasts around 8 years
- No evaporation, no runoff and no percolation.
- Perfect irrigation allows plants to grow to their maximum potential.
- The grow stream runs automatically 24, 7 (24 hours and 7 days a week).

6

Irrigation Systems

Lecture 5- Crop water requirement



Lecturer: Dr Aram Ali

1

Evapotranspiration

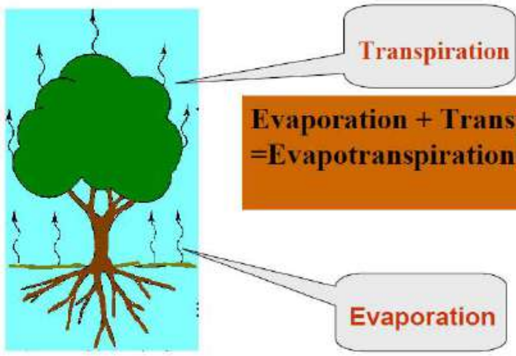
Concepts

Crop evapotranspiration under **standard conditions** (ETc) is the evapotranspiration from excellently managed, large, well-watered fields that achieve full production under the given climatic conditions.

crop evapotranspiration under **non-standard conditions** (ETc adj) is the evapotranspiration from crops grown under management and environmental conditions that differ from the standard conditions

2

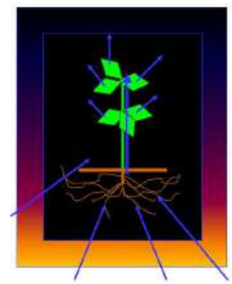
Evaporation and transpiration occur simultaneously



Evaporation + Transpiration =Evapotranspiration(ET)

Evaporation

refers to the movement of water from the soil surface or water surface in field into the atmosphere



Transpiration

refers to the movement of water from the soil into a plant, up the plant body, and out the plant's leaves into the atmosphere.

3

Factors affecting evapotranspiration

Theoretical research and experimental studies have proven that there are several factors affecting the amount of evapotranspiration. The principal factors are :

Factors affecting evapotranspiration:
- Weather parameters
- Crop factors
- Management and environmental conditions

4

Determining evapotranspiration (ET)

Methods for determing ET can be divided into three categories

1. Experimental measurement

2. Method on the basis of reference crop evapotranspiration

3. Method for direct calculations

5

Computing crop evapotranspiration

Computing crop evapotranspiration（ETc）under under standard or nonstandard conditions

standard conditions :

$$\mathbf{ETc} = kc \times ETo$$

Non-standard conditions :

$$\mathbf{ETc\ adj} = ks \times kc \times ETo$$

where,

ks water stress coefficient

kc crop coefficients

6

How to compute evapotranspiration

- ETo can be computed from meteorological data. As a result of an Expert Consultation held in May 1990, **the FAO Penman-Monteith** method is now recommended as the sole standard method for the definition and computation of the reference evapotranspiration. The FAO Penman-Monteith method requires radiation, air temperature, air humidity and wind speed data.
- ETo can also be estimated from **pan evaporation**. Pans have the proven practical value and have been used successfully to estimate ETo by observing the water loss from the pan and using empirical coefficients to relate pan evaporation to ETo. However, special precautions and management must be applied.

7

FAO Penman-Monteith

- From the original Penman-Monteith equation and the equations of the aerodynamic and canopy resistance, the FAO Penman-Monteith equation is:
-

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

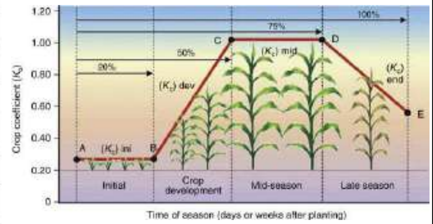
- where
- ETo reference evapotranspiration [mm day-1],
- Rn net radiation at the crop surface [MJ m-2day-1],
- G soil heat flux density [MJ m-2 day-1],
- T air temperature at 2 m height [° C],
- u2 wind speed at 2 m height [m s-1],
- es saturation vapour pressure [kPa],
- ea actual vapour pressure [kPa],
- es - ea saturation vapour pressure deficit [kPa],
- Δ slope vapour pressure curve [kPa ° C-1],
- γ psychrometric constant [kPa ° C-1].

8

Crop factor, Kc

Values of the crop factor (Kc) for various crops and growth stages

Crop	Initial stage	Crop dev. stage	Mid-season stage	Late season stage
Barley/Oats/Wheat	0.35	0.75	1.15	0.45
Bean, green	0.35	0.70	1.10	0.90
Bean, dry	0.35	0.70	1.10	0.30
Cabbage/Carrot	0.45	0.75	1.05	0.90
Cotton/Flax	0.45	0.75	1.15	0.75
Cucumber/Squash	0.45	0.70	0.90	0.75
Eggplant/Tomato	0.45	0.75	1.15	0.80
Grain/small	0.35	0.75	1.10	0.65
Lentil/Pulses	0.45	0.75	1.10	0.50
Lettuce/Spinach	0.45	0.60	1.00	0.90
Maize, sweet	0.40	0.80	1.15	1.00



9

Using evaporation pan

ETc = kc × ETo

Using Blaney-Criddle Equation

$$ET_o = p\,(0.46T_{mean} + 8)$$

ETo crop evapotranspiration (mm/day),
p mean daily percentage of annual daytime hours
Tmean mean daily temperature (°C)

10

CALCULATION

- Calculating the crop water need on a monthly basis

$$\mathbf{ETcrop = ETo \times Kc\ \ (mm/day)}$$

February: ET crop = 5.0 × 0.45 = 2.3 mm/day

March: ET crop = 5.8 × 0.70 = 4.1 mm/day

April: ET crop = 6.3 × 0.95 = 6.0 mm/day

May: ET crop = 6.8 × 1.15 = 7.8 mm/day

June: ET crop = 7.1 × 0.85 = 6.0 mm/day

11

Calculate the monthly and seasonal crop water needs.

Note: all months are assumed to have 30 days

February ET crop = 30 × 2.3 = 69 mm/month

March ET crop = 30 × 4.1 = 123 mm/month

April ET crop = 30 × 6.0 = 180 mm/month

May ET crop = 30 × 7.8 = 234 mm/month

June ET crop = 30 × 6.0 = 180 mm/month

The crop water need for the whole growing season of tomatoes is <u>786</u> mm

12

Calculation Example Blaney-Criddle

Given

Mean Tmax in April = 29.5°C

Mean Tmin in April = 19.4°C

Mean daily percentage of annual daytime hours (**p**) = 0.29

Question

Determine for the month April the mean ETo in mm/day using the Blaney-Criddle method

Answer

Formula: **ETo = p (0.46 T mean + 8)**

Step 1: determine **T mean**:

$$Tmean = \frac{Tmax+Tmin}{2} = \frac{29.5+19.4}{2} = 24.5^{o}C$$

Step 2: determine **p**:

p = 0.29

Step 3: calculate ETo:

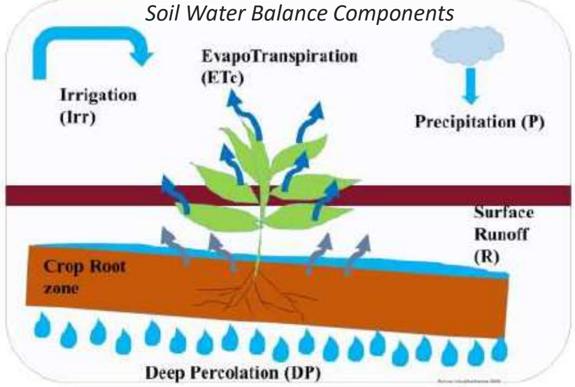
ETo = 0.29 (0.46 × 24.5 + 8) = **5.6 mm/day**

13

Irrigation Systems

Lecture 6- Irrigation Scheduling

Soil Water Balance Components



Lecturer: Dr Aram Ali

1

Irrigation Scheduling

- Irrigation scheduling is defined as frequency with which water is to be applied based on needs of the crop and nature of the soil.

- Irrigation scheduling is nothing but number of irrigations and their frequency required to meet the crop water requirement.
- Process of maintaining an optimum water balance in the soil profile for crop growth and production

Irrigation scheduling may be defined as **scientific management techniques of allocating irrigation water based on the individual crop water requirement (ETc) under different soil and climatic condition, with an aim to achieve maximum crop production per unit of water applied over a unit area in unit time**.

2

Advantages of Irrigation Scheduling

- It enables the farmer to schedule water rotation among the various fields to minimise crop waster stress and maximum yield.
- It reduces the farmer's cost of water and labour
- It lowers fertilizer costs by holding surface runoff
- It increases net returns by increasing crop yields and crop quality
- It minimises water logging problems
- It assists in controlling root zone salinity problems
- It results in additional returns by using the "Saved" water to irrigate non-cash crops

3

Practical considerations in irrigation scheduling

- Crop factors
- Water delivery system
- Types of soil
- Salinity hazard
- Irrigation methods
- Irrigation interval
- Minimum spreadable depth

4

Effect of application of right amount and excess amount of water

Excess irrigation is harmful because

- It wastes water below root zone.
- It results in loss of fertilizer nutrients.
- It causes water stagnation and salinity.
- It causes poor aeration.
- Ultimately it damages the crops.

However, Irrigation scheduling has its own meaning and importance according to the nature of the work.

5

Scheduling Methods

Ask the Past

- Methods here include:

❑ Traditional, irrigating at certain crop stages or times because this is the way it has been done in the past; and

❑ Rigid, irrigating on a fixed cycle usually as a result of some external constraint such as a rotational irrigation supply system.

Ask the Crop

❑ Visual assessment – growth rate, curl in leaves and wilting of plant parts;

❑ Measurement of stomatal or leaf water potential (pressure bomb);

❑ Measurement of crop canopy temperature (infra-red thermometer); and

❑ Measurement of stem sap flow.

All of these methods measure the plant response to stress and as a result occur too late for effective scheduling of irrigations.

6

Ask the Soil

- ❑ Visual assessment of soil condition;
- ❑ Measurement of soil moisture content by gravimetric sampling;
- ❑ Measurement of soil matric potential(tensiometers); and
- ❑ Inference (indirect measurement) of soil moisture content by measurement of various Electrical or other properties of the soil – neutron scattering, time domain reflectometry, capacitance.

All of these methods, with the exception of the first, allow the soil moisture content to be charted with time. As well as telling when to irrigate these methods allow forward prediction of when the next irrigation will be required. They are also the only methods that give an accurate indication of how much water need be applied.

Ask the Atmosphere

This method involves the use of estimates of evaporation to estimate the crop water use.

Soil moisture status is inferred. It has many of the same advantages as scheduling by soil moisture measurement but is arguably less accurate.

7

Irrigation Scheduling -- Primary Factors

- Know available soil water for each unit depth of soil
- Know depth of rooting for each crop
- Know allowable soil moisture depletion at each stage of plant growth
- Use evapotranspiration data to estimate crop water use
- Measure rainfall in each field
- Know water retention and Plant available water capacity (volume) used for crops

8

Available Soil Water

- Soil absorbs and holds water in much the same way as a sponge.
- A given texture and volume of soil will hold a given amount of moisture.
- The intake rate of the soil will influence the rate at which water can be applied.
- The ability of soil to hold moisture, and amount of moisture it can hold, will greatly affect the irrigation operational schedule

9

Soil Moisture

- **Hygroscopic water** is moisture that is held too tightly in the soil to be used by plants.
- **Capillary water** is moisture that is held in the pore spaces of the soil and can be used by plants.
- **Gravitational water** drains rapidly from the soil and is not readily available to be used by plants.

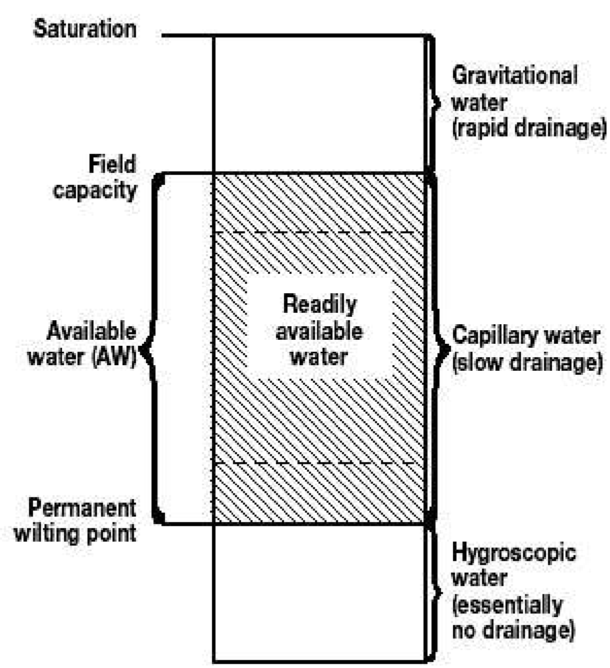
10

Soil moisture

- The **permanent wilting point** represents the boundary between capillary water and hygroscopic water.
- Because hygroscopic water is not usable by plants, continuous soil moisture levels below the permanent wilting point will result in damage to or death of the plants.
- **Field capacity** represents the boundary between gravitational water and capillary water. It is the upper limit for soil moisture that is usable by plants.

11

Soil, Water, Plant relationship

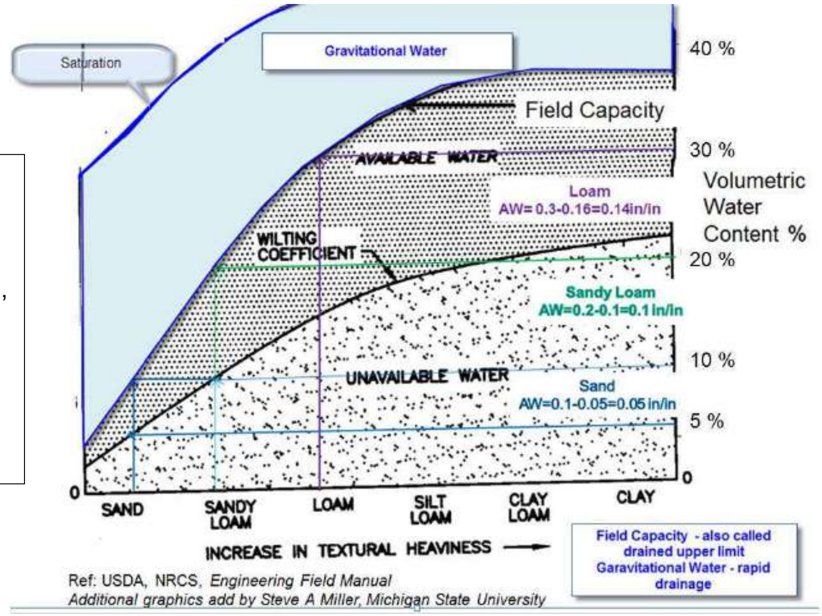


12

1) Note that wilting coefficient increases as texture becomes finer.

2) Field capacity θ_v increases as texture becomes finer until silt loams, then levels off.

3) Greatest plant-available H_2O capacity (PAWC) occurs with medium- rather than fine-textured soils.



13

Example: Irrigation Scheduling

Calculate the amount of water required to maintain optimum soil moisture in the root zone considering soil moisture characteristics. **Permanent wilting point= 25mm, Field capacity = 38mm, and the refill point = 35mm**. (*SW2=SW1-ETc+Rainfall+Irrigation*)

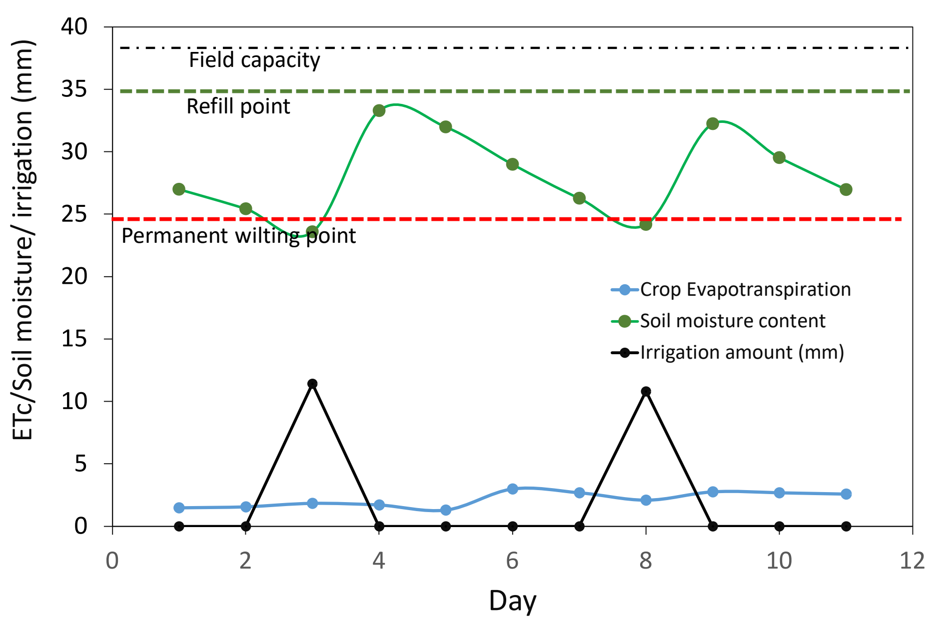
Days	Evaporation (mm/day)	Crop factor (Kc)	ETc (mm/day)	Soil moisture	Irrigate?	Rainfall (mm)	Applied water in (mm)
1	3.3	0.45	1.485	27	0	0	0
2	3.5	0.45				0	
3	4.1	0.45				0	
4	3.8	0.45				0	
5	2.9	0.45				0	
6	5	0.6				0	
7	4.5	0.6				0	
8	3.5	0.6				0	
9	4.6	0.6				0	
10	4.5	0.6				0	
11	4.3	0.6				0	

14

Calculations: Irrigation scheduling

Days	Evaporation (mm/day)	Crop factor (Kc)	ETc (mm/day)	Soil moisture	Irrigate?	Rainfall (mm)	Applied water in (mm)
1	3.3	0.45	1.485	27	0	0	0
2	3.5	0.45	1.575	25.425	0	0	0
3	4.1	0.45	1.845	23.58	***Irrigate***	0	11.42
4	3.8	0.45	1.71	33.29	0	0	0
5	2.9	0.45	1.305	31.985	0	0	0
6	5	0.6	3	28.985	0	0	0
7	4.5	0.6	2.7	26.285	0	0	0
8	3.5	0.6	2.1	24.185	***Irrigate***	0	10.815
9	4.6	0.6	2.76	32.24	0	0	0
10	4.5	0.6	2.7	29.54	0	0	0
11	4.3	0.6	2.58	26.96	0	0	0

15



16