

<b>COURSE CODE:</b>	WMA 403
<b>COURSE TITLE:</b>	Principles of Irrigation
<b>NUMBER OF UNITS:</b>	3 Units
<b>COURSE DURATION:</b>	Three hours per week

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### COURSE DETAILS:

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<b>Office Location:</b>	COLERM
<b>Other Lecturers:</b>	Dr. Awomeso

### COURSE CONTENT:

Soil : Types of soil.

Soil moisture, field capacity, wilting coefficient, available water.

Water requirements of crop

Consumptive use of water

Estimation of evapo-transpiration

Blaney Criddle

Penman method

Irrigation efficiencies

Effective rainfall

Net irrigation requirements

Gross irrigation requirements

Water requirements of major crops

Quality and classification of irrigation water

Problem of drainage

### COURSE REQUIREMENTS:

. This is a compulsory course for all students of Agriculture and the department of water resources management and Agrometeorology in the

University. In view of this, students are expected to participate in all course activities and have minimum of 75% attendance to be able to write the final examination.

## READING LIST:

1. Ayoade, J.O. Tropical hydrology and water resources
2. Duru, L .1984. Climate, Water and Agriculture in the tropics. Longman publishers. London, UK
3. Gordon, W.1981. Tropical Agriculture the Development of Production, 4th edn., Longmans, London, UK.
4. Shaw, M. 1994. Hydrology in practice. Van Nostrand Reinhold. Berkshire, UK.
5. Yayock, J.Y., Lombin, G., Owonubi, J.J. 1988. Crop science and production in warm climates. MacMillan publishers. London USA

## LECTURE NOTES

### SOIL

Soil is thin fragment formed from weathering of rock which is found on the uppermost layer of the earth's crust on which plant grow.

### **Components of soil**

- (1) **In-organic matter (mineral)** – solid part-silt, sand, clay.

This is the mineral matter represents small rock fragment of the soil, it is about 45% of the total volume of the soil.

It consist of gravel, storms, sand silt and clay

### **Importance**

- 1) It forms the solid part of the soil which provides support for plant
- 2) Mineral matter is the main source of plant nutrient such as Nitrogen, calcium, mg, fe etc.
- 3) It represents the home or habitat of all soil living organism
- 4) It holds water and air for both plant and animal activities

- 5) Mineral matter gas moderating effect on soil temperature and porosity

## **(2) Organic Matter**

The organic matter represents the remains of the decomposition of plants and animals. It is about 5% of the total volume of the soil e.g. roots of plant, residue of crop, decay animal. When they are decay to form a dark colour on the upper part of the soil. They mix with the soil to form hummus

### **Importance**

- (1) very rich in plant nutrients
- (2) habitat of many soil micro-organism
- (3) prevent leaching in the soil
- (4) prevent soil erosion and evaporation of soil water
- (5) allows for good drainage and holds water in the soil for plant use
- (6) it increases water holding capacity of the soil

## **(3) Soil Water**

Soil water refers to the water in the soil which is usually obtained either from rain or irrigation. Water is 25% of the total volume of the soil when water is too much in a soil it becomes water logged water logging can be corrected by drainage.

### **Importance**

- (1) Agent of weathering of rock
- (2) Dissolve of plant nutrient into solution
- (3) Essential raw materials for photosynthesis
- (4) Loss of water from plant through transpiration helps in cooling of plant.
- (5) Aids easy tillage of the soil

- (6) Promotes the activities of soil organism
- (7) It is needed for the germination of seeds
- (8) It provides the medium for soil reaction
- (9) Needed for seed germination
- (10) It aid turgidity of cells

#### **(4) Soil Air**

Refers to the gases present in the soil pores found between the soil patches. The amount of soil air varies depending on the amount of soil water, size of pore spaces, type of soil and the amount of living organisms in the soil. It is about 25% of the total volume

##### **Importance**

- (1) Necessary for growth and development of plants (oxygen).
- (2) It promotes easy germination of seeds
- (3) Means of reproduction of soil organisms
- (4) Excess of CO<sub>2</sub> in the soil, when combined with water can cause acidity and aid weathering of rock
- (5) It is needed in soil reactions, particularly carbon and nitrogen cycles

#### **(5) Living organism**

This refers to plants and animals which inhabit the soil. They vary from microscopic organism to bigger organisms. Some are harmful to crops and livestock e..g. bacteria, fungi, virus, millipede, centipede, earthworm.

## **Importance**

- (1) help improve aeration of the soil
- (2) help decompose organic materials in the soil to form hums
- (3) aid percolation of water
- (4) improve soil structure
- (5) some organism like bacteria help to fix nutrients in the soil.
- (6) Some are pests and parasites that causes diseases to crops

## **CLASSIFICATION OF SOIL**

### **A) According to age of formation**

- 1) Youthful: youthful soil is fully pervious
- 2) Mature has low permeability
- 3) Senile has little or no productively

### **B) According to geological process of formation**

- 1) Residual soils: They are formed by disintegration of rocks under various action of weathering
- 2) Alluvial soil: by deposition of water borne agents
- 3) Eolian soil: by deposition by wind action.
- 4) Colluvial soil: formed by deposition by rain wash below foot hills
- 5) Volcanic ash: ash deports due to volcanic eruption.
- 6) Glacial soil: formed by transportation and deposition by glaciers.
- 7) Soils of aggradations:- accumulating soils
- 8) Soils of degradation: the soils that are continuously zooming out
- 9) Pan, clay pan: they are impervious hard layers formed due to compaction of  $\text{CaCO}_3$ ,  $\text{Fe}_2\text{O}_3$ , silica etc.

### C) Classification according to salt content

- 1) Ped – O- cal: soil rich in calcium
- 2) Ped-al-fer: soil rich in aluminum or iron salts.
- 3) Hums: soil rich in organic salt

### D) Classification According to particle size

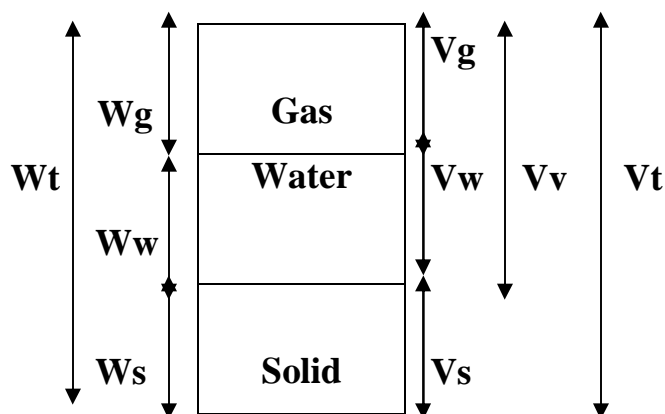
A composition soil can be classified on the basis of particle sizes, depending upon the % of sand, salt and clay contents.

### Mechanical properties of Soil

From the forgone you will recall that the soil under natural condition consist of three major types of materials as follows:

- Gas
- Liquid
- Solid

### Types of Materials



The percentage of this ingredient will be different under different condition and the degree of compaction. This we can determine by finding the density of each.

$$\text{Density} = \frac{\text{weight}}{\text{Volume}}$$

Hence

(1) Particle Density refers to the dry soil density only. It is the weight of soil solid per unit volume of solid excluding gas and water. It is termed true or real density

$$\text{density of soil } (\gamma_s) = \frac{W_s}{V_s} = \frac{\text{Kg}}{\text{m}^3} \text{ or } \text{g/cm}^3$$

where  $W_s$  = weight of dry soil  
 $V_s$  = volume of dry soil  
 $\gamma_s$  = particle density

also for water

$$\text{Density of water } \gamma_w = \frac{W_w}{V_w}$$

$$\text{and Density of gas } \gamma_g = \frac{W_g}{V_g} = 0$$

also recall

$$(2) \text{ Specific density (Gs)} = \frac{\gamma_s}{\gamma_w} = \frac{\text{density of solid}}{\text{density of water}}$$

$$\begin{aligned} G_s &= \frac{\gamma_s}{\gamma_w} = \frac{W_s}{V_s} \bigg/ \frac{W_w}{V_w} \\ &= \frac{W_s}{V_s} \times \frac{V_w}{W_w} \end{aligned}$$

No unit

### (3) Void Ratio

Soils can exist in loose or dense state depending on the amount of space or void which are usually filled partially or totally with liquid. (This space are formed as pores, void or capillary). We must also find a way of expressing the loose or denseness of a particular soil. This we can achieve by the expression called void Ratio.

Void- Ratio is expressed as the ratio of volume of void in a soil to the volume of solid soil.

This is expressed mathematically as

$$\text{Void Ratio (e)} = \frac{V_v}{V_s} \times 100 \%$$

(no unit)

### **Soil Moisture**

Water present in the soil can be classified into 3 categories.

- (1) Hygroscopic water: when an oven dried sample is kept open in the atmosphere it absorbs some amount of water from the atmosphere. This is known as hygroscopic water, it is not capable of being moved by force of gravity or capillary forces, it is not available for plant use.
- (2) Capillary water: The water available in excess of hygroscopic water which exists in pores or spaces of the soil by molecular attraction. (it is available to plant)
- (3) Gravitational water: That part in excess of hygroscopic and capillary water which will move out of the soil if favorable drainage is provided.



## **Soil Moisture Content**

It is important to know as much water a soil contains and this is determined by the ratio of weight of water in a particular volume of soil to the weight of soil solid in same volume it is expressed as

### Dry Weight

$$\text{Water content, } W = \frac{W_w}{W_s} \times 100$$

$$W = \frac{W_t - W_w}{W_s} \times 100$$

Wet Weight = moisture content percentage by volume

W = bulk density x moisture content by weight

= cm/m depth of soil

## **Gravimetric method of soil moisture measurement**

### Steps

- (1) collect soil sample using auger
- (2) weigh the soil and oven dry in oven at 105°C for about 24 hours until moisture is driven off
- (3) remove from oven, cool slowly to room temperature
- (4) weigh again

## **Soil Moisture Range**

- (1) Saturation capacity

This is called maximum moisture holding capacity or total capacity. It is the amount of water required to fill all pores spaces between soil

particles by replacing all air held in pore spaces. It is the upper limit of possible moisture content.

(2) Field Capacity (FC)

This is the moisture content of the soil after free drainage has removed most of the gravity water. The concept of field capacity is very useful in arriving at the amount of water available in the soil for plant use.

(3) Permanent wilting point (PWP)

Wilting coefficient is that water content at which plants can no longer extract sufficient water from the soil for its growth. This is at the lower end of available moisture range.

(4) Available Moisture

The difference in water content of soil between field capacity and PWP is known as Available Moisture.

## **Methods of Irrigation**

### **Definitions**

Irrigation is an artificial application of water for growing crops in a period when rainfall is non-uniform or ill-distribution of rainfall in space or in time (spatially or temporally).

### **Uses of Irrigation**

- 1) It adds water to soil to supply moisture needed for the growth of crops
- 2) It saves crops drying for short duration drought.
- 3) It cools atmosphere making the environment favorable for growth of crops
- 4) It washes and dilute salts in soils
- 5) It reduces the hazard of soil piping
- 6) It is soften tillage pan

- 7) It serves as a solvent for nutrients and aids its transportation in plant

### **Scope of Irrigation**

Irrigation is divided into two aspects

- (i) Engineering Aspects
- (ii) Agricultural aspects

### **Engineering Aspects**

- (1) Design, construction and maintenance of Dam, reservoir and hole forcing
- (2) Construction of convergence structures : by a network of canals and control structure like gates, regulators, flumes or weirs etc.
- (3) Application of water to Agricultural field by different methods of irrigation
- (4) Drainage: Design of network of drainage canal to prevent waterlogging

### **Agricultural Aspect**

- (1) Determination of the depth of water in each application e.g. say you apply water every 10 days i.e. 3 times per month for 1200mm total depth within 10 days interval of application for a crop of 100 days maturity period, then each application will amount to:

$$\frac{1200}{10} = 120\text{mm/application}$$

- 2) Distribution of water uniformly and periodically
- 3) Soil science: capability of soil to hold irrigation water e.g. clay is least permeable than sandy loam, clayey loam and as such retain water without appreciable loss.

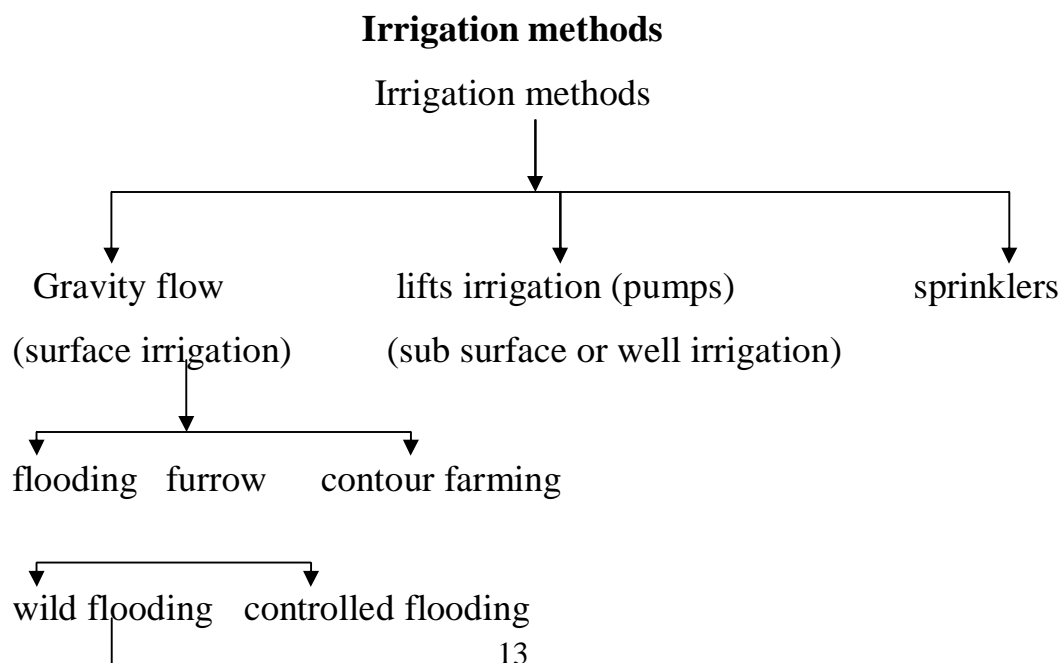
- 4) Reclamation of waste and alkaline soil-All large irrigator projects are multipurpose water development project e.g. irrigation, Hydropower and water supply
- 5) Flood control
- 6) Soil conservation – prevention of erosion by vegetation, contour farming, gully control
- 7) Irrigation canals also provides water for fishing and wild life development e.g. duck, fowl etc.

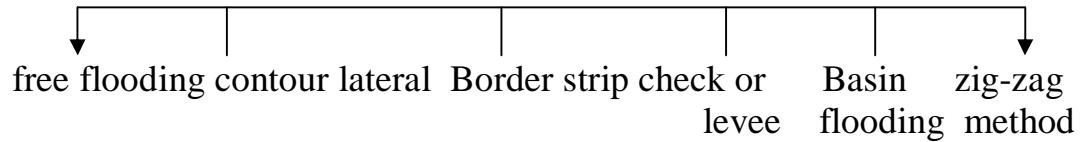
### **Benefit of Irrigation**

- 1) Increases food production
- 2) Protection from drought
- 3) Cultivation of cash crops e.g. sugarcane, cotton, groundnut, tobacco.
- 4) Addition to wealth of the Nation by revenue increase, saves foreign exchange from importation of food crops
- 5) Add prosperity to people's life
- 6) Hydropower generation:- multipurpose irrigation project is also used for hydro-power generation,
- 7) Water supply scheme:- multi-purpose project
- 8) Navigation:- multipurpose irrigation project also used for Navigation (inland) and also helps in transportation of Agricultural products to market and it also aid communication
- 9) Canal plantation:- Trees can be planted in wet vicinity of the canal thereby cool environment prevails and aids Animals grazing
- 10) Improvement of ground water storage:- with seepage from irrigation canals, reservoirs etc. into ground water source thereby recharging it.
- 11) Aids tourisms in an area
- 12) It helps in employment

## ILL Effects of Irrigation

- 1) Construction of dams has led to the displacement of people from their original homes and lands. The consequence is high cost resettlement.
- 2) Fluctuation in the volume of water in rivers also resulting in low yield of crops
- 3) Irrigation equipments is expensive to purchase and maintain
- 4) Silting of dams thereby reducing flow
- 5) Health hazards e.g. breeding of mosquitoes, green bushes around reservoir area breads tse-tse fly which cause sleeping sickness, river blindness etc.
- 6) Disasters as a result of flooding
- 7) Water logging and salinity
- 8) Damp climate
- 9) Environmental effects





## Flooding

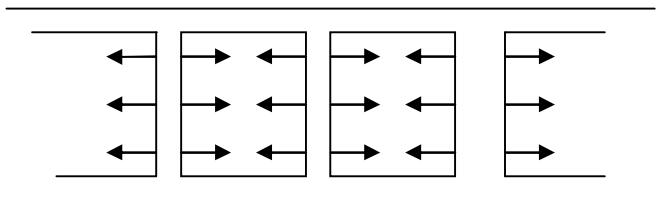
### Flooding

When you have plenty of water flood the field, saturate the soil and do plantation. It is wasteful method.

This is divided into two types:-

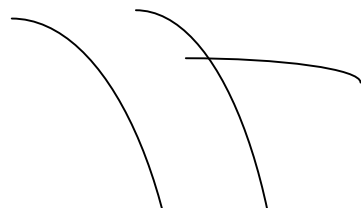
- (i) wild flooding – flood land in uncontrolled manner, saturates soil and do plantation
- (ii) control flooding:- water flows is controlled by a network of structure like canal, gates, regulator, slices etc.

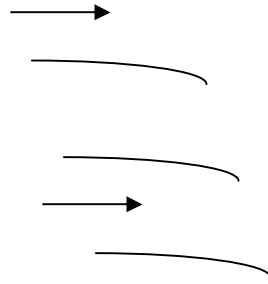
### Free flooding



Generally, plots are oblong or rectangular not square. Water flows into the field through ditch or sub-lateral.

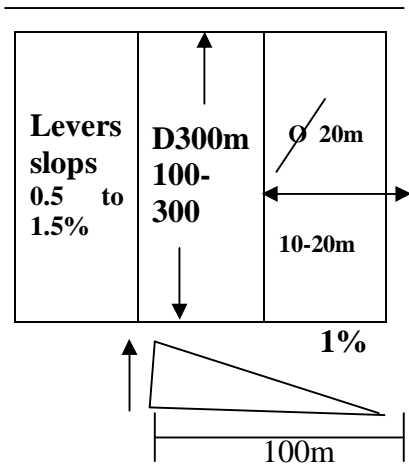
### Contour lateral





This method is applicable in steeper slope size, the field is cut by a dense network or small contour laterals. The spacing of which depends on the slopes of the hill and soil types

### Border strips

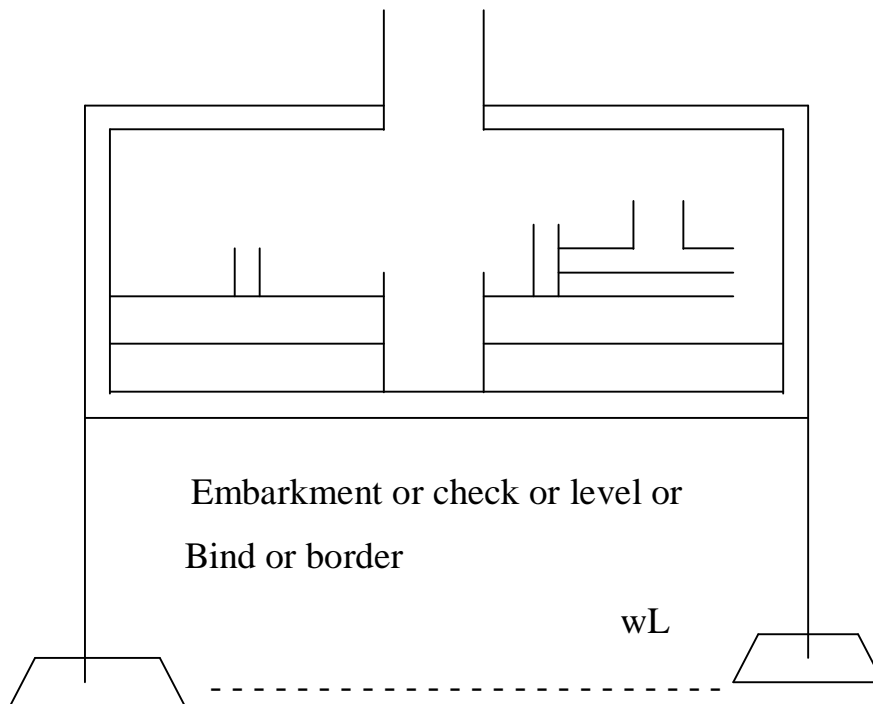


In this method the field is divided into series of strips 10 to 20m wide and 100-300m long. The strips are separated by low embankment or bonds and run down slope. Discharge 0.014 to 0.028 Cumecs: This method can be best with  $0.014\text{m}^3/\text{s} = 0.14 \times 1000\text{L}/\text{s}$  adopted for leveled land.

### Check flooding

Is a comparatively large canal supplies water to an area which is enclosed by embankment /levees/checks/border,

The levees are 2-3m wide and 25-30cm high. Low height permit tractors and other Agricultural machines to cross the level easily. This method is suitable for leveled land (as against slopping hilly land)



### Basin flooding

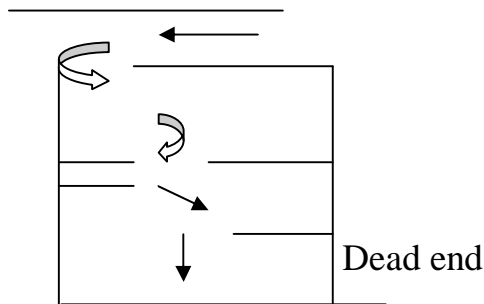
A particular method of check flooding suitable for irrigation of tree crop such as citrus- Orange, Lemon, Cocoa, Coffee. This method are formed for



one large tree (individual trees) or a group of trees e.g orchard (piece of ground usually enclosed with fruit trees). Water is supplied to basin through ditches (narrow channels)

### **Zig-Zag**

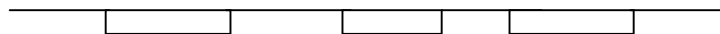
It is a special method of flooding where water takes a circulation or zig-zag path until it comes the dead end of the field.



### **Furrow Irrigation**

These are use for row crops, maize, sugarcane, cotton, tobacco, potatoes, groundnuts etc. not the whole of land is wet but only half of the land gets wet, evaporation loss is reduced. Furrows are deep and narrow channel of vertical side. A furrow is 3m long for garden but up to 500m long for field crops. Generally 100-200m length is preferred. Slope is usually 0.2 to 5%. Depth of furrow is up to 30cm when soil is impermeable (clay). In ordinary soil of 20-25cm depth is okay and 8-10cm wide.

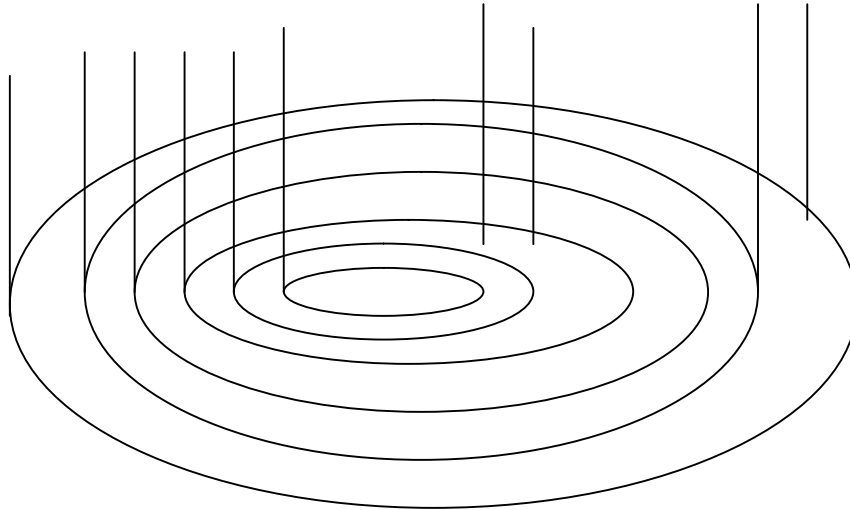
### **Corrugations**



Are small channelets or small furrows used extensively for pasture forage crop e.g. Alfa – Alfa, vegetation etc.

## Contour farming

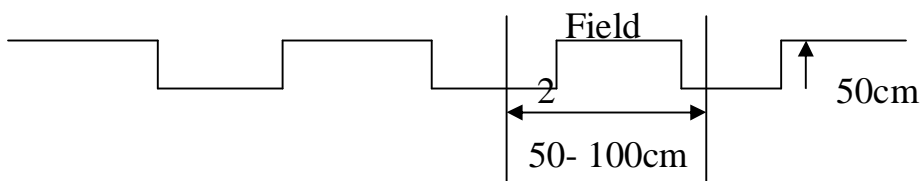
Contour farming is practical in hilly areas having steep slopes. Farming is done along the contour but not across the hill. Irrigation water is stored at upper end and supplied to the field



Contours are lines of equal slope.

## Subsurface Irrigation

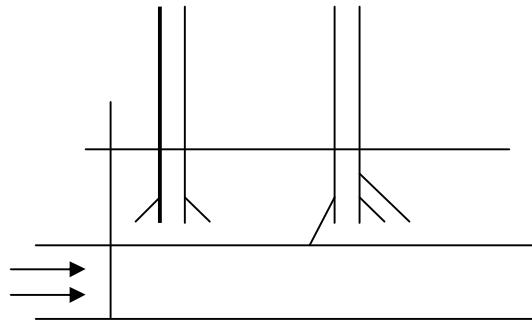
Ground water:- Water below ground level. Irrigation at root zone. Water is supplied to a series of ditches  $\frac{1}{2}$  -1m deep and 25-50cm wide having vertical sizes.



Water seeps and plants draw water by root. Supply of water maintains high water table. Water is supplied by the following to the field in subsurface irrigation.

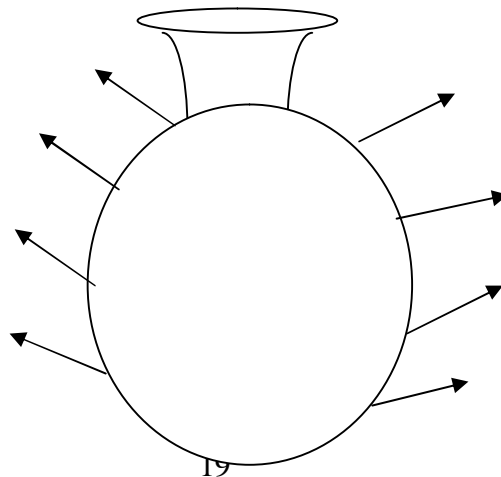
- (1) Canals

- (2) Drips – perforated pipes laid in the field below the soil to saturate the land and keep the water table high so that plan can draw water by its roots

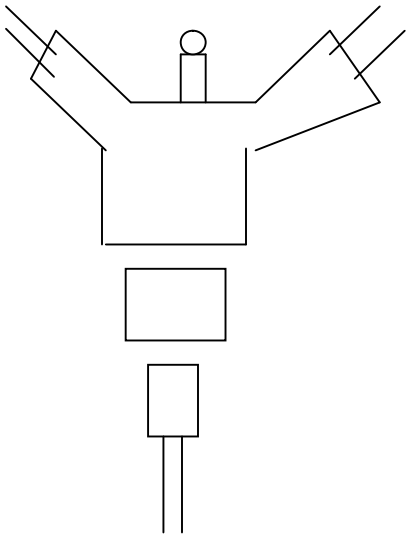


(3) **Pitcher Irrigation**

A simple, efficient and economic way to provide localized sub-surface irrigation known as pitcher irrigation has been developed at central Soil Salinity Research Institute, Kamal, India (1974). It is a locally baked earthen pot known as pitcher. It is used to provide and distribute water in the root zone. The pitcher is buried in the soil and water instead of spreading on the whole field is filled in the pitcher. Through the pores, water oozes out and wets the soil in the vicinity of the pitcher thus making it fit for sowing seeds and planting seedling.



## Sprinkler Irrigation



Sprinkler supply water to the field by a Sprinkler head or perforated pipe over the land, No canal system is required, though initially it is costly as it required pumps and pipe but highly economical and technically viable/feasible, the method is more useful where :

- 1) Land cannot be prepared for surface method
- 2) Slope is excessive
- 3) Topography is irregular
- 4) Soil excessively permeable or impermeable
- 5) Depth of soil is shallow over gravel or sand.

In sprinkler irrigation, land leveling, Land grading and canal digging is eliminated (advantages)

Sprinkler can be

- (1) Permanent
- (2) Semi-permanent

(3) Potable or Nursery irrigation

A pump lift water and pushes it through the distribution pipes. Sprinkler system consist of perforation in pipes pressure pipes is  $1.4\text{kg/cm}^2$  to  $21\text{kg/cm}^2$

**Advantages of sprinkler method**

- 1) Erosion can be controlled
- 2) Uniform application of water is possible
- 3) Irrigation is better controlled, light irrigation is possible for seedling and plants which are very young
- 4) Land preparation is not required
- 5) Labor cost is reduced since no ditches or borders are required
- 6) More land is available for cropping
- 7) Surface runoff is eliminated
- 8) Small streams of irrigation water can be used efficiently
- 9) Time and amount of fertilizer application can be controlled
- 10) Crop damage from temperature extremes can be reduced
- 11) It can act as a standby drainage pumping plant.

**Limitation**

- 1) Wind may distort sprinkler pattern
- 2) A constant water supply is needed for commercial use of equipment
- 3) Water must be clean and free from sand or other particle
- 4) Power requirements for pumping is high
- 5) Heavy soil with low intake (infiltration rate) cannot be efficiently irrigated.

### **Factors that affects the choice of Irrigation Method**

- 1) Topography of the area (field)
- 2) Cost involved in installation and maintenance
- 3) Availability of water (quantity and quality)
- 4) Water source (surface or ground)

### **Consumptive Use of Water**

Crop water use, also called evaporation transpiration (ET) is an estimate of the amount of water transpired by the plants and the amount of evaporation from the soil surface around the plants i.e depth of water consumed by evaporation and transpiration during plant growth.

Evaporation refers to the transfer of water from water body and soil surface into the atmosphere. Also considerable quantity of water may also be taken up by vegetation, plants absorb water through their root systems and diffuse it back into the atmosphere through leaves through the process of transpiration.

The rate of transpiration depends on

- (1) Climatic condition
- (2) The type of plant root
- (3) Water availability
- (4) The driving force 'solar energy'

Most of the water that enters the plant roots does not stay in the plant less than 1% of the water withdrawn by the plant is actually use the in photosynthesis (i.e. assimilated by the plant). The rest of the water moves to the leaf surface where it transpires (evaporates) to the atmosphere.

### **Measurement of Evapo-transpiration/Consumptive use of Crop**

## Direct method

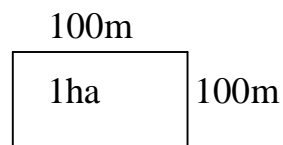
- 1) Lysimeters
- 2) Evaporation pan
- 3) Evaporimeters

## Estimation Methods

- (1) Water balance method
- (2) Blamey Criddle Method
- (3) Perman equation

## Consumptive use in relation to plant water requirement

When consumptive use of a plant is known from the above, you can plan water requirement for the entire field. Suppose a 100 days maturity crop like maize, wheat is grown and it requires consumptive use of water 400mm in a field of 1ha.



$$\text{Area} = 10,000\text{m}^2 = 1 \text{ ha}$$

$$\text{Maize} = 400\text{m (Cu)} = 0.4\text{m (depth of water consumed)}$$

Volume of water require for the area (1ha) land planted with maize

$$= 10,000 \times 0.4 = 4000\text{m}^3$$

Recall that maize = 100 day crop

$$\text{Converting to second} = 100 \times 24 \times 60 \times 60$$

$$= 8,640,000\text{sec}$$

You require

$$\begin{aligned} \text{Total water need} &= 4,000\text{m}^3 \\ &= 4000 \times 1000 \text{ litre} \\ &= 4000, 000 \text{ litres} \end{aligned}$$

in 8, 640, 000 sec

$$\begin{aligned} \text{Rate of water supply} &= \frac{4000,000}{8,640,000} \text{ L/S} \\ &= \frac{1}{2} \text{ L/S} \end{aligned}$$

Water required for maize = 5 litre/sec/ha.

### **Factors affecting consumptive use**

Evaporation which depend on

- 1) Humidity
- 2) Mean monthly temp.
- 3) Growing season of crop and cropping intensity
- 4) Irrigation depth or depth of water applied for irrigation (availability of water)
- 5) Monthly precipitation
- 6) Wind velocity
- 7) Soil and Topography
- 8) Irrigation practices and method of irrigation

### **Determination of irrigation requirements**

The irrigation requirement is seriously affected by the system efficiency which is accounted for by different losses experienced during water application. In order to determine irrigation requirements of a certain crops during the base period, the following must be known.



**Effective Rainfall, Re:** it is the part of precipitation falling during the growing period of a crop that is available to meet evapotranspiration needs of the crop

Example      Precipitation. Record

Sept.      =      100mm

Oct.      =      50mm

Nov.      =      Nil

Dec.      =      Nil

If the consumption use of crop ( $C_u$ ) is taken = 1000m

and losses = 300mm

The water requirement of crop field = 1300

But for Nov. and Dec. = Nil

and total supplied by rainfall = 150 for the four month.

Hence Irrigation requirement = 1300 – 150

= 1150mm

### **Consumptive Irrigation requirement: CIR**

The consumptive irrigation requirement is defined as the amount of water that is required to meet the ET need of crop during its full growth.

$CIR = C_u - R_e$

Taken  $R_e = 50\text{mm}$

$C_u = 1000\text{mm}$

$CIR = C_u - R_e = 1000 - 50 = 950\text{mm}$

### **Net irrigation Requirement: NIR**

Net irrigation is defined as the amount of irrigation water required at the plot to meet ET need as well as other needs arising out of losses by percolation, see page, leading etc.

$NIR = CIR + \text{losses due to percolation, leaching etc.}$

$$Cu - Re + Dp$$

Suppose losses due percolation = 100mm

Then.

$$\begin{aligned} NIR &= Cu - Re + Dp \\ &= 1000 - 50 + 100 \\ &= 1050\text{mm} \end{aligned}$$

### **Field Irrigation Requirement (FIR)**

Field irrigation requirement is the amount of water required to meet “net irrigation requirement (NIR) plus water loss in percolation in field water courses, field channel and field application of water

$$FIR = \frac{NIR}{\cap \alpha}$$

$\cap \alpha =$  water application

say  $\cap \alpha = 90\%$

$$\text{the FIR} = \frac{NIR}{\cap \alpha} = \frac{1050}{0.9} = 1170\text{mm}$$

### **Gross Irrigation Requirement**

Gross irrigation requirement is the sum of water required to satisfy the field irrigation requirement FIR and the water loss to conveyance in distributing canals up to the field.

$$GIR = \frac{FIR}{\cap c}$$

$\cap c =$  due to conveyance losses in canals, losses in distribution canal up to the field (conveyance efficiency  $\cap u$ )

suppose  $\cap c = 80\%$

$$\begin{aligned} \text{GIR} &= \frac{\text{FIR}}{\eta_c} = \frac{1170\text{mm}}{0.8} \\ &= 1463\text{mm} \end{aligned}$$

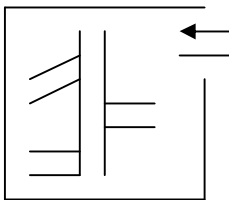
Note that

$$\text{GIR} - C_u = \text{losses}$$

$$\text{i.e. } 1463 - 1000 = 463 \text{ (losses).}$$

### Irrigation efficiency

Irrigation efficiency can be based on the amount of water applied to a field or to entire irrigation system, taking into account losses acquired into distribution system.



$$100\text{m}^3 = \text{volume supplied}$$

$$20\text{m}^3 = \text{losses of water applied}$$

$$\text{efficiencies} = \frac{\text{volume} - \text{loss}}{\text{volume applied}} \times 100$$

$$\frac{100 - 20}{100} = 0.8$$

$$\text{i.e. field irrigation efficiency} = 80\%$$

$$\eta_u = \frac{C_u}{w_a} \times 100$$

$$\eta_u = \text{field irrigation eff.} = C_u = \text{water use}$$

$$= \text{water applied} - \text{losses}$$

$$= w_a = \text{water applied}$$

### Example

1) Suppose total water applied  $W_a = 1250\text{mm}$

$$\text{Losses} = 150\text{mm}$$

$$\eta_u = \frac{C_u}{W_a} = \frac{W_a - \text{losses}}{W_a} = \frac{1250 - 150}{1250}$$

$$W_a - \text{loss} = \frac{1100}{1250} \times 100 = 88\%$$

(2) In a rice plantation with consumptive use  $C_u = 1000\text{mm}$  and losses on the field being  $300\text{mm}$

Solution

The total water use (applied) =  $1000 + 300 = 1300$

Field irrigation efficiency

$$= \frac{1300 - 300}{1300}$$

$$= 1000 \times 100 = 70\%$$

**Irrigation Terms**

**Duty** is defined as the irrigation capacity of water i.e. it is a relationship between the area of crop irrigated and quantity of water required during the entire period of growth of crop (Base period).

e.g if 3 cumecs can irrigate 5100 ha then duty of irrigation will be

$$3 \text{ cumecs} \Rightarrow 5100\text{ha}$$

$$1 \text{ cumec} \Rightarrow Z\text{ha}$$

$$3 \times Z = 5100\text{ha}$$

$$1 \text{ cumec} = \frac{5100}{3}\text{ha}$$

**Base Period:-** time from sowing to harvesting crop during which water supplied by irrigation

## **Delta**

Total depth of irrigation in mm or m that you apply on the field from sowing to harvesting

$$\text{FIR} = \text{Delta} = \Delta$$

## **IRRIGATION WATER QUALITY**

The quality of some water is not suitable for irrigating crops. Irrigation water must be compatible with both crops and soils to which it will be applied.

Generally a water analysis and a legal description of the land proposed for irrigation are required before a recommendation can be made.

The quality of water for irrigation is determined by its salts content. An analysis of water for irrigation should include the cations and anions.

Cations:- calcium, magnesium and sodium.

Anions:- bicarbonate, carbonate, sulfate, chloride, some crops are sensitive to boron, so it is often included in the analysis.

## **Water for Irrigation**

The water for irrigation must be

- (1) Compatible with crop
- (2) Compatible with the soil to which it is applied

## **Analysis of water for irrigation**

$$\text{Temp} = < 40^{\circ}\text{C}$$

$$\text{PH} = 6 - 9$$

Cation:- Ca, mg, Na, K in excess is injurious in irrigation,

Anion =>  $\text{HCO}_3$ ,  $\text{CO}_3$ ,  $\text{NO}_3$ , Cl in excess quality will

- (a) Reduce osmotic activities of plant thus preventing absorption of nutrients from the soil
- (b) They may have direct chemical effect on the metabolism of plant and may reduce soil permeability which inhibits change causing harm to production of any crop.

The concentration of salt is determined by (concentration of salinity)

$$C_s = \frac{C_Q}{Q - (C_u - R_e)}$$

Where

- $C_s$  = Concentration of salt in irrigation water
- $Q$  = Total quality of water applied
- $C_u$  = consumptive use
- $R_e$  = effective rainfall

**Salt content in irrigation water (Unit)**

- ppm - part per million = mg/L
- 1ppm = 1mg/L

milliequivalent per litre (Meq/L)

$$\text{Meq/L} = \frac{\text{Equivalent weight}}{1000}$$

$$\text{Na} = 23 = \frac{23}{1000}$$

- (1) Boron:- Boron is essential for the normal growth of plant but it is required in small quantity, some crops are sensitive to boron, so it is also important in irrigation water.

Sugarcane may tolerate large concentration of boron in irrigation but crop like cowpea, groundnut etc. are very sensitive to boron.

Boron concentration of more than 2 ppm is harmful to most crops while 3 ppm may be lethal to most crop.

### **Irrigation water Classification**

There are two most important factor to look out for in irrigation water quality analysis.

- (1) Total Dissolved solid (TDS)
- (2) Sodium Adsorption Ration (SAR)

TDS: measure concentration of soluble salt in water sample called salinity it is expressed in terms of electric conductivity

#### Unit:

Millimhos per centimeter (Mmhos/cm)

deci - siemens per meter (ds/m)

Micro mhos per cm ( $\mu$ mhos/cm)

Where  $1000\text{mmhos/cm} = 1 \mu\text{mhos/cm} = 1 \text{ ds/m}$

Ohm = resistance

conductivity =  $\frac{1}{\text{Ohm}}$  = mhos =  $\frac{1}{\text{resistance}}$

can also be expressed as

ppm or mg/l  
micro -mho x 0.6 = ppm = mg/l

Classification based on salt concentration or EC, irrigation water has been classified into 4 types by USDA stand – soil conservation service.

Low conductivity water =  $C_1$

Medium conductivity water =  $C_2$

High conductivity water =  $C_3$

Very conductivity water = C<sub>4</sub>

As outlined in table below

Classification of irrigation water based on EC

S/N	Type of water	Suitability for irrigation
1	Low salinity water (C1) conductivity between 100 to 250 $\mu\text{mhos/cm}$ at 25 <sup>0</sup> C	suitable for all types of crop and all kind of soils. Permissible under normal irrigation practice except on soil of extremely low permeability
2	Medium salinity water (C2) conductivity between 250 to 750 $\mu\text{mhos/cm}$ at 25 <sup>0</sup> C	Can be used if a moderate amount of leaching occurs. Normal salt tolerant plants can be grown with much salinity control.
3	High salinity water (C3) conductivity between 750 to 2,250 $\mu\text{mhos/cm}$ at 25 <sup>0</sup> C	Unsuitable for soil with restricted drainage. Only high salt tolerant plants can be grown e.g. sugar cane, palm trees, coconut etc. In C3, cowpea, groundnut cannot be grown due to high sensitivity for irrigation
4	Very high salinity water (C4) conductivity between >2,250 $\mu\text{mhos/cm}$ at 25 <sup>0</sup> C	Unsuitable for all kinds of plants and soils



### Classification of water according sodium concentration

Irrigation water	Sodium concentration
Sea water	35,500ppm
Dead sea (Jordan)	150,00 – 200,000ppm

An irrigation water having a higher Na% will after some time give rise to soil having a large percentage of replaceable Na in the colloid. Such soil is Black Alkali (soil unsuitable for Agriculture).

The percentage of Na is determined from the following equation

$$\% \text{ Na} = \frac{100 \text{ Na}}{\text{Ca} + \text{mg} + \text{Na} + \text{K}}$$

If percentage of Na is more, the aggregation of soil grains breaks down and soil becomes less permeable (bad drainage). Even on sandy soil with good drainages water of 85% Na. (given by equation) are likely to make soil impermeable of the prolonged use. With constant irrigation with high Na water, the soil will become:

- 1) Plastic
- 2) Sticky when wet and
- 3) Crack on drying

### Sodium Absorption Ratio (SAR)

Irrigation water is classified on Na Concentration on the basis of a factor called (SAR) given by

$$\text{SAR} = \frac{\text{Na}}{\sqrt{\frac{\text{Ca} + \text{mg}}{2}}} \text{ (No unit)}$$

SAR varies from 0 to a large number but for irrigation we use SAR value up to 26 or less

Based on SAR, water is classified into 4 types

- (1) Low Na water             $S_1$
- (2) Medium Na water       $S_2$
- (3) High Na water          $S_3$
- (4) Very high Na water     $S_4$

The characteristics of the four Na water are shown in table below.

S/N	Type of water	Suitability for irrigation
1	Low sodium water with $S_1$ SAR: 0-10	Suitable for all type of crops and all kind of soil except for those crop which are highly sensitive to Na (Cowpea, groundnut, Vegetable etc)
2	Medium sodium water with $S_2$ SAR: 10-18	Suitable for course texture or organi soil with good permeability (sand, sandy loam etc.)..Relatively unsuitable for fine textured soil (clay, clayey loams).
3	Medium sodium water with $S_3$ SAR: 18-26	Harmful for almost all types of soils. Requires good drainage, high leaching, gypsum addition
4	Very high sodium water with $S_4$ SAR: >26	Unsuitable for Irrigation.

### **Boron**

The boron content of water is of great important for many crops. Sugar cane may tolerate large concentration of boron in irrigation water while other crops such as cowpea, groundnut etc. are very sensitive to boron. Boron

concentration of more than 2 ppm is harmful to most crops. 3ppm may be lethal is most crops.

### Alternative classification of irrigation water

Table below gives an alternative classification of irrigation water based on the following factors:-

- (1) Electrical conductivity EC.
- (2) Total salt concentration. (TDS),
- (3) % sodium concentration. (given by formula  $\% Na = \frac{100 Na}{Ca + mg + Na + k}$ )
- (4) Boron Concentration. in ppm
- (5) SAR

Water class	Electrical conductivity	Total salt concentration	% Na	Boron concentration	SAR
1	0-1000	0-700	60	0.0 to 0.5	0 to 10
2	1000-3000	700-2000	60-75	0.5 to 2.0	10 to 18
3	>3000	>2000	>75	>2.0	>26

Class 1: Water are considered excellent to be good for most plants

Class 2: Water are considered to be good to injurious probably harmful to more sensitive crops

Class 3: Water are considered unsuitable under most conditions

### WATER LOGGING

Is the concentration of excess water (rainfall or irrigation water) on the soil which may be due to excess water after gravitational water (saturation not freely drained)

#### Causes of water logging

- (1) Impermeable rock strata

- (2) Rainfall amount more than infiltration
- (3) Undulating land (Topography of Area)
- (4) Land use management practices
- (5) Bad drainage
- (6) Soil type

### **Control of water Logging**

- (1) Surface drainage – to take out excess irrigation water which is mixed with salinity in soil using drainage canal.
- (2) Sub surface drainage – buried tile or pipe (30 – 20 cm Ø)
- (3) Controlling seepage loss from reservoir or canal
- (4) Scientific management of irrigation water such as
  - Use water judicious (Cu)
  - Practices that increases infiltration and reduce runoff land management such as mulching, tillage and intercropping.
  - Climatic study

### **PRINCIPLES OF DRAINAGE AND FLOOD CONTROL**

Drainage is the withdrawal of excess water from the soil if water is unable to drain down the soil profile because of the structure or type of soil or if water table is high because of the topography of the area, the soil will be saturated for all or most of the year.

Provision of drainage is needed in majority of irrigation scheme. The aim of drainage is to remove unwanted water in order that the soil structure and aeration are maintained. An access to the field for cultivation and harvesting is assured.

Adequate drainage occurs naturally where free drainage soils are linked by a permeable medium to some suitable outlet. However, commonly there are errors in the natural system and so artificial means are required to assist the drainage process.

In many cases, natural drainage is entirely inadequate and a complete artificial system is needed from pipe drains below the field through a major channel conveying the out flow to a place of safe disposal.

### **Need for Agricultural Drainage**

- (1) Removal of water logging from the field of irrigation
- (2) Prevent loss of yield or even crop failure
- (3) Removal of saline water from soil
- (4) Prevent unwanted soil wetness and lack of air (aeration) in the soil which may cause roots not to respire and prevent problem of root not being well spread.
- (5) Prevent slow germination of seed or in some cases may not occur at all
- (6) Cause wetting of soil and subsequently disturb the function of tools.

### **Methods of Agricultural Drainage**

- (1) Surface Drainage
- (2) Sub-surface Drainage

#### **Surface Drainage**

This is needed for

- (1) The removal of storm rainfall where subsurface drainage is not economically feasible.
- (2) For the collection and disposal of surface irrigation runoff.

The first situation is commonly found in heavy soil in the tropics (i.e. clay soil, clay loamy soil). Wet season rainfall of high intensity fall on soils with low infiltration rate and hence surface drainage is required to remove the excess water. It is necessary to estimate the excess storm rain to design a field surface which will shed the water without eroding and to design disposal channel with adequate capacity.

### **Sub – surface drainage**

This is used to

- (1) Control water table which will otherwise rise to the ground surface for extended period.
- (2) Improve the internal drainage (i.e soil structure of low permeability and this permit the free movement of air and water

The sub-surface water is collected by

- (1) Deep ditches
- (2) Permeable buried pipe

The surface water is collected by

- (1) Culverts under road
- (2) Canals
- (3) Drop structure (structure meant for reduction of elevation)

to loose elevation and reduce channel bed slopes where necessary and protective lining for bends and junction

### **Note**

Concrete is the most widely use in the tropical and arid region because of problem of high saline for all or part of the year. This is to prevent structure from corrosion.