NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF AGRICULTURAL SCIENCE

COURSE CODE: CRP 306

COURSE TITLE: PRINCIPLES OF IRRIGATION AND DRAINAGE

COURSE GUIDE

CRP 306
PRINCIPLES OF IRRIGATION AND DRAINAGE

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INTRODUCTION

Principles of irrigation and drainage: This is a two credit course for 300Level students of Bachelor of Science (B Sc.) degree (Crop production programme). The course consists of 16 units in two modules which deal with introduction to irrigation and soil reaction, erosion and drainage. This course guide tells you briefly what the course is all about, and how you can work through these units. It suggests some general guidelines for the amount of time you are likely to spend studying each unit in order to complete it successfully. It also gives you some guidance on your tutor Marked assignments.

WHAT YOU WILL LEARN IN THIS COURSE

The main aim of this course "Principles of irrigation and drainage" is to introduce the fundamental principles upon which irrigation and drainage practices are based upon. By studying this course you would be able to understand the interaction between the soil, plant, environment and water, so that you would be able to manipulate the plants and their external conditions for better growth and development and increase crop yield through efficient water utilization.

COURSE AIMS

The aim of the cause is to acquaint you with the basic principles of irrigation and drainage in crop production so as to achieve high crop yield. This would be achieved through:

- understanding the relationship between soil, plant, water and atmosphere
- understanding the critical stages of crop growth where water is highly needed.
- understanding the water use efficiency and how to achieve it
- understanding why water is apply to crop, when to apply the water and at what quantity
- knowing the techniques used in water application and maintenance of the systems
- understanding soil reaction, their effect on crop performance, control and the drainage systems of draining excess water from the field to achieve better crop growth

COURSE OBJECTIVES

In order to achieve the course aims, certain overall objectives have been set. In each unit specific objectives are set. These objectives are usually stated at the beginning of each unit. You should pay attention to the objectives of each unit before starting to go through them. You can always refer back to the unit's objectives to check your progress. You should also look at them after completing a unit. By so doing you can be sure that you have achieved what the unit expects you to acquire. By meeting these objectives, the aims of the course as a whole would have been achieved. These objectives include:

- Define and state the importance of irrigation
- Explain the relationship that exist within soil –water- plant – atmosphere
- State factors that affect water requirement of crops
- State water requirement of different crops
- Classify crops based on water requirements
- State and explain types of irrigation requirements and also know how to calculate irrigation requirement
- State and explain the methods of determining irrigation scheduling
- State the benefits of irrigation scheduling
- State critical growth stages of different crops
- State the growth stages affected by irrigation practice
- Described water cycle
- Explain the agronomic practices of some irrigated crops
- State the different irrigation resources in Nigeria
- Estimate the quantity of different irrigation resources in Nigeria
- Explain the types of maintenance
- State the effects of poor maintenance
- State the care of irrigation equipments
- Explain the types of irrigation systems stating the advantages and disadvantages of each system.
- State crops that suit different topography
- state the effects of salinity, alkalinity and acidity on crops and soil and the control measures of the different soil conditions
- Explain the types of erosion
- State the methods of controlling soil erosion
- Explain the types of drainage and state the advantages and disadvantages of each types of drainage

WORKING THROUGH THIS COURSE

To complete this course you are required to read the study units carefully and read other recommended materials. You will be required to answer some questions based on what you have read in the Content to reaffirm the key points. At the end of each unit there are some Tutor-Marked Assignments (TMA) which you are expected to submit for Marking. The TMA forms part of your continuous assignments. At the end of the course is a final examination. The course should take you 12 to 13 weeks to complete. The component of the course is given to you to know what to do and how you should allocate your time to each unit in order to complete the course successfully on time.

COURSE MATERIALS

The main components of the course are:

1. Course guide
2. Study units
3. Tutor Marked assignments
4. References/Further reading

STUDY UNITS

Module 1 Introduction to Irrigation

Unit 1	Definition, importance and purpose of irrigations
Unit 2	Soil-water-plant-atmosphere relationship
Unit 3	Assignment of water requirement for crops – Meteorological approach
Unit 4	Irrigation requirement
Unit 5	Consumptive water use and evapotranspiration
Unit 6	Irrigation scheduling
Unit 7	Critical growth stages for water need of different crops
Unit 8	Economic and efficient use of water
Unit 9	Hydrological cycle and role of water in crop growth
Unit 10	Agronomic management of irrigated crops and problems Associated with irrigation
Unit 11	Irrigation resources in Nigeria
Unit 12	Maintenance of irrigation equipments
Unit 13	Irrigation systems or techniques

Module 2 Soil reaction, erosion and drainage

Unit 1	Soil salinity, alkalinity and acidity
Unit 2	Soil erosion
Unit 3	Soil drainage

TUTOR-MARKED ASSIGNMENTS (TMA)

There are tutor Marked assignments and self assignment in each unit. You would have to do the TMA as a revision of each unit. And there are four Tutor Marked Assignments you are required to do and submit as your assignment for the course. This would help you to have broad view and better understanding of the subject. Your tutorial facilitator would inform you about the particular TMA you are to submit to him for Marking and recording. Make sure your assignment reaches your tutor before the deadline given in the presentation schedule and assignment file. If, for any reason, you cannot complete your work on schedule, contact your tutor before the assignment is due to discuss the possibility of an extension. Extensions will not be granted after the due date unless there are exceptional circumstances. You will be able to complete your assignment questions from the Contents contained in this course material and References/Further reading; however, it is desirable to search other References/Further reading, which will give you a broader view point and a deeper understanding of the subject.

FINAL EXAMINATION AND GRADING

The final examination for the course will be 2hrs duration and consist of six theoretical questions and you are expected to answer four questions. The total Marked for the final examination is 70 Marked. The examination will consist of questions, which reflect the tutor Marked assignments that you might have previously encountered and other questions within the course covered areas. All areas of the course will be covered by the assignment. You are to use the time between finishing the last unit and sitting for the examination to revise the entire course. You might find it useful to review your Tutor Marked Assignments before the examination. The final examination covers information from all parts of the course.

MAIN COURSE

CONTENTS PAGE

MODULE 1 INTRODUCTION TO IRRIGATION

UNIT 1 DEFINITION, IMPORTANCE AND PURPOSE OF IRRIGATIONS

CONTENTS

1.0 INTRODUCTION

All living things require nutrition as one of their characteristics as living things. Nutrition is required for growth and reproduction and they are supplied to living things in different forms. Water is essential for both plant and animal life. When water is in short supply in plants it causes wilting and this reduces yield of plant. To avoid this reduction in yield there is need to supply plant with water during period of shortage. This act of supply water to plant during period of shortage is what you will be dealing with in this unit and subsequent units.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define irrigation
- state the importance of irrigation
- state the forms of irrigation.

3.0 MAIN CONTENT

3.1 Definition

Irrigation is generally defines as the artificial application of water to soil for the purpose of supplying the moisture essential for plant growth. The primary reason for irrigating crop is to supplement water availability from natural sources such as rainfall, dew, flood and ground water which seep into the root zone.

3.2 Purpose of |Irrigation

Generally, irrigation is carried out for the following purposes.

- To add water to the soil in order to supply moisture essential for plant growth
- To provide crop insurance against short duration drought
- To cool the soil and atmosphere thereby making the environment more favourable for plant growth.
- To wash out or dilute salt in the soil
- To soften tillage pan and clods
- To facilitate the functioning of some micro organisms
- To enhance fertilizer application – fertigation

SELF-ASSESSMENT ASSESSMENT

i. Define irrigation
ii. State 4 purpose of irrigation

3.3 Importance of Irrigation

The following are the importance of irrigation

i. Increase crop yield
ii. Provide means of production of special crops e.g. wheat, maize etc
iii. Provide employment for farmers during dry season

iv. Increase the economy of a nation through export
v. Increase additional income to the farmer
vi. Intensification of land use

3.4 Forms of Irrigation

Irrigation forms are of two types depending on the way the water is applied to the crops in the field. These are:

i. **Gravitation form of irrigation**: This is the application of water to the field in a natural form. The water flow naturally or it is guided to the field from the source to the field without any use of force. Surface irrigation uses gravitational force to apply water to crop field.
ii. **Pressurized pump form of irrigation**: This is the application of water to the field using artificial force to direct or pump the water to the field. The sub surface, sprinkler and drip irrigation uses this form of irrigation through the use of pumping machine which pumps water to the field of crops.

4.0 CONCLUSION

Irrigation makes plant survival possible and these lead to increase in crop yield which also leads to food sufficiency. Irrigation also makes crop production a all year round activity

5.0 SUMMARY

Irrigation is the artificial application of water to the soil for the following purposes

- Supply moisture essential for plant growth
- Provide insurance against short duration drought
- To cool the soil and atmosphere therefore making if favourable for plant growth
- To wash out salt in the soil
- To soften tillage pans and clods.

The importance of irrigation include increase in crop yield, provision of employment, increase the economy of a nation among others.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define irrigation
2. State 5 purpose of irrigation
3. State 5 importance of irrigation

7.0 REFERENCES/FURTHER READING

Larry, G. James. (1993). Principles of farm irrigation. John Wiley and Sons Inc.

Ogiever Erebor (2003). Comprehensive Agricultural Science for Senior Secondary Schools. A. Johnson Publisher Limited.

UNIT 2 SOIL–PLANT–ATMOSPHERE RELATIONSHIP

CONTENTS

1.0 INTRODUCTION

The soil is the medium were plant is grown and it provide plant with nutrient and water which it receive from the atmosphere. When plant dies, they add to the nutrient in the soil. This shows that the soil, plant and the atmosphere are related in one way or the other. One cannot exist without the other. This unit deals with Soil, plant and atmosphere.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- explain the relationship that exist within soil – plant – atmosphere
- explain the role of plant in the relationship
- explain the role of soil in the relationship
- explain the role of atmosphere in the relationship.

3.0 MAIN CONTENT

3.1 Soil-Plant-Atmosphere Relationship

The plant needs water and nutrients, the soil store the water and the nutrients needed by plants and the atmosphere provide the water and the energy needed by the plant to withdraw water and nutrient from the soil. The plants add nutrient to the soil when they die. The role of the soil, plant and atmosphere are described below.

3.1.1 Soil

The soil stores water needed by plant. adsorptive and capillary forced called matrix forces hold significant amount of water which can be removed and used by plant in the void spaces (air spaces) between soil particles and the minimum forces is required to remove water from the soil varies with the amount of water in the soil. As the soil void spaces between soil particles are filled with water and soil approaches saturation, the matrix forces holding the water in the soil approaches zero. Conversely, as water content of the soil approaches zero, the matrix forces approaches negative infinity. This, it is easier for plant to obtain water when the soil is moist than when it is dry. Between saturation and absolute dried points, two soil important contents are relative to the plant. These contents are field capacity and permanent wilting points (defined as the upper and lower unit of soil water that is available to plant respectively). Field capacity is less than saturation while the soil is not absolutely dried at permanent wilting point.

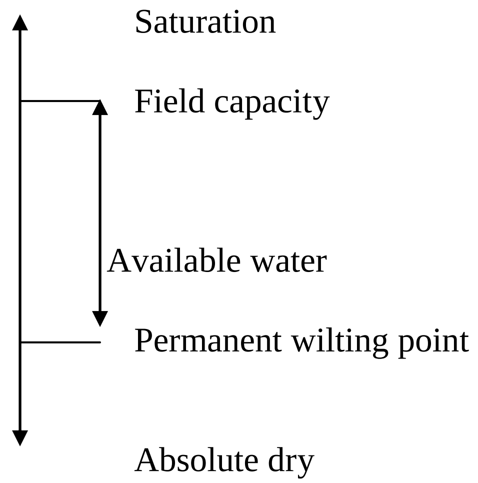


Figure 1: Position of water in the soil

Evaporation and transpiration often combined and are called evapotranspiration. They are necessary to remove the water from field capacity. As water is removed and soil matrix forces increases it becomes increasingly more difficult for the plant to remove water. When the plant is unable to remove water, the soil is at its permanent wilting point. Water at this point is not available to the plant. Most of the water is held by the absorptive forces and is called "hydroscopic water". The water between field capacity and permanent wilting point that is available to plant is called available water. The following equation is used to compute the available water.

$$\text{Available water (AW)} = \frac{D\,(FC - PWP)}{100}$$

Where D = Depth of root zone (cm)
FC = field capacity
PWP = permanent wilting point

Although plants are theoretically able to obtain water from the soil whenever water content exceed permanent wilting point, the actual rate at which they transpire decreases as the stomata closes in response to declining soil water content.

SELF-ASSESSMENT EXERCISE

Define field capacity and permanent wilting point

3.1.2 Plant

About 60-90% of a physiologically active plant is water. Water is required by the plant for the following purposes viz: photosynthesis, digestion, growth, transport of minerals and photosynthates (food material produced during photosynthesis), structural support and transpiration. The plant uses water primarily for transpiration. The plant use only about 5% of the total water absorbed for physiological functioning. Most of the water is lost in transpiration and therefore, it has to be replaced. Transpiration involves the conversion of water from the liquid state to the vapour phase within the leaves and its transport system through the stomata of the leaf into the atmosphere. Transpiration occurs when vapour pressure within the leave exceeds that of the surrounding air (atmosphere) and stomata are open to allow carbon dioxide into the plant for photosynthesis.

The plat extracts water from the soil to replenish water lost by transpiration. Water moves through the soil into the roots up to xylem and into the leaves due to water potential gradient between the leaf and the soil. This process is called “passive absorption”. As the plant removes water from the soil, the water content of the soil decreases and total water potentials decreases. At the same time the conductivity (resistance to water movement in the soil) of soil decreases. As this situation continues, the plant begins to dehydrate, hence total water potentials in the leaves decreases in order to maintain transpiration rate. When leaf water potential is sufficiently low, the leaf will be dehydrated to the extent that the stomata begin to close. This results in a lower rate of transpiration. Since carbondioxide enters the leaf through the same pathway (stomata) as water vapour escapes, stomatal closure will also result in decreased photosynthetic rate causing a reduction in growth, yield and quality of the produce.

Humid conditions enable plants to draw soil moisture almost up to permanent wilting point. On the other hand in hot and dry conditions, plants may show wilting symptoms in spite of enough available water present in the root zone. Shallow rooted plants like paddy rice and tomato requires frequent water application than moderately deep and very deep rooted crops such as wheat, groundnut, maize, sorghum, cotton and sugarcane. Under field conditions, solar radiation supplies the energy for evaporation process. Wind is also important in removing water vapour from the field.

SELF-ASSESSMENT EXERCISE

i. List three (3) deep rooted crops
ii. Briefly explain the process of transpiration

3.1.3 Atmosphere

The atmosphere provides energy needed by the plant to withdraw water from the soil. If the soil water is not limiting and stomata are fully open, then the conditions in the atmosphere that control the rate of transpiration are.

i. The humidity of the air surrounding the plant.
ii. The temperature and the humidity of air carried to the plant by wind and
iii. The total radiation available to the plant.

Increasing the humidity of the air surrounding the leaf, other conditions remaining constant, will decrease the vapour pressure differences between the leaf and surrounding air. Wind sweeps away any layer of water vapour accumulated around the leaf and either increases or decreases transpiration rate. If the air around the leaf is replaced with warmer and or drier air, the transpiration rate increases. Conversely, if the wind brings cooler and or move humid air, the transpiration rate decreases whether in shade or sun. Radiation influences the of transpiration in two ways first, radiation rises leaf temperature above that of the surrounding air and hence increases transpiration since the saturated vapour pressure in the leaf increases as leaf temperature rise. The temperature of leaf in the shade is approximately equal to the air temperature so the vapour pressure radiant is less. Secondly, the presence of light (short wave radiation) triggers the opening and closing of the stomata. The stomata of most plant are opened during the day and closed at night.

4.0 CONCLUSION

The plant need the soil and the atmospheric factors such as temperature radiation, wind and rainfall for it survival and ultimate yield. The soil also relies on the plant for its nutrient and organic matter which are acted upon by the above atmospheric factors during the process of soil formation.

5.0 SUMMARY

The relationship between soil, plant and atmosphere cannot be overemphasized. The soil is a store house of nutrient and water required by plant absorb the water and nutrient from soil and also carbondioxide from the atmosphere for its growth and development and at the end releases water vapour to the atmosphere and nutrient to the soil when they die. The atmosphere on the other hand control transpiration rate and provide water to soil inform of rainfall.

6.0 TUTOR-MARKED ASSIGNMENT

1. State two ways in which radiation influences the rate of transpiration
2. Briefly explain the relationship between soil, plant and atmosphere.

7.0 REFERENCE/FURTHER READING

Larry, G. James. (1993). Principles of farm irrigation. John Wiley and Sons Inc.

UNIT 3 CROP WATER REQUIREMENT

CONTENTS

1.0 INTRODUCTION

Irrigation is the artificial application of water to crop for the purpose of supply moisture essential for growth, provide crop assurance against short drought and to facilitate continuous cropping among others. This practice of irrigation complement food supply obtained during the rainfed agriculture so as to increase food production to enhance the attainment of food sufficiency. The water requirement of crops varies with crop and environment the crops are found. In this unit you would study water requirement of crops and factors that influence it.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define water requirement of crop and irrigation requirement
- state factors that affect water requirement of crops
- state water requirement of different crops
- classify crops based on water requirement.

3.0 MAIN CONTENT

3.1 Water Requirement of Crop or Crop Water Requirement

Water requirement of crop (WR) is that quality of water, regardless of its sources, required by a crop in a given period of time for its maturity. It includes losses due to evapotranspiration or consumptive use plus the losses during the application of irrigation water which may be unavoidable. It can also be defined as the depth or amount of water needed to meet the water loss through evaporation. In other words, it is the amount of water needed by the various crops to grow optimally.

The water requirement of crops varies with crops and it mainly depends on.

- **The climate factors** such as sunlight or radiation, temperature rainfall and wind. Sunny and hot climate crop need more water per day than in a cloudy and cool climate.
- **The crop type**. Crops with cuticles or waxes on their leaves surface reduce evapotranspiration and as such require less water than those that do not have. Crops like maize or sugarcane held more water than crops like millet and sorghum. Also nature and shape of the crop leaf affect the crop water requirement, this so because the surface for evapotranspiration are more in broad leafed crops, as such they need more water than narrow leaved crops.
- **Soil type** – The retention and transmissivity of water in the soil affect water requirement of crops.

The table below shows the major climatic factors and their effect on crops based on water requirement of crop.

Table 1 – Effect of major climatic factor on crop water requirement

	Crop water requirement	
Climatic factor	High water required	Low water required
Temperature	Hot	Cool
Humidity	Low (dry)	High (humid)
Wind speed	Windy	Little wind
Sunshine	Sunny (no clouds)	Cloudy (no sun)

The highest crop water requirements are thus found in areas which are hot, dry, windy and sunny. The lowest values are found when it is cool, humid and cloudy with little or no wind.

Table 2 below gives the amount of water required by different crops in their whole production period.

Crop	**Water requirement (mm)**
Rice	900 – 2,500
Wheat	450 – 650

Sorghum	450 – 650
Maize	500 – 800

SELF-ASSESSMENT EXERCISE

i. State 3 factors that determine water requirement of crops
ii. State the water requirement of maize and wheat

3.2 Classification of Cop Based on Water Requirement

On the bases of water requirement of crops, crops are grouped into 3 different groups namely.

i. **Hydrophytes** – These are crops that require lot of water for their growth and development e.g. paddy rice, Banana, sugarcane etc. They are usually grown on swampy land or in valley where there is lot of water or water for irrigation.

ii. **Mesophytes** – These are crops that require moderate water for their growth and development. They are between hydrophetes and xerophytes e.g. maize, sorghum, soya beans, groundnut, tomato etc. They are usually grown on will drained soils.

iii. **Xerophytes** – These are crops that require little water for their growth and development. Xerophytes can withstand drought and survive in presence of mist and dew e.g. cowpea, millet, date palm, etc. they are crops found in the sahel and desert areas.

SELF-ASSESSMENT EXERCISE

i. Define water requirement of crop
ii. List the climatic factor that affect water requirement of crop
iii. List other factors that affect water requirement of crop

4.0 CONCLUSION

The knowledge of water requirement of crops helps a farmer to know the quantity o f water to apply to different crop based on their water needs. This will encourage proper utilization of nutrient in the soil as over irrigation would lead to leaching of nutrient beyond root zone of crop.

5.0 SUMMARY

The amount of water required by a crop in its whole production is called water requirement of crop. Crop water needs is mainly depends on climatic factors, crop factors and soil factors. On the bases of crop water requirements, crops are classified into hydrophytes, mesophytes, and xerophytes.

6.0 TUTOR-MARKED ASSIGNMENT

1. Classify crops based on crop water requirement
2. State two crops in each of the class above
3. State the water requirement of the following crops
    a. Maize
    b. sorghum
    c. Tomato
    d. groundnut.

7.0 REFERENCES/FURTHER READING

FAO (1986). Irrigation water management: Irrigation water needs. www.fao.org/docrep/S2022E/s2022e07.htm

Larry, G. James. (1993). Principles of farm irrigation. John Wiley and Sons Inc.

UNIT4 IRRIGATION REQUIREMENT OF CROP

CONTENTS

1.0 INTRODUCTION

Irrigation plays a vital role in crop sustainance and survival and there is need for the farmer to be knowledgeable in it so that he knows the quantity of water to apply in terms of water need of crops during short period of drought or in the dry season. The unit you are about to study deals with the amount of water crop required during irrigation under normal condition.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define irrigation requirement of crop
- state the types of irrigation requirement
- explain the types of irrigation requirement
- know how to calculate irrigation requirement.

3.0 MAIN CONTENT

3.1 Irrigation Requirement

The irrigation requirement (IR) of a crop is the total amount of water that must be supplied by irrigation to a diseased free crop growing in a large field with adequate soil water and fertility and achieving full production potential under a given growing environment. The irrigation requirement includes water used for crop consumptive use, maintaining a favourable salt balance within the root zone and overcoming non uniformity and inefficiencies of irrigation system or equipment. The irrigation requirement does not include water from natural sources such as rainfall that crop can effectively use. The irrigation requirement (IR) can be conputed when the evapotraspiration (ET) is known using the equation.

$$IR = \frac{100(Drz\ (\theta f - \theta i) + ET + L - Pe)}{Ei}$$

Drz = Dept of root zone (cm)
θf and θi = soil moisture content by volume

At end (final) and beginning (initial) of the time interval being considered

L = Leaching requirement
ET = Evapotranspiration
Pe = Effective Precipitation (rainfall)
Ei = Overall efficiency of irrigation in percentage (%).

3.2 Types of Irrigation Requirement

There are two types of irrigation requirement namely:

a) Net Irrigation requirement
b) Gross Irrigation Requirement

3.2.1 Net Irrigation Requirement (NR)

Net irrigation requirement is that amount of irrigation water which is required to bring the soil moisture of the effective root zone to field capacity (FC). The aim of irrigation is not to saturate the soil but to bring the soil to field capacity and the amount of water required to bring the soil to field capacity is know as net irrigation requirement. Net irrigation can be calculated using the following equation.

$$D = \frac{(MF - MS) \times BD \times d}{100}$$

Where D = Net amount of water to be applied
d = effective root zone depth
MF = Moisture at field capacity
MS = Soil Moisture before irrigation
BD = Bulk density.

Example - A soil has the following characteristics field capacity 30%
Effective root zone = 100cm
Bulk density = 1.325g/cm^3
Actual soil moisture = 15%

Calculate the amount of water depth of water

Solution - $D = \frac{(MF - MS) \times BD \times d}{100}$

$= \frac{30 - 15 \times 1.325 \times 100cm}{100}$

$= 0.15 \times 1.325 \times 100$

$= 19.88cm$ (depth of water)

1hectare = 10,000m^2

Then for 1hectare = $\frac{19.88 \times 10{,}000m^2}{100}$

$= 0.\ 1988 \times 10{,}000$

= 1988m2(water to be applied for 1hectare)

SELF-ASSESSMENT EXERCISE

What constitute irrigation requirement

3.2.2 Gross Irrigation Requirements (GR)

This is the total amount of irrigation water to be diverted to the farm from the source. It include net irrigation requirement and losses incurred during transportation and application (Transportation losses include evapotranspiration, while application include run off, deep percolation and seepage and transpiration unever distribution of water).

Gross irrigation requirement can be calculated using the following equation.

$$GR = \frac{\text{Net irrigation(NR)}}{\text{Field efficiency of the system}}$$

Where GR = Gross irrigation requirement
NR = Net irrigation

SELF-ASSESSMENT EXERCISE

i. Define irrigation requirement
ii. State the two types of irrigation requirement.

4.0 CONCLUSION

The calculation of irrigation requirement is important for efficient water use in an irrigation scheme. When irrigation requirement is not calculated and water is applied anyhow, it could leach nutrient or cause erosion.

5.0 SUMMARY

Irrigation requirement is the sum total of irrigation water needed for a crop in a specified time plus the losses occurring in the field during distribution such as seepage percolation etc. There are two types of irrigation requirement which are net irrigation requirement and gross irrigation requirement.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the types of irrigation requirement
2. State 2 types of application and transportation losses.

7.0 REFERENCES/FURTHER READING

Larry, G. (1993). Principles of Farm Irrigation. John Wiley and Sons Inc.

Chendia K.T.C. (2012). Water Requirement of Different Crops. Booklet No 226

UNIT 5 CONSUMPTIVE USE AND EVAPOTRANSPIRATION

CONTENTS

1.0 INTRODUCTION

Irrigation water is applied for crop to use in there growth and development. However, not all the water applied is used up by the crop and the amount use or the uptake of the irrigated water depends on the evaporation and transpiration of water from the soil surface and leaf surface respectively. This unit you are about to study deals with water use by crop for the physiological processes and water loss through evaportranspiration.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define consumptive use and evapotranspiration
- state the types of consumptive use
- know how to determine evapotranspiration
- state the method of determining evapotranspiration.

3.0 MAIN CONTENT

3.1 Consumptive use

Water is transferred to the atmosphere by direct evaporation of water from soil and plant surfaces as well as by transpiration. Since these processes are not easily separated, they are combine and called evapotranspiration. Consumptive use includes water used in all physiological processes as well as direct evaporation from soil surface and plant surfaces. The consumptive use exceeds evapotranspiration by the aporaphotosynthate, structural support and growth. Since this difference is less than 1% evapotranspiration and consumptive use are normally assumed to be equal.

3.2 Types of Consumption Use

There are 3 types of consumptive use applied to crops. They are daily, seasonal and peak period consumptive use.

i. **Daily Consumption use**

This is the total amount of water used by crop for evapotranspiration (transpiration and evaporation) in 24hrs or in a day. This varies with plant stage of growth from germination to senescence. At germination it is low and when the plant is fully developed it increases and later decreases at senescence (leaf dropping).

ii. **Seasonal consumptive use**

This is the total amount of water used by the crop for evapotranspiration through the growing season of the crop. It is the sum total of daily consumptive use of a crop from germination to harvesting.

iii. **Peak consumptive use**

This is the average daily consumptive use within 6-10 days of the highest consumptive use of the season. It is highest at harvest time. For irrigation purpose you use peak consumptive use instead of daily consumptive use because daily consumptive use varies with the growth stage of the crop. For crop that requires 3 months to grow and mature, in planning for irrigation water to be used, you times the peak consumptive use with the number of days to maturity to get the total amount of the water required.

SELF-ASSESSMENT EXERCISE

i. Define consumptive use
ii. Explain the three (3) types of consumptive use
iii. State three (3) component of consumptive use

3.3 Evapotranspiration (ET)

Evaporation is the escape of water in form of vapour from the soil to the atmosphere through wind. Transpiration is the escape of water in form of vapour from the plant stomata in the leaf to the atmosphere through wind. These two processes are joint together and are evapotraspiration which is the escape of water in the form of vapour from the plant and soil surface to the atmosphere through wind. Evapotraspiration is affected by climatic factors such as sunshine, temperature, wind and rainfall. Soil fertility or organic matter, soil Contenture and amount of mulch materials on the soil and factors such as types of crop, growth stage of the crop and size of crop leaf affect evapotraspiration.

3.4 Determination of Evapotraspiration

There are many methods used in determining evapotraspiration but the most commonly used methods are:

1. Direct methods; through use of conservation mass principle.

The most widely used direct techniques are based on conservation of mass principles.

$$Ds = Drz\ (\theta f - \theta i)$$

Where Ds = changes in soil moisture within the control volume during the time interval being considered

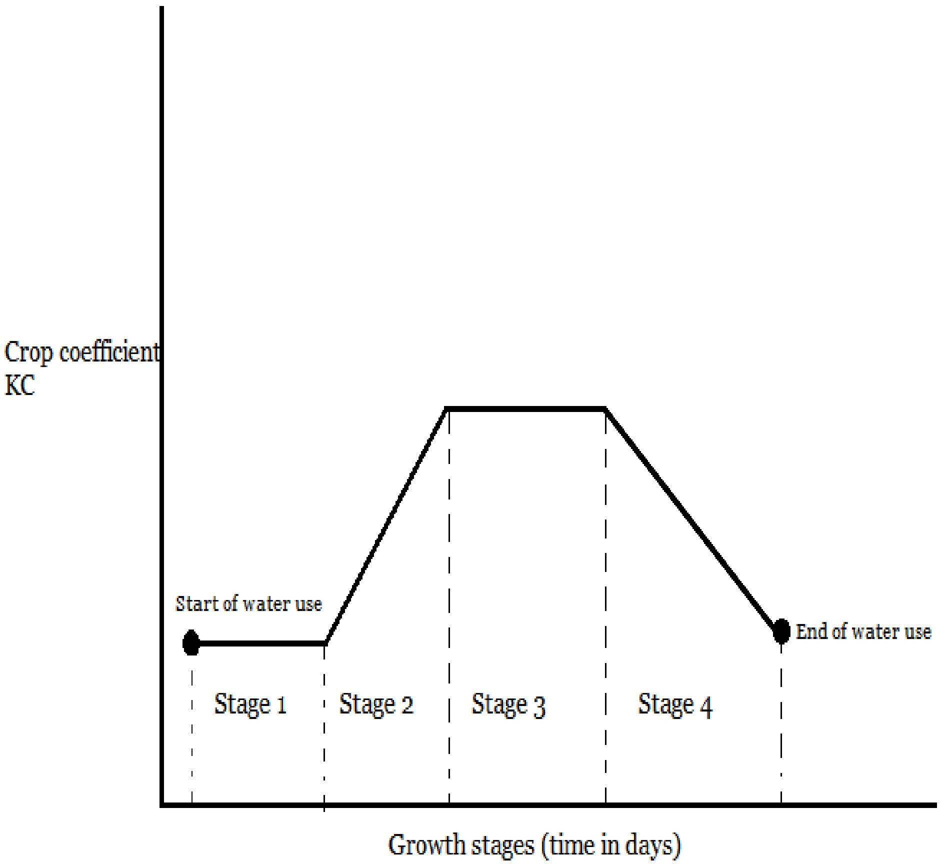
Drz = Depth of root zone (below soil surface) θf and θi = soil moisture content by volume at the end (final) and beginning (initial) of the time being considered.

2. Calculate methods of evapotranspiration all method for computing crop evapotranspiration involves the following equation.

ET = Kc x ETo
Where ET = evapotranspiration (mm/day)
ET = References/Further reading crop evapotranspiration (mm/day)
Kc = crop coefficient or crop factor

Reference crop evapotranspiration may be potential evapotranspiration of crop reference evapotranspiration. Potential evapotranspiration is the maximum rate at which water available can be removed from soil and plant surfaces. Potential evapotranspiration depends on the amount of energy (sunlight) available for evaporation and varies from day to day. Reference crop everpotranspirantion is the rate of everpotranspiration from a large area covered by green grass which grow actively, completely shades the ground and which is not short of water. Many methods with different data requirement and level of sophistication have being developed for computing reference crop evapotranspiration. Some of these methods require daily relative humidity, solar radiation, wind and air temperature data while others need only mean monthly temperature.

The crop coefficient "KC'' relate to the actual rate at which the crop is determined experimentally and relate to the physiological of the crop, the degree of the crop cover, the location where the data were collected and method used to compute the reference crop evapotranspiration. The value of crop coefficient for field and vegetable crops generally increase from an initial plateau to a peak plateau and then decline as the plant progresses through it growth stage. Figure below shows the typical variation of crop coefficient with growth stages.



Variation of crop coefficient with growth stages

Growth stages (time in days)
Variation of crop efficient with growth stages.

Stage 1 = Initial stage (seedling development)
State 2 = Crop development (increase in water use)
Stage 3 = Mid season (flowing to beginning of fruiting)
Stage 4 = Late season (fruiting to harvesting)

3. Calculating References/Further reading crop evapotraspiration using pan evaporation data.

Measuring the lost of water from an open phase pan of water is a relatively inexpensive and simple way of assessing the evaporating capacities of the atmosphere. The amount of water evaporating from a pan (that is pan evaporation) is determined by measuring the change in water level in the pan and correcting for precipitation has been prevented or negligible.

The principles of the pan ration is as follows:

- The pan is installed in the field
- The pan is filled with a known quantity of water (surface area of the pan is known and the water depth is measured).
- The water is allowed to evaporate during certain period of time (usually 24 hours) for example, each morning at 7:00am a measurement is taken. The rain if any, is measured simultaneously.
- The amount of evaporation per unit (the differences between the two measured water depths) is calculated; this is then pan evaporation: E pan or EP (in mm / day)
- The E pan is multiplied by a pan coefficient K pan or KP, to obtain References/Further reading crop evapotranspiration ETo daily pan evaporation is routinely measured of weather stations using the formula.

ETo = Kp x Ep
Where ETo = reference crop evaporation
Kp = pan coefficient that account for differences in pan type
Ep = pan evaporation

Example = Given the following daily pan evaporation data, calculate reference crop evaporation using O.8 as pan coefficient.

Date	EP (mm)	ETo (mm)
July I	12.2	12.2 x 0. 8 = 9.76mm/day
July 2	11.2	11.2 X0. 8 = 8.66mm/day
July 3	8.4	8.4 x 0.8 = 6.72mm/day
July 4	6.6	6.6 x 0.8 = 5. 28mm/day
July 5	9.7	9.7 x 0.8 = 7.76mm/day
July 6	9.7	9.7 x 0.8 = 7.76mm/day
July 7	8.1	8.1 x 0.8 = 6.48mm/day
July 8	6.6	6.6 x 0.8 = 5.28mm/day
July 9	8.6	8.6 x 0.8 = 6.88mm/day
July 10	5.8	5.8 x 0.8 = 4.64mm/day
	EP = 88.3	ETo = 70.64mm/10days.

Solution = ETo = Kp x EP
KP = 0.8
Daily ETo = 0.8 x daily EP

July 1 ETo = 0.8 x 12.2 = 9.76mm/day
Total ETo = Addition of the daily ETo
Or EP x Kp
= 88.3x 0.8
Total ETo = 70.64mm/10days.

4.0 CONCLUSION

The knowledge of consumptive use, evaportranspiration and reference crop evaporation is important in planning for irrigation. This world guide the farmer to estimate his crop at different stages of their growth and this would enhance water use efficiency.

5.0 SUMMARY

Consumptive use Include all water used in physiological processes as well as for direct evaporation from the soil and plant surface. Consumptive use is of three types namely. Daily, seasonal and peak and usually peak consumptive used to calculate irrigation requirement of crop. Evaporation and transpiration are component of consumptive use and because the two cannot be separated, they are jointly called evapotranspiration. The method used in calculating evapotranspiration and reference crop evapotranspiration includes pan evaporation and use of equation.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define evapotranspiration
2. State 3 and briefly explain 2 types of consumptive use
3. State the principle used in pan evaporation

7.0 REFERENCE/FURTHER READING

Larry, G. James. (1993). Principles of farm irrigation. John Wiley and Sons Inc.

UNIT 6 IRRIGATION SCHEDULING

CONTENTS

1.0 INTRODUCTION

Crop under irrigation need water but when the water are applied wrongly it could lead to leading of nutrients, soil erosion or accumulation of salt in the soil. The knowledge of water requirements, crops irrigation requirement and consumptive use is not enough for you to know the amount of water to apply. There is need for you to know when to apply water to crops and this is known as irrigation scheduling.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define irrigation scheduling
- state and explain the methods of determining irrigation scheduling
- explain the strategies of irrigation scheduling
- state the benefits of irrigation scheduling.

3.0 MAIN CONTENT

3.1 Definition of Irrigation Scheduling

Irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper scheduling is essential for the efficient use of water energy and other production input such as fertilizers. It allows irrigation to be considered with other farming activities including cultivation and chemical application. Among the benefits of proper irrigation scheduling are:

- Improve crop yield and for quality
- Water and energy conservation and
- Lower production costs.

3.2 Method used in Determining Irrigation Scheduling

Different methods are used to determine when to irrigate. They may be grouped into the following.

- Plant indicator
- Soil indicator
- Water budget techniques.

3.2.1 Plant Indicators

Monitoring crop or plants is the most direct method of determining when to irrigate. Since the primary objective of irrigation is to supply plant with the water they need when it is required. Normally, it is necessary to relate plant parameter to soil water content in order to determine the amount of irrigation.

a) Appearance and Growth

Visual indicator (appearance) of the need for water includes leaf wilting, shoot wilting and leaf colour. Measurement of stern diameter and height is monitored regularly to determine growth rate. The need to irrigate is indicated by a low growth rate. Appearance and growth are not after effective parameters for scheduling full irrigation since plant have been short of water for long time enough to adversely affect production when changes in appearance and for growth can be dictated. Crop appearance most be carefully interpreted since diseases and improper nutrient levels may produce changes in appearance similar to those associated with water stress. The primary advantage of appearance and growth as indicator of when to irrigate is simplicity.

b) Leaf Temperature

Rises in leaf temperature in addition to those related to increases in air temperature are associated with reduced transpiration rate resulting to partial or total stomata closure. Air and leaf temperature may be remotely sensed from the ground, aircraft and possibly satellite. One popular method to use of hand held infra red thermometer to measure the different between plant canopy or leave and ambient air temperature for each day (usually 1-1½ hours after noon). The numbers of degree by which company temperatures exceed air temperature for each day are accumulated until a certain critical level is reached. When this level which depends on the crop and soil is reached, it is time to irrigate. Days when company temperature is less than the air temperature are neglected.

c) Leaf Water Potential

The measurement of leaf water potential is another indicator of the plants need for water. Lower potentials indicate a greater need for water. Leaf water potential measurement is a destructive procedure that involves the removing a leaf and placing it in a pressurized chamber. The pressure in the chamber is slowly increased until fluid is forced from the leaf stem. The pressure required is a measure of the leaf moisture potential. Care must be taking in carrying out this measurement because leaf age, leaf exposure to solar radiation and time of the day can significantly affect the result. Usually, mature leaves are selected from a specific standardized location on the plants and measurements are made of a particular time of the day. Although commercial instruments for measuring leaf water potential by irrigators is not wide spread. Since considerable time, care and training are required to obtain reliable results.

d) Stomata Resistance

Stomata resistance is an index to the need for water since it is related to the degree of stomatal opening and the rate of transpiration. In general, high resistances indicate significant stomata closure, reduced transpiration rate and the need for water. Commercially available leaf or diffusion promoters are used to measure stomatal resistance. The large amount of time and the increase level of skill required to make and interprete stomatal resistance measurement limit their use to research purpose.

3.2.2 Soil Indicators

Soil based irrigation scheduling involves defer mining the current water content of the soil comparing it with a predetermined minimum water content and irrigating

a) Appearance and Feel Method

With experience, one can judge soil water content by the appearance and feel of the soil. The soil probe (anger) is needed to obtain soil sample from lower portion from the root zone for examination (Tables present guides for judging how much available water has been removed from the soil).

b) Gravimetric Sampling

This is a direct method of measuring the water content of soil samples taken from a field. Samples are weight, dried at 105-110^{o}c and re-weight after drying. Usually 24 hours is required to dry samples to a constant weight. Equation below is used to compute the percentage water content on a dry weight bases.

$$\%MC = \frac{Mwet - Ddry \times 100}{Mdry}$$

On a volume bases it is computed using the following equation

$$\% \text{ Mc by volume} = \frac{\text{Volume of water in soil (vw)} \times 100}{\text{Total volume of soil and soil and voids (vt)}}$$

Example = Given the following data calculate the soil water conContent

Weight of wet soil 100cm^3 soil = 131g

Weight of dry soil 100cm^3 soil = 121g

Solution = $\% \text{ Mc} = \frac{Mwet - Mdry \times 100}{Mdry}$

$= \frac{131 - 121 \times 100}{121}$

$= \frac{10 \times 100}{121}$

= 8.26%

Although the gravimetric method is simple and reliable, the sample is distractive and techniques time consuming. In addition, data are least one day old when they became available for scheduling.

c) Tensiometer

Tensiometer is a ceramic cup filled with water and connected through a wetted filled tube to either a vacuum gange or a mercury monometer. Water moves in and out of the cup in response to changes in soil water conContent. Tensiometer produces measurement of soil water potentials that are related to soil. Tensiometer may interfere with cultivation and can require considerable time for installation and maintenance. In addition, they have a relatively limited range of operation (0- 80 centibars (Pf).

3.2.3 Water Budgeting Techniques

Here you use the pan evaporation data of reference crop evapotranspiration to compute when to irrigate it is similar to soil indicator method. Instead of measuring soil water content, it is computed using the following equation.

$$0i = \frac{0 (I - 1) - 100 (ET - Pe)}{Drz} I$$

Where 0i = soil water in percentage by volume at the end of the I and the i-1 respectively

Pe = Effective precipitation
ET = Evapotranspiration
Drz = Depth of root zone.

Other methods used in determining irrigation scheduling include farmers experience which farmers usually rely on, neuton probe, porous blocks and feeling the soil with hard.

SELF-ASSESSMENT EXERCISE

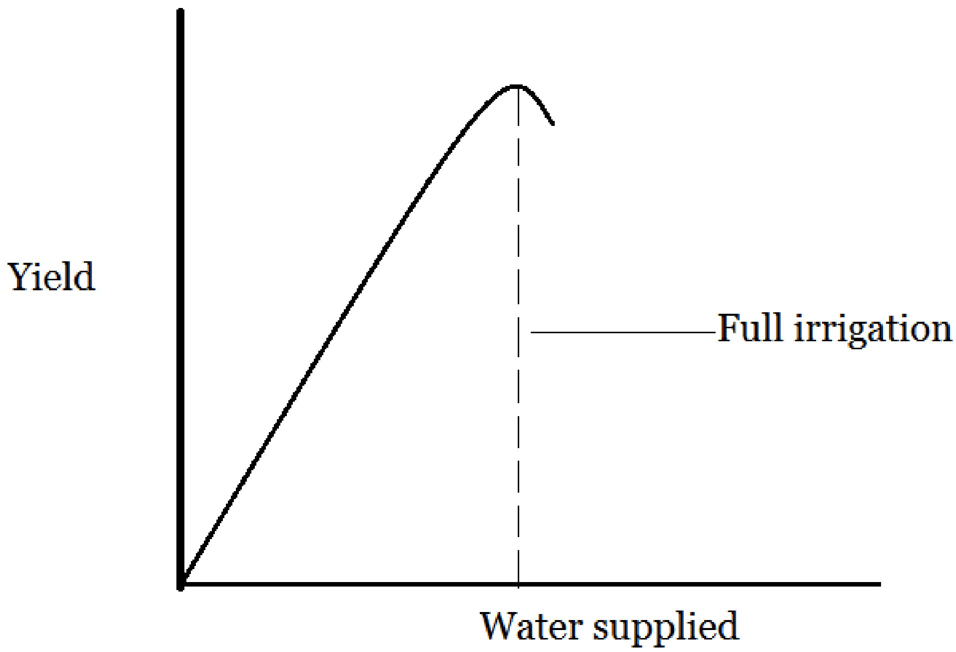
i. Define irrigation scheduling
ii. What are the benefit of irrigation scheduling
iii. List the plant indicator methods used in determining when to irrigate.

3.3 Irrigation Scheduling Strategies

The irrigation scheduling strategies are design to either fully or partially provide the irrigation requirement. They include

3.3.1 Full Irrigation

This involves providing the entire irrigation requirement and result in maximum production as shown in the production function in the figure below.



Exceeding full irrigation reduces crop yield by reducing soil creation and restricting gas exchange between the soil and atmosphere. Full irrigation is economically justified when water is readily available and irrigation costs are low. However, there is no efficient use of water.

3.3.2 Deficit Irrigation

Partially supporting the irrigation requirement is a practice that has been deficit irrigation.

4.0 CONCLUSION

Irrigation scheduling enables you to know when to irrigate and the quantity of water to apply to growing crops at different stages. This makes use of water very efficient and reduces cost of irrigation and also increase yield of farmers.

5.0 SUMMARY

Irrigation scheduling is the determination of when to irrigate and what quantity of water to apply per irrigation. The methods used in determining when to irrigate include, plant indicator, soil neuton probe. Irrigation scheduling strategies are full and deficit irrigation and the benefit of irrigation scheduling are improved crop yield, water and energy conservation and low cost of production or irrigation.

6.0 TUTOR-MARKED ASSIGNMENT

1. Differentiate between plant indicator and soil indicators
2. List the types soil indicators method
3. Explain the soil indicators methods you know

7.0 REFERENCE/FURTHER READING

Larry, G. James. (1993). Principles of farm irrigation. John Wiley and Sons Inc.

UNIT 7 CRITICAL GROWTH STAGES FOR WATER OF DIFFERENT FIELD CROPS

CONTENTS

1.0 INTRODUCTION

Crop require water for their physiological process and where water is in short supply it causes water stress and this lead to wilting and reduction in growth, development and yield of the crop. There are certain stages of the growth of plant that it can withstand water stress and there are certain stages that are critical without water yield is drastically reduced. This stage is called the critical growth stages of a crop or plant. In this unit you will be studying the critical stages for water of different crops.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state critical growth stages of different crops
- state the growth stages affected by irrigation practice
- state crops that do not have critical stage.

3.0 MAIN CONTENT

3.1 Critical Growth Stages Water of Different Crops

Critical growth stage of crop for water is the stage of it growth that water is seriously needed to avoid loss of crop or reduction in yield. At this stage, adequate water is supplied to maximize water use efficiencies so as to increase or maintain the yield potential of the crop. Different crops have different critical growth stages depending on the type of yield of the crop.

The critical growth stages of some crops are listed below.

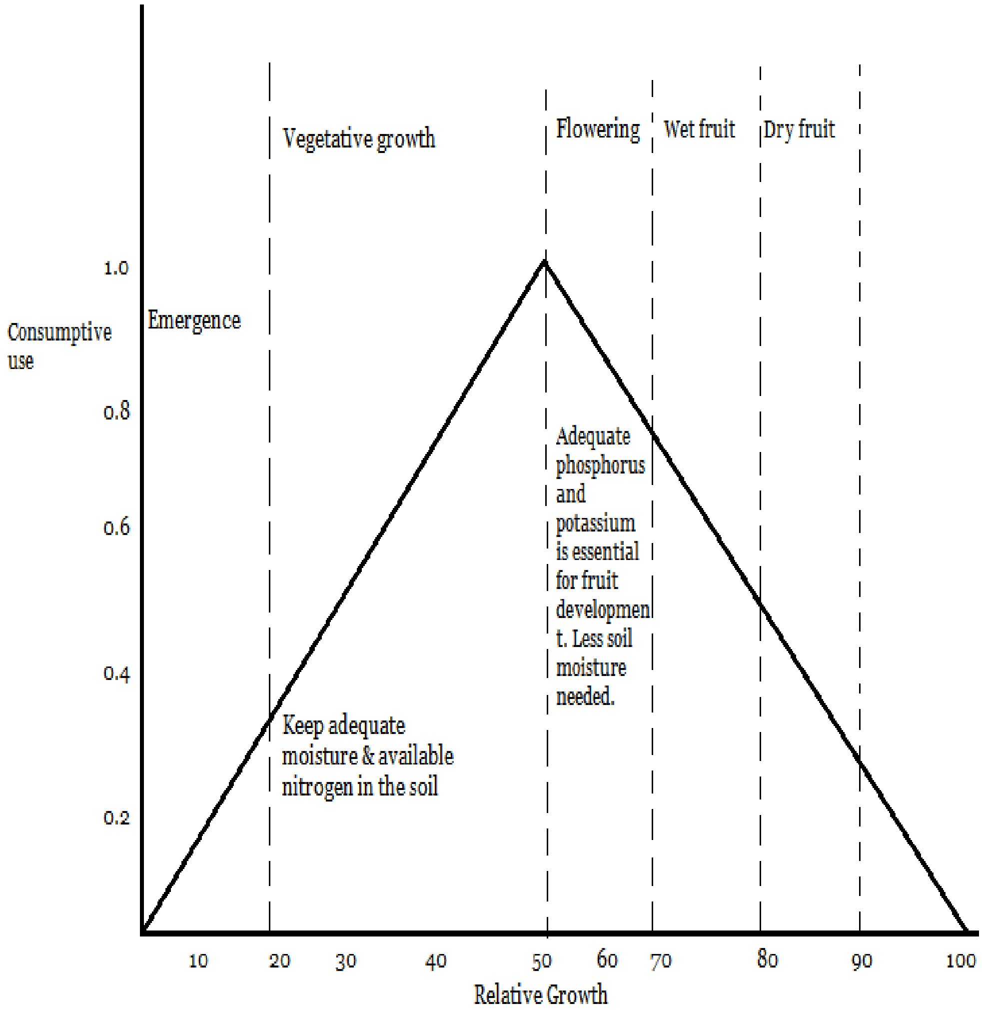
S/N	Crop	Growth period sensitive to water stress	Growth internal in which irrigation produces greatest benefits
1.	Sorghum	Boot heading	Boot to soft dough stage
2.	Wheat	Boot flowering	Jointing to soft dough
3.	Maize	Tassel-pollination	12 leaf to blister kernel
4.	Cotton	At 1st bloom-peak bloom	1st bloom to bolls well formed
5.	Bean	Flowering –early pod fill	Axillary bud-pod fill
6.	Potatoes	Tuberization	Tuberization-maturity
7.	Soya bean	Flowering – early pod fill	Axillary bud-pod fill
8.	Sugarcane	No cirtical stage	
9.	Onions	Bulb formation	
10.	Tomatoes	After fruit set	
11	Fruit trees	Any point during growing season	

3.2 Stages of Growth Affected by Irrigation Practice

Stages of growth affected by irrigation practice growth of plants can be divided into three stages with regard to irrigation practice. These stages are

i. Vegetative stage
ii. Flowering stage
iii. Fruiting stage

The relationship between these three stages of growth to consumptive use (water use for growth and development) is shown in the figure below.



Generalized curve comparing consumptive – evaporation ration to relative growth of crop.

The types of soil also should be considered. Sandy soil will require water frequently (2 times / day) while clay require application once in 2 – 3 days.

Note that during the vegetative stage, consumptive use continuous to increase. Flowering occurs near and during consumptive use peak. The fruiting stage is accompanied by a decree in consumptive use until transpiration essentially ceases during the late part of the formulation of dry fruit. The fruiting stage can be divided into two parts, the wet fruit which follow flowering and the dry fruit stage following the wet fruit growth. Dry fruit is accompanied by a decrease in consumptive use until transpiration ceases and the plant is death. The amount of water applied and the frequency of irrigation most be adjusted to the actual consumptive use of the crop, water holding capacity of the soil and depth of rooting-Naturally, shallow sandy soil will require quite different scheduling irrigation than will be required by deep clay loan soil.

SELF-ASSESSMENT EXERCISE

State the 3 stages of growth affected by irrigation

3.2.1 Irrigation during the Vegetative Stage of Growth

A good moisture supply should be available to plant at all stages of vegetative growth. When vegetation is produced, nitrogen is particularly essential. Light, frequent irrigation are generally desirable because of the need to keep ample moisture in a soil for the relatively shallow root system. For perennial crops with deep root system, less frequent but heavier irrigation are necessary. Wherever excessive temperature exist, frequent irrigation may be desirable for cooling the soil and the plant.

3.2.2 Irrigation during the Flowering Stage of Growth

Since consumptive use is at a maximum during the flowering stage, care should be exercise to ensure adequate moisture in the root zone. How ever, the increased consumptive use is upset by the normal increased depth of root. Deeper roots here a greater root zone depth and hence greater water supply available. When the increasing depth of rooting is considered, the frequency of irrigation for most crops remains reMarkedable constant during the vegetative and flowering period. Best production is obtained, if the crop is kept adequately irrigated during both vegetative and flowering periods.

3.2.3 Irrigation during Fruiting Stage of Growth

The root system is essentially extended to its maximum depth by the time fruiting occurs and the consumptive use has began to degrease reducing the water requirement of the crop and the frequency of irrigation. During production of dry fruits irrigation has essentially ceased. The slight water requirements of the crops are met from the stored water in the soil. The last heavy irrigation should normally be given during the wet fruiting stage so that the deep root will have water available during final development of the fruit. Tubers like potatoes and peanuts required adequate moisture during the entire growth period. Allowing the soil became to dry between irrigation causes uneven tubers. Ample aeration is also essential. For this reason, good potatoes are generally produced on sandy loam soil which can be irrigated frequently without creating a problem. However soil often increase resistant to the growing tuber and thereby restrict growth and result in non-uniform tubers. For this reason, in addition to aeration problems, tuberous crops do better on sandy soils than clay soils. It is good to remember that sufficient moisture most be available to fully developed wet fruit. For example soft fleshy fruits, green peas and grains will not be firm and fully formed unless ample moisture is available. Excessive irrigation during the fruiting stage will stimulate vegetative growth for some crops and result in a reduction in fruiting. For example cotton which is normally planted yearly and is a perennial crop which will start new vegetative growth during the time the cotton is ready for pick.

4.0 CONCLUSION

Apart from knowing the water requirement of crops and irrigation scheduling, there is the need for the farmer to know the critical growth stages of different crops so that water is supplied to the crop to reduce yield reduction or loss.

5.0 SUMMARY

Different crops have different critical growth stages that water must be supplied in the right quantity for optimum production. While the critical growth stages of cereal crops is boot-heading or tussling, tuber crops critical growth stage is the tuber formation stage. There are three stages the plant growth that is affected by irrigation practices and these stages are vegetative, flowering and fruiting stages.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define critical growth stage of crops
2. State the critical growth stages of the following crops Maize, Cotton, Potatoes and Soyabean
3. Briefly explain the three stages affected by irrigation practices

7.0 REFERENCE/FURTHER READING

Larry, G. James. (1993). Principles of farm irrigation. John Wiley and Sons Inc.

UNIT 8 ECONOMIC AND EFFICIENT USE OF WATER

CONTENTS

1.0 INTRODUCTION

Agriculture consumes the largest amount of water less efficiently. If food crisis is to be solved, there is no other alternative than to increase area under irrigation which can be made possible only when we use our present water resources most judiciously for irrigating our agricultural crops. This unit you are about to study deals with the way to economically and efficiently use water to increase crop production while minimizing water wastage.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state the economic use of water
- state the efficient use of water
- calculate water use efficiency, water convey once efficiency, water distribution efficiency etc
- explain guidelines for efficient use of water.

3.0 MAIN CONTENT

3.1 Water Use Efficiency

Since crops require irrigation at different stages, the scheduling of irrigation should be planned very systematically. In the early stages, crop require usually lesser amount of water and any excess water applied is either wasted or propagated through more vegetative growth instead of deeper root penetration. More water is required, in tillering, flower formation and fruiting stages. When the soil is alkaline or saline or if the water contains more soluble salts, water requirement is higher.

Need of water varies according to different seasons, tillage practices, vegetative growth, cropping system and land shapes therefore climatic conditions, genetic variation in plants, agronomic practices, reduction of evapotranspiration and water stress, fertilizer application, plant protection measure including need control becomes the essential aspect in irrigation management.

Water use efficiency (WUE) is the ration of crop yield to the amount of water depleted through evapotranspiration (ET). Water utilization by crop is generally described in terms of kilogram (Kg) of yield per hectare in millimeter in the field. Water use efficiency could be increased either by in creasing the crop yield to achieve an integrated use of productive inputs. Decreasing evapotranspiration requires adaptation of the plant varieties to the micro-environment and other genetic and climatic improvements. Optical irrigation and production efficiency should also be aimed in economic evaluation of water use by crops.

$$\mathbf{WUE} = \frac{\mathbf{crop\ yield}}{\mathbf{ET}}$$

Where WUE is water use efficiency
ET =Evapotranspiration

The genetic variation in plant influence water use efficiency. Those plants with higher rate of photosynthesis usually have higher water use efficiency e.g. maize, sorghum and sugar cane. Most of the pulses, oilseeds and cereals like wheat, barley and oats have lower rates of photosynthesis as well as water use efficiency. It is also found that hybrids and modern varieties have higher rate of water use efficiency, both for agronomic and climatological considerations.

According to the water use efficiency and by comparison among different crops, one may be able to choose the crop to be cultivated. See the table below

S/N	Crop varieties	Water requirement in a typical tract	Yield	Water use effieciency (WUE) per mm of water.
1	Rice	1200	4500	3.7
2.	Sorghum	500	4500	9.0
3.	Maize	620	5000	8.0
4.	Wheat	400	5000	12.5

Productivity of cereals per unit of water

From the above table, wheat has highest productivity, followed by sorghum and rice has the lowest water use efficiency.

SELF-ASSESSMENT EXERCISE

i. Define water use efficiency (WUE)
ii. Give the formular for calculating water use efficiency.

3.2 Guidelines to efficient use

The following are some guidelines for improving irrigation practices for different field crops.

1. Before irrigating, check the soil moisture in the root zone at several locations and estimate the amount of water required to bring the soil to field capacity. The moisture should be close to field capacity throughout the rooting depth.
2. Determine the depth of water applied to the field during irrigation to know whether water covers the rooting depth.
3. Determine whether the water applied correspond with the amount needed by the crop. This help to prevent over and under utilization of water.
4. During irrigation check whether the intake opportunity time is about the same throughout the field. When irrigation is done by the border method, does the water stand about as long at the lower and middle of the field as it does at the upper end? Sprinkler and drip have more uniform water-stand than surface.
5. Observe the amount of irrigation water flowering out of the field as waste. Irrigation water should at all time be evenly distributed to avoid run off as waste.

3.3 Economic Uses of Water

Water provides goods eg drinking water, irrigation water and services (e.g hydroelectricity generation, recreation and amenity) that are utilized by agriculture, industry and household. Provision of many of these goods and services is interrelated, determined by the quality and quality of available water. Water is a “bulky” resource. This means that its economic value permit weight or volume tends to be relatively low. Therefore, its conveyance entails a high cost permit of volume and is often not economically viable over long distance unless high marginal volume can be obtained. The costs of abstraction (removal), storage and conveyance of water tend to be high relative to the economic value that is placed on the use of additional unit of water. This can create values for water that are location specific (located were it is needed). Further characteristics of water are that the quantity of supply cannot be readily specified, it is determined by various processes such as the flow of water; evaporation from the surface; and percolation into the ground. In the case of surface water, supply is determined largely by the climate. Consequently, the quantity supplied is variable and can be unreliable. This can preclude certain uses of water (e.g development of water-dependent industries) and affect the values of water in some uses (e.g irrigation). The quality of water, that is the nature and concentrations of pollutions can be exclude certain uses e.g. drinking water for household use, but have no impact on others e.g. hydroelectric power generation.

Economic use of water can be achieved through modern irrigation techniques to increase farmer's income while reducing cost in respect to irrigate. Irrigated agriculture consumes 80% of the worlds developed water resources. In addition, very poor rate of utilization of surface irrigation methods, which range around 40%, this is continually provoking demands to improve irrigation efficiency by the use of modern technology. Such irrigation demands permits a rate of utilization of 70-80% and that of drip irrigation even reaches efficiencies of more than 90%. However, economic use of water is only partly a question of the techniques applied. It depends to a greater extend on the management of water development and application and on technical, economic and socio-cultural framework conditions. If water resources continue to decline and the cost of water rises correspondingly, a more refined technical method of surface drip irrigation (SDI) may become a serious alternative to conventional irrigation systems.

One of the methods recommended as a means of improving the economic efficiency of water utilization in irrigation farming is simply to curb the water supply. The basic idea behind this method, which is known as deficit irrigation, is to supply less water than would be needed to achieve maximum yield and accept the somewhat lower yield for the sake of avoiding disproportionately high irrigation costs that would be required to saturate the plant growth potentials. In economic terms, cost reduction through deficit irrigation may be geared to maximizing the financial profit per hectare or per cubic metre of water used

4.0 CONCLUSION

Water has always been a vital part of agriculture and the quality and quantity of water used should always be certain to improve its efficient and economic use. In modern times, agriculture is not the largest user of water but is the largest consumer of water and as such should be manage and utilized wisely for the different purposes it is put into.

5.0 SUMMARY

Water use efficiency (WUE) is the ratio of crop to the amount of water depleted through evapotranspiration (ET) and it is given as

$$WUE = \frac{\text{crop yield}}{ET}$$

Where – WUE = water use efficiency
ET = Evapotranspiration

The guidelines for efficient use of water include:

1. Checking soil moisture in the field before irrigation include
2. Determining the depth of water applied in the field whether it covers the rooting zone.
3. Determining the relationship of water supplied with water needed.
4. Amount of irrigation water flowing as waste.

Economic use of water is usually affected by location, quality and quality of water. Location specific create value for water.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain water use efficiency
2. Calculate the water use efficiency given the following crop water requirement and their yield.

	Crop	Water requirement (mm)	Yield
	Rice	1200	4500
	Maize	625	5000
	Wheat	400	5000

7.0 REFERENCES/FURTHER READING

Chendia K.T.C. (2012). Water requirement of different crops. Booklet No 226

FAO (2007). Economic valuation of water resources in agriculture. www.fao.org/docrep/007/cy5582

Peter Wolff and Thomas-M. stein (1999). Efficient and economic use of water in agriculture – possibilities and limits. Natural resources and Development vol 49/50,151-159.

UNIT 9 HYDROLOGICAL CYCLE OR WATER CYCLE AND ROLE OF WATER IN CROP GROWTH

CONTENTS

1.0 INTRODUCTION

The resources use for the irrigation is water which is found on the surface of the earth, sea, dams, river and underground. Water is essential for plants and animals physical, chemical and biological processes of life. This unit you are about to study deals with processes that occur in a cycle called water cycle.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- described water cycle
- give a schematic description of water cycle
- state the processes involved in water cycle
- state the role of water in crop growth.

3.0 MAIN CONTENT

3.1 Hydrological Cycle

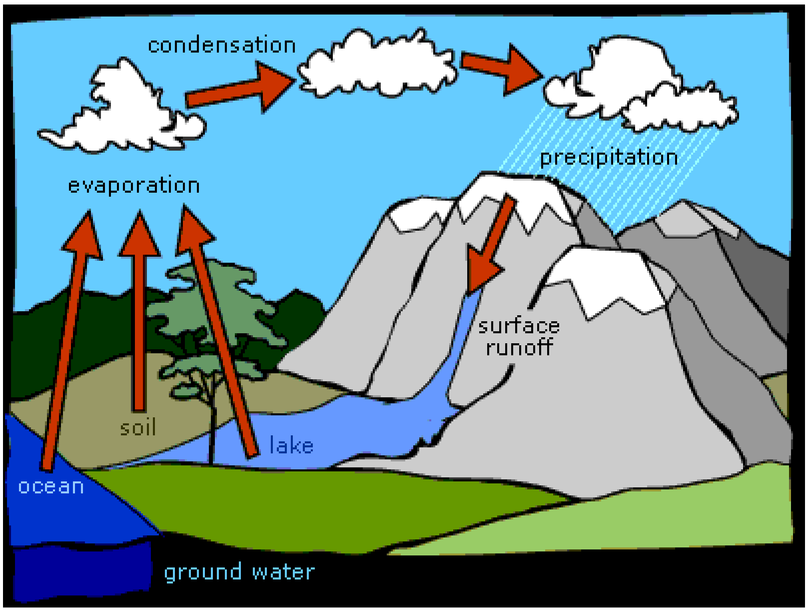
The hydrological cycle also known as water cycle or the H_2O cycle, describes the continuous movement of water on, above and below the surface of the earth. Although the balance of water on earth remains fairly constant over time, individual water molecules can come and go, in and out of the atmosphere. The water moves from one reservoir to another, such as from river to ocean, or from the ocean to the atmosphere, by the physical processes of evaporation, condensation, precipitation, infiltration, runoff and surface flow. In so doing, the water goes through different phases: Liquid, solid (ice) and gas (vapour).

The sun, which drives the water cycle, heats water in the oceans and seas. Water evaporates as water vapour into the air. Ice and snow can sublimate directly into water vapour also. There is also evaporation of water from the soil and plant surfaces which transpire to the atmosphere inform of water vapour. The rising air currents or wind take the vapour up into the atmosphere where cooler temperatures cause it to condense into clouds. Air currents move water vapour around the globe, cloud particles collide, grow and fall as snow or hail, sleet, and can accumulate as ice caps and glaciers, which can store stove frozen water for thousands of years. Most water falls back into the oceans or onto land as rain, where the water flows over the ground as surface runoff. A portion of the runoff enters rivers in valley in the lands cape, with streamflow moving water towards the oceans. Runoff and ground water are stored in freshwater in lakes. Not all runoff flows into rivers as much of it soaks or percolate into the ground as in filtration. Some water infiltrate, deep into the aquifers, which store freshwater for long period of time.

Some infiltration crops close to the land surface and can seep back into surface-water bodies (rivers and ocean) as groundwater discharge. Some groundwater finds opening in the land surface and comes out as freshwater springs in the land surface and comes out as freshwater spring. Over time, the water returns to the ocean, where our water cycle stated.

SELF-ASSESSMENT EXERCISE

i. List the three (3) phases of water
ii. List three (3) processes involved in water cycle
iii. What are the other names of water cycle?



Water cycle

3.2 Role of Water in Crop Growth

Water plays a significant role in the life of both animals and plants. Water is essential for crop production as it is required for germination of seeds and as soon as growth starts water fills a number of important roles in the physiology of the plant; the roles which only water can play as a result of its unique physical and chemical properties include:

- Thermal properties – Temperature regulation
- Solvent properties – Carrier of solutes and nutrients
- Biochemical reaction _ Involved in photosynthesis processes
- Transparency properties – Allows sunlight to penetrate to power photosynthesis in the cells.

A physiologically active plant consist of 60 – 90% of water. Water is required by the plants for the following purposes.

i. Photosynthesis – This is the process whereby plants produce their food (photosynthate) for growth and development using carbondioxide and water in presence of light. The equation is given thus

$6CO_2$ + $6H_2O$ Light energy $\xrightarrow{\quad}$ C6 H_{12}O6 + 60_2
Carbondioxide water chlorophyll Glucose oxygen.

ii. Transport of nutrient and photosynthate – Water is a medium where nutrient absorb from the soil and photosynthate produce from photosynthesis are through the Xylem and Phleom. This is possible because of its solvent property.

iii. Structural Support – Water support the plant in its structure through the different cells in the plant. Water helps to maintain turgor pressure needed to control the opening and closing of stomata.

iv. Transpiration – This is the evaporation of water or loss of water from the surface of the plant to the atmosphere. Water released during respiration escape to the atmosphere via transpiration. Transpiration occurs in plants so as to maintain water balance in the plant system since it continually absorb by the plant root.

4.0 CONCLUSION

Water is essential in the life of plant and animals since it constitute 60 – 90% of their weight. Plants can't survive without water and shortage of water causes the plant wilt and this reduce yield in general. Plant requires water at all stages of growth even though the quantity may vary with the growth stage.

5.0 SUMMARY

Water cycle describes the process that drives the movement of water throughout the hydrosphere. Water has three phases which are liquid, gas and solid. The processes of water cycle include evaporation transpiration, condensation, precipitation, infiltration, runoff and sub surface flow.

Water in plants is about 60-90% and it role in plant growth include photosynthesis, transportation, transpiration structural support and growth.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe water cycle with the aid of a diagram
2. Briefly explain 4 roles of water in crop growth.

7.0 REFERENCE/FURTHER READING

Wikipedia. (2013). The water cycle.

UNIT 10 AGRONOMIC PRACTICES OF IRRIGATED CROPS AND PROBLEMS ASSOCIATED WITH IRRIGATION

CONTENTS

1.0 INTRODUCTION

Crops, whether rain fed or irrigated, are usually planted on the field and they are taken care off from the establishment up to harvesting and processing before they are finally consumed by the consumer. Irrespective of the time of planting, the care of crops is the same except for some crops that may need special practices during the course of their growth. The agronomic practices of irrigated crops would be the main focus of the unit.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state the agronomic practices of irrigated crops
- explain the agronomic practices of some irrigated crops
- explain the production of irrigated crops
- explain the problems associated with irrigation.

3.0 MAIN CONTENT

3.1 Agronomic Practices of Irrigated Crops

Agronomic practices are the care carried out on planted crops before, during and after establishment of the farm. All crops require some kind of agronomic practices and crops that can be irrigated are of no exception. The agronomic practices of some irrigated crop are discussed below.

3.1.1 Cabbage

Scientific name: *Brassica oleracea* var. *capitata*

Family: *Brassicacae* or *Cruciferae*

Cultivars: Sugarloaf, Drumhead (flat), Cape spitskool. Also consult the seed retailers

Soil: Cabbages will grow in most well-drained soils that are high in organic matter. Optimum pH 5.5-6.1. When pH falls below 5.5, lime should be applied a month before planting

Climate: Cabbage can be grown throughout the year, with the exception of some areas. Cool, moist weather conditions produce the best crops. Mature plants can tolerate temperatures of -3°C, but prolonged low temperatures in the range -1-4°C will induce bolting resulting in seed production. The optimum temperature is 18°C, with a maximum of 24°C and an average minimum of 4.5°C. Very wet conditions followed by dry periods results in head bursting. Under warm summer conditions the plants are more susceptible to aphid infestation and cabbage diamondback moth. Both pests require routine control. Bacterial black rot is common in summer

Land preparation
Land preparation for sowing involves land clearing and tillage. Land clearing may be done manually (using machete, hoe), mechanically (using bulldozers!, stumper) or chemically (using non-selective herbicides in zero or no-tillage system). After clearing, tillage is done. Tillage involves the turning of the topsoil either manually (traditionally, minimum tillage) mechanically (conventional tillage), essentially targeted at creating a favourable environment for crop establishment. Primary tillage loosens the soil and mixes in fertilizer and/or plant material, resulting in soil with a rough Contenture. Secondary tillage produces finer soil and sometimes shapes the rows. It is done by using various combinations of equipment such as mouldboard plough, disc plough, harrow, dibble, hoe, shovel, rotary tillers, subsoiler, ridge- or bed –forming tillers, and rollers.

Seed amount: 450 g/ha

Seedbeds: 5 beds of 10 m x 1 m each will cater for 1 ha Mix 60 grams of Compound fertilizer (N:P:K) per m^2 into the seedbed soil

Transplanting: After 4-6 weeks, during the cooler period of the day

Spacing: 45-60 cm between the rows and 30-45cm within the row, giving a plant population of 49300-74000 plants/ha

Planting time: All the time of the year
Growth period: Seedbed: 4-6 weeks. In the field: 4-5 months depending on the variety.

Fertilizers: organic fertilizers are best used for this vegetable. However, N:P:K 15:15:15 at the rate of 50kg/ha can be applied to enhance vegetative growth.

Harvesting: Harvesting is done by selecting those heads that are firm, although hybrid cultivars will be ready almost at the same time

Expected yield: Greater than 25 tons/ha, depending on the cultivar and management

Pests:

- **Aphids:** *Symptoms*: Poorly-developing leaves, curling inside covering a clusters of aphids

Control: Use Dimethoate 40 EC, at 10 ml/10 litres of water, when the insects have been observed on a few plants

- **Spider Mite:** *Symptoms*: Little red mites, mostly on the underside of the leaves forming small webs, making leaves dry and stem curly in later stage

Control: Use Nuvacron 40, at 50 ml/10 litres of water, when first signs are detected

- **Diamondback Moth**:*Symptoms*: Small green caterpillars are observed often covered in a web, eating leaves

Control: Use Carbaryl 85% WP, at 20 g/10 litres of water

Diseases:

- **Damping Off**: It is caused by *Rhizoctonia, Pythium, Phytophtora* and *Fusarium. Symptoms*: Bottom of seedling is pinched, followed by wilting. *Control*: Pre-dust seed with Thiram. Avoid over-watering while on the seedbed
- **Downy Mildew**: *Symptoms*: Seedlings show white moulds halfway up the stem; leaves show watery spots on the underside when held against the sunlight and white spots on the upper side

Control: Prevention: dust seed with Thiram. Prevention and cure: routine spray Ridomil MZ 72, at 25 g/10 litres of water, on crops grown between February and April as well as in areas were the disease is common

- **Black Rot**: Caused by the bacteria *Xamthomonas campestris*

Symptoms: Brown spots on the outside areas of the leaves and black spots on stems

Control: Possible by antibiotics, since it is a bacterium, but they are expensive. Use Copper Oxychloride 85%, at 40 g/10 litres of water, to suppress, when the first signs of the disease are observed

- **Soft Rot**: *Symptoms*: Rotting of leaves and stem. Very bad smell, especially during rainy season

Control: No control possible

SELF-ASSESSMENT EXERCISE

i. Explain the agronomic practices of cabbage
ii. State the diseases of cabbage

3.1.2 Tomato

Scientific name: *Lycopersicon esculentum (L.)*

Family: *Solanaceae*

Varieties: Roma, Rossol, Floridade, Rodade, Money maker, Red Khaki, Heinz,Ife plum, Ronita,Marglobe, Valiant, Ibadan local etc

Determinate varieties typically spread laterally and therefore do not need staking. Determinate tomato plants also tend to ripen together, a good choice if intending to process or canned the tomatoes. Indeterminate varieties continue to grow and therefore the need to be staked or trellised for best production

Soil: Tomatoes can grow well in a wide range of soils from sandy-loams to clays. Soil depth should be 60 cm and the soil well-drained. Growth is best in lighter soils, sandy loams to clay loams. Heavy soils that get waterlogged during the rainy season must be avoided. Optimum soil pH 5-6.5. Apply lime when pH falls below 5.

Climate: Temperature: Tomatoes are very frost sensitive and require warm weather for 4.5 months. Seed germinates best at temperatures between 15-25°C. Maximum growth for both vegetative and fruiting occurs when minimum day temperatures do not fall below 21°C and minimum night temperatures do not fall below 15°C. High day temperatures cause blotchy ripening and soft fruit. Low temperatures increase the incidence of badly-shaped and poor quality fruit. Temperature is an important factor influencing fruit set. Best results are achieved when temperatures are between 18-20°C. Tomato is not a day-length sensitive crop.

Land preparation

Land preparation for sowing involves land clearing and tillage. Land clearing may be done manually (using machete, hoe), mechanically (using bulldozers!, stumper) or chemically (using non-selective herbicides in zero or no-tillage system). After clearing, tillage is done. Tillage involves the turning of the topsoil either manually (traditionally, minimum tillage) mechanically (conventional tillage), essentially targeted at creating a favourable environment for crop establishment. Primary tillage loosens the soil and mixes in fertilizer and/or plant material, resulting in soil with a rough Contenture. Secondary tillage produces finer soil and sometimes shapes the rows. It is done by using various combinations of equipment such as mouldboard plough, disc plough, harrow, dibble, hoe, shovel, rotary tillers, subsoiler, ridge- or bed –forming tillers, and rollers.

Humidity: Hot dry spells, followed by heavy rain, cause the ripening fruit to crack. Moist overcast weather conditions cause fruit splitting, foliar and fruit diseases and delayed ripening

Seed amount: A hectare will require about 160 g of seed/ha

Spacing: *Determinate*: 1 m between the rows and 30 cm within the row
Indeterminate: 1-1.2 m between the rows and 30-45 cm within the row

Planting time: Best period is March to November. Tomato is transplanted after 6-8 weeks in the nursery. Tomatoes can be transplanted deeper than the original soil marked level. Seedling trays give the best crop since it suffers less from transplant shock

Cultural practices: For all indeterminate varieties it is best to stake or trellis the plants, so as to get the best quality and yield. Removing side branches to leave only one or two improves fruit size, quality and facilitates spraying and harvesting. Determinate varieties can also be trellised if the farmer is aiming for high quality, but the material required is less than for the indeterminate types

Trellising/Staking methods:

- Poles
- Strong poles and 2 or 3 horizontal wires
- Strong poles, 1 top horizontal wire and strings to suspend the plants on the wire. Length of poles 1.5 m, buried 0.30 m.

Growth period: Tomatoes can last a total of 6 months from sowing to harvesting, depending on cultivar, management and growing conditions.

Fertilizers: Apply N;P;K 15:15:15 at the rate of 50kg/ha.

Harvesting: Harvest starts 4 months after transplanting. It is usually harvested by hand picking of the ripe fruits.

Expected yield: 30 tons/ha or more, depending on the cultivar and management.

Pests:

- **Red Spider Mite**: Small reddish mites on the underside of the leaves, sucking the plant sap.

Symptoms: Curled leaves, with silver spots and the plants look yellowish
Control: Spray Metasystox 25 EC, at 10 ml/10 litres of water, when first insects appear.

- **Thrips**: *Symptoms*: Silverish mottling of the leaves.

Control: Spray Malathion 50 WP, at 10 g/10 litres of water, when first observed.

- **Nematodes:** *Symptoms*: Individual plants here and there in the field look stunted and knots and malformed roots.

Control: Field treatment difficult and expensive. To use a 4-year rotation with nonsensitive crops.

Diseases:

- **Leaf Blight** One of the most devastating diseases of tomato, enhanced by high relative humidity *Phytophtora* sp.: (>70%) and day temperatures between 22-25°C.

Symptoms: Brown necrotic spots on the leaves starting from the top of the leaves; on the underside the leaves are covered with a white mycelium; brown to black spots on the stem and fruit, as if attacked by frost. The disease spreads very fast within a week.

Control: Is usually late, but remove all infected branches and spray with Bravo 500, Milraz 76 WP or Dithane M45, at 20 g/10 litres of water, alternating with Ridomil MZ 72, at 35 g/10 litres of water, routine spraying is advised.

- Early Blight Conditions which are wet, with high relative humidity and temperatures 24-28°C.

Alternaria solani: *Symptoms*: On young plants in the seedbed are long, zoned spots on the lower stem. On the leaves brown zoned spots surrounded by a yellow halo. It also can attack the stems and fruits.

Control: Same as for Late Blight

- **Wilts**: Can be caused by several micro-organisms: *Fusarium oxysporum*, takes 2 weeks to develop, *Rhizoctonia solani*, takes less than a week to develop, and *Verticillium dahlia.*

Symptoms: Observed when one cuts through the stem: the vascular bundles are brown. One side of the plant dies.

Control: Heat treatment of seed as well as dipping the seedlings in a Thiram solution at transplanting.

- **Bacterial Canker**: Caused by *Corynebacterium* sp.

Symptoms: Seen when the vascular system is observed: it is brown. A cut stem put in water will produce a milky ooze out of the cut end.

Control: No control available, except hygiene and heat-treating the seeds.

- **Leaf Spot**: Starts 1 week before flowering.

Symptoms: Necrotic spots on the leaves, the inner part is whitish.

Control: Routine spray Dithane M45, at 25 g/10 litres of water, or Copper Oxychloride 80%, at 50 g/10 litres of water.

- **Mosaic viruses**: *Symptoms*: Stunted plants, with curled leaves, light green in colour, flowers dropping and brown spots on the fruit.

Control: Spray against the insects that spread the virus vectors, like white fly (*Bemisia tabaci*). Spray Cymbush 20 EC, at 50 ml/10 litres of water, or Metasystox 25 EC, at 10 ml/10 litres of water, or Parathion or Malathion and or Decis routine spray recommended.

3.2 Problems associated with irrigation

Irrigation has numerous advantages to the crops, farmer and his immediate environment. However, it is associated with some problems that can make irrigation to have negative effect. The problems associated with irrigation include:

1. Build up of pests and diseases
2. Seasonality of sources of water
3. High cost of equipments
4. High cost of installation of the systems
5. Requires the services of skilled personnel
6. Topography of the land

4.0 CONCLUSION

The success of any crop production is dependent on the management of the agronomic practices carried out on the crop. A well managed crop gives better yield while a poorly managed crop gives poor yield. Farmers should always adhere and uses best agronomic practices for a crop so as to have potential yield of the crop.

5.0 SUMMARY

Agronomic practices are usually carried out on crops for better yield irrespective of the time of planting. The agronomic practices carried out on irrigated crops include land preparation, climatic and soil requirements, planting, weeding, fertilizer application, pest and disease control as well as harvesting of a crop. The agronomic practices of cabbage and tomato are discussed

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the production of tomato under its agronomic practices
2. Explain the problems associated with irrigation
3. State the diseases of tomato, their symptoms and control

7.0 REFERENCES/FURTHER READING

Andreas P. Savva and Karen Frenken (2002). Agronomic Aspects of Irrigated Crop Production. Fabeon Chigumira, Harare.

Ogiever Erebor (2003). Comprehensive Agricultural Science for Senior Secondary Schools. A. Johnson Publisher Limited.

UNIT 11 IRRIGATION RESOURCES IN NIGERIA

CONTENTS

1.0 INTRODUCTION

Irrigation is the artificial application of water to the surface of the soil in order to create conducive atmosphere for the growth and survival of plants. This is usually done during dry season and period of drought or rain storage during rainy season. In this unit, you will be studying irrigation resources in Nigeria that provide water for irrigation scheme in the country.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state the different irrigation resources in Nigeria
- estimate the quantity of different irrigation resources in Nigeria.

3.0 MAIN CONTENT

3.1 Irrigation Resources in Nigeria

The earth estimated to have about 1386, 000,000 km^3 volume of water with 97.22% of it in oceans, 2.1% in glaciar and iceberg and about 0.03% of water circulated annually by precipitation, transpiration and evaporation. This 0.03% is the critical amount that includes snow end rain, flowing surface water, under ground recharged water (percolation water) and atmospheric evaporative water vapour. This natural water circulation is called the hydrologic cycle or water cycle.

Nigeria's total annual renewable water resources are estimated at 286.2km^3 Annual internally produced resources amount to 221 cubic kilometers (Km^3), made up of 214km^3 surface water and 87km^3 ground water, while 80km^3 of the latter is assumed to be overlap between surface water and ground water. External water, resources (coming from other countries) i.e. water that is coming from Niger, Cameroon and Benin. Exploitable surface water resources are estimated to be 80 percent of the natural flow, which is about 97km^3 / year. Annual extractable ground water resources are about 59.51km^3, distributed as follows 10.27km^3 in the south. Dam capacity is estimated to be 44.2km^3.

Total annual water withdrawal was estimated at 8.km^3 for the year 2000. Agriculture was the biggest water user with 5.5km^3 or 69% of the total water withdrawal, followed by the domestic sector with about 1.7mk^3 (10 percent).

3.1.1 Surface Water

These are cheaper and easier to use as compare to ground water. The composition of surface water varies with the terrain through which the water slope because the dissolving mineral that that enters that water varies. The kinds and amount of material that are dissolved in surface water exhibits extreme variations. The composition of surface water is often critical to the uses that can be made of it. There are four principal surface water basins in Nigeria namely:

a. The Niger Basin has an area of 584,193 km^2 within the country, which is 63 percent of the total area of the country, and covers a large area in central and northwestern Nigeria. The most important rivers in the basin are the Niger and its tributaries Benue, Sokoto, and Kaduna.
b. The Lake Chad Basin in the northeast with an area of 179,282 km^2, or 20 percent of the total area of the country, is the only internal drainage basin in Nigeria. Important rivers are the Komadougou Yobe and its tributaries Hadejia, Jama'are, and Komadougou Gena.
c. The southwestern littoral basins have an area of 101,802 km^2, which is 11 percent of the total area of the country. The rivers originate in the hilly areas to the south and west of the Niger River.
d. The southeastern littoral basins, with the major watercourses being the Cross and Imo Rivers, have an area of 58,493 km^2, which is six percent of the total area of the country, and receive much of their runoff from the plateau and mountain areas along the Cameroon border.

SELF-ASSESSMENT EXERCISE

i. State two sources of irrigation resources
ii. State the 4 principal surface sources of water in Nigeria

3.1.2 Ground Water

Most of the recent increase in irrigated land area has been possible because of a greater use of ground water. The ground waters are water found in under ground reservoir in the deeper stratum and substratum. These underground reservoirs are usually found in porous rock formation called aquifers. Most aquifers extends from few kilometers to 20 or 30 km long but may connect for 100th of km. these porous strata can be sand gravel, porous sand stones and channel in partly dissolved limestone. Ground water generally has a more constant temperature, less sediments and less dissolved materials. However, drilling wells and pumping to lift water from ground water reservoir are must more expensive than the surface reservoirs.

Nigeria has extensive groundwater resources located in eight recognized hydrological areas together with local groundwater in shallow alluvial (fadama) aquifers adjacent to major rivers. They are:

a. The Sokoto Basin Zone comprises sedimentary rocks in northwest Nigeria. Yields range from below 1.0 to 5.0 liter per second (L/s).
b. The Chad Basin Zone comprises sedimentary rocks. There are three distinct aquifer zones: Upper, Middle and Lower. Borehole yields are about 1.2 to 1.6 L/s from the Upper unconfined aquifer and 1.5 to 2.1 L/s from the Middle aquifer.
c. The Middle Niger Basin Zone comprises sandstone aquifers yielding between 0.7 and 5.0 L/s and the Alluvium in the Niger Valley yielding between 7.5 and 37.0 L/s.
d. The Benue Basin Zone is the least exploited basin in Nigeria extending from the Cameroon border to the Niger-Benue confluence. The sandstone aquifers in the area yield between 1.0 and 8.0 L/s.
e. The Southwestern Zone comprises sedimentary rocks bounded in the south by the coastal Alluvium and in the north by the Basement Complex.
f. The South-Central Zone is made up of Cretaceous and Tertiary sediments centred on the Niger Delta. Yields are from 3.0 to 7.0 L/s.
g. The Southeastern Zone comprises Cretaceous sediments in the Anambra and Cross River basins. Borehole numbers are low due to abundant surface water resources.
h. The Basement Complex comprises over 60 percent of the country's area. It consists of low permeability rocks and groundwater occurs in the weathered mantle and fracture zones with yields of between 1.0 and 2.0 L/s.

4.0 CONCLUSION

Nigeria has a well drained network of rivers and streams and extensive underground resources that provide the surface water for irrigation. This irrigation resources cover the whole country and if well tapped can increase food production that would lead to food security and poverty eradication among the rural populace.

5.0 SUMMARY

Nigeria is bless with irrigation resources in form of surface water and underground water totaling on estimated of about $286.2km^3$ made up of $214km^3$ surface water and $87km^3$ underground made up of 214 km^3 surface water and $87km^3$ under ground water. There are four principal surface water basins in Nigeria which are Niger basin, Lake chad basin, southwestern Littoral basin and south eastern littoral basins. The under ground water are located in eight recognized hydrogeological areas namely: Sokoto basin zone, chad basin zone, middle Niger basin zone, Banue basin zone, Southwestern zone, South central zone, Southeastern zone and the basement complex.

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly describe the irrigation resources in Nigeria
2. List the four principal surface water basin.
3. List the eight recognized hydrogeological underground water resources in Nigeria.

7.0 REFERENCES/FURTHER READING

Cuter J. Cleveland. Retrieved January 22, 2nd 2013. wwweoearth.

FAO (2008). Water profile of Nigeria. In: Encyclopedia of earth. Eds. org/article/water profile of Nigeria.

UNIT 12 MAINTENANCE OF IRRIGATION EQUIPMENTS

CONTENTS

1.0 INTRODUCTION

Irrigation is the artificial application of water to the surface of the soil to supply moisture to plants, soften tillage and cool the environment. This is done through irrigation systems which could be surface, subsurface, sprinkler or drip depending on the farmer's financial strength, the crop to be planted and the terrain of the land. For the irrigation systems to function continuously there is the need for maintenance culture on the irrigation system otherwise there would be system failure. In this unit, you will be studying the maintenance of irrigation equipments.

2.0 OBJECTIVES

At the end of the unit, you should be able to:

- define maintenance
- state the types of maintenance
- explain the types of maintenance
- state the effects of poor of maintenance
- state the care of irrigation equipments.

3.0 MAIN CONTENT

3.1 Maintenance of Irrigation Equipment

Maintenance is the tasks to be done to keep an irrigation system in a good working order or condition while system operation refers to practices of running irrigation systems to ensure that irrigation is effective, water is not wasted and the system is sustainable.

- What needs to be maintained in irrigation system include ;
  - Pumping units,
  - Buried pipelines,
  - Hydrants,
  - Lateral pipes and accessories,
  - Sprinkler nozzles ,
  - sprinkler heads,
  - Canals and other infrastructure such as night storage dams,
  - Electrical wires/ Cables,
  - Suction side

3.2 Types of Maintenance Activities

There are three types of maintenance activities that are carried out on irrigation equipments. They are:

- Routine maintenance.
- Emergency works.
- Deferred maintenance / Scheme improvement.

3.2.1 Routine Maintenance (normal)

- Activities that have to be repeated throughout the lifetime of an irrigation scheme to keep it functioning.
- Includes all work necessary to keep the irrigation system functioning satisfactorily and is normally done annually.
- Some activities are daily routines which do not require special skills

Activities which do not require special skills:

- Greasing of gates;
- Removing vegetation from embankments, canals and drains;
- Removing silt from canals drains and structures.
- Whenever possible, should be done by the farmers

Routine maintenance activities require skilled artisans

- Repairs to gates and measuring structures;
- Repainting of steel structures;

- Installation of water level gauges;
- Maintenance and small repairs of pumps and engines.

Larger routine maintenance jobs done between irrigation seasons

- Major repair or replacement of gates, pumps, and engines;
- Large-scale silt clearance from canals and drains;
- Large-scale maintenance of roads and embankments.
- For very large or difficult jobs, may need to hire a contractor.

3.2.2 Emergency Works/Special Maintenance

Immediate action to prevent or reduce the effects of unexpected events such as:

- Breach or overtopping of canal embankment or river dike, causing flooding;
- Critical failure of pumps or head-works, causing interruption of irrigation water supply;
  - Natural disasters such as floods, earthquakes or cyclones.
- Unforeseeable nature makes it very difficult to take specific preventive action.
- General safeguards be installed in prone areas, - a "special reserve fund" or budget allocation should be established for repair work.
- Operational staff be trained so that they know what to do when disaster occur – e.g cutting off the power to a overheated pump, closing the head-works in case of a canal breach.
  - Good communication system required

3.2.3 Deferred Maintenance/Scheme Improvement

- Work done to regain the lost flow capacity in canals, reservoirs and structures when compared to the original design.
- Includes large modifications to the canal system and structures arising from important changes (cropping patterns, drainage problems, etc.)
- Difficult to differentiate between so-called 'deferred maintenance' and a 'rehabilitation programme'.
- ‘Deferred maintenance‘ - undertaken with funds from the national budget allocated to operation and maintenance - rehabilitation programmes - an investment and the funds come from a loans, national development

SELF-ASSESSMENT EXERCISE

i. Define maintenance and system operation in irrigation

ii. State the routine maintenance that does not require a skill personnel

3.3 Care of Irrigation Equipment

- Storage of poly pipes (HDPE), and If necessary, pipes should be rolled up carefully to avoid damaging the pipes.

- Lateral pipes especially HDPE, should be laid on a specially build frame/ rack or on a place where there are fully supported to avoid permanent sagging.
- Sagging results in pipes leaking during irrigation sessions.

- **Laterals**: Aluminium pipes should not be dragged along the ground as this would result in damage and besides that, soil would enter the pipes.
- Care should also be taken when the pipes are moved in an area with electricity lines, to ensure that there is no contact with the lines.
- **Rubber seals, rings and hooks**, Portable aluminium pipes are connected through couplings with rubber rings in order to ensure watertight connections.

These rings have a lifespan of about two years and need to be replaced accordingly.

- Drag hose, hose and riser assembly. Their life expectancy is about eight years. However, at times perforations or cuts occur during cultivation. In this case, line joiners can be used to repair the hoses.
- Rubber flap of the riser assembly which, depending on quality, can last about five years, also requires regular replacement.
  - The same holds true for the garden tap rubber or leather seal.
- **Sprinklers.** All nozzles are replaced at least every two years (four seasons).
- Worn out nozzles should be replaced in order to maintain the correct flow and distribution of water from the sprinklers,
- The tension of the sprinkler spring and the wear of some of the plastic seals also require attention as this may cause sprinkler malfunction,

- It is therefore necessary that every four to five years the sprinklers are taken to the supplier for an overall check-up.
- Regular inspections of sprinkler heads for example before use and during irrigation help to identify malfunctioning sprinkler heads.
- **Hydrants.** Rubber seals should be inspected for leakages; worn out rubber seals should be replaced.
- **Buried pipelines.** Inspections should be carried out for leaking sections and exposed sections which are vulnerable to fires, traffic, weather elements and vandals,
- **Gate/ isolation valves**. Isolation valves, when unused for long periods, get stuck to the opening position and cannot be closed any more for the purpose of isolating the areas of breakages from other areas. This causes the whole system to be down, until repairs are made for minor breakages. It is therefore necessary that once a month all isolation valves are checked by opening and closing as well as lubricated.
- **Canals and other infrastructure such as night storage dams-** require regular inspections and maintenance in order to identify and remedy leakages and seepages, silting , vegetation growth etc,
- **Pumping units.** (Gland packing, oil, bearings, shafts, alignment). Pump motor should also not be exposed to water.
- **Electrical wires/ Cables**. Regular inspections required to identify naked or exposed wires , loose connections sagging wires, tree interference with cables or LT lines, etc,
- **Suction side.** Attention should be given and maintenance should be carried out on foot valves, suction baskets, silt in suction chambers/ sump, etc).

3.4 Effects of Poor Maintenance

- Leaks can result in water logging in some places in the field crops in such areas are usually over irrigated resulting in nutrients and fertilizers being leached.
    - This leads to yield reduction,
- Leakages and blockages (due to e.g. silt and vegetation) can result in poor system performance such as reduction in the delivered water which implies reduced amounts of water reaching the crops; hence crops can suffer from moisture stress which results in reduced yields,
- Vegetation, water logging and marshy conditions encourage the proliferation of disease causing organisms such as mosquitoes and snails. Hence out breaks of diseases such as malaria and bilhazia may occur.

- This affects production due to down time resulting from illness.
- Expenses will also be incurred in seeking medication for the affected work force.
- System breakdowns usually at critical stages are likely to happen due to lack of maintenance.
- The breakdowns are usually expensive and time consuming to repair. Crop failure may occur as a result of this.

4.0 CONCLUSION

The effectiveness of irrigation system depends on the maintenance of the system during and after operation as such all maintenance culture or guidelines on irrigation equipment should be adhered to at all times by the farmer. This would increase water use efficiency and increase yield of crop grown.

5.0 SUMMARY

Maintenance of irrigation equipments is the tasks to be done to keep an irrigation system in a good working order/condition. The types of maintenance carried out on irrigation equipments are;

- Routine maintenance.
- Emergency works.
- Deferred maintenance/Scheme improvement

Poor maintenance of irrigation equipments can cause system leakage or breakdown/blockage, inefficient water use and eventually yield reduction.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the three types of maintenance
2. State the care of irrigation equipments
3. State the effects of poor maintenance

7.0 REFERENCE/FURTHER READING

Mufute, N.L. (2012). General guidelines on the maintenance of irrigation equipment. Midlands State University.

UNIT 13 IRRIGATION SYSTEMS OR TECHNIQUES

CONTENTS

1.0 INTRODUCTION

Irrigation is the artificial application of water to the crop for the purpose of providing moisture required for it growth. An adequate water supply to the crop is important for it growth and the quantity required by crops varies and should be met for optimal production. Various methods can be used to supply irrigation water to the crops and each method has its advantages and disadvantages which should be taken into account when choosing the method which is suited to the local circumstances. This unit will deal with the various method or system of irrigation that can be used to apply irrigation water to crops.

2.0 OBJECTIVES

At the end of the unit, you should be able to:

- state the different types of irrigation system
- explain the types of irrigation systems
- state the advantages and disadvantages of each system
- state system that suit different crops and topography.

3.0 MAIN CONTENT

3.1 Irrigation Systems

The principal function of irrigation system is to supply crops with irrigation water in the quantity and at the time it is needed. Specific functions include diverting water from the source, conveying it to individual field within the farm, distributing it within each field and regulating flow.

3.2 Types of Irrigation System

There are several ways of directing, conveying and applying irrigation

3.2.1 Diversion Methods

There are two primary ways of diverting surface and underground water.

a. **Gravity method** – Water is admitted from open water source into the farm channels and pipelines by gravity.
b. **Pump methods** – This involves the use of centrifugal pumps to divert water from the source. The source of power usually is electrical motors and internal combustion engine.

3.2.2 Conveyance Method

Water is conveyed from the source to cropped areas of the farms in networks of open channels and for pipelines. Open channels may be lined or unlined and pipelines partially open to the atmosphere or pressurized.

a. **Open Channels** – They are usually graded in the direction of flow and may be either lined or unlined. They are used with surface and ground water sources and farm application systems. Open channels and lined with hard surface lining such as concretes, asphalts and soil sealants to reduce maintenance cost, channels size and seepage losses through the channels beds and walls. Unlined ditches are used because of their low capital cost and eased of constructions and demarcation.

b. **Pipelines** – on farm, pipe networks are classified as open (low head) or close (pressurized) depending on whether the system is open to the ground surface or buried. Surface pipelines can be placed below the tillage zone to minimized damage by machine

SELF-ASSESSMENT EXERCISE

i. Define irrigation systems
ii. State the methods of water diversion in irrigation systems

3.2.3 Application Systems

Application systems or irrigation system is the application of the irrigation water directly to the crop. Application systems differ with soil and sub soils, topography, nature of water supply, size of farm land and crop grown. There are basically three application systems. They are.

i. Surface irrigation system
ii. Sprinkler irrigation system
iii. Drip or trickle irrigation system.

3.2.3.1 Surface Irrigation

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

3.2.3.1.1Basin Irrigation

Basins are flat areas of land, surrounded by low bunds. The bunds prevent the water from flowing to the adjacent fields. Basin irrigation is commonly used for rice grown on flat land or in terraces on hill sides. Trees can also be grown in basins, where one tree is usually located in the suitable for crops that are unaffected by standing water for long period.

3.2.3.1.2 Furrow Irrigation

In this type of irrigation, water is allowed to flood through the furrows (inbetween ridges) so that the water wet the ridges gradually. This is done along a gentle slope to avoid the risk of erosion. This type of irrigation can be applied to crops that are grown on ridges.

3.2.3.1.3 Border Irrigation

This method consists of dividing a field into long narrow plots by low bunds extending in the direction of the slope. The bed of each field is level from side to side and water lows down the slope of the border, guided by the bunds on either side. The size of the strips and the quantity of water let in would depend upon the nature of the soil and crop. Surface irrigation system generally require small initial investment (except when excessive land smoothing is required), more labour intensive and applied water less efficiently than other types of irrigation systems surface irrigation system are best suited to soil with moderate to low infiltration capacity (permeable soil) and land with relatively uniform terrain and stop less than 2%.

3.2.3.2 Sprinkler irrigation system

Sprinkler irrigation is similar to natural rainfall. Water is pumped through a pipe system and then sprayed onto the crops through rotating sprinkler heads. Sprinkler irrigation system apply water effectively, here relatively high capital cost, low labour requirement and used more energy than other application methods. Sprinkler irrigation is adapted to many soils and can be successfully be used to irrigate:

a. Permeable soils that is difficult to irrigate using other application system.
b. Lands with combination of shallow soils and terrain that prevent proper land smoothening needed for other irrigation system.
c. Land having step slope and easily erodible soil
d. Undulating terrain that will be too costly to smooth for use with other irrigation system.

Sprinkler irrigation can be used for frost protection fertilizer and chemical application, wind erosion control, crop and soil cooling, delaying fruit and bud development and use for germinating seeds.

3.2.3.3 Drip or Trickle irrigation system

Drip irrigating system is the frequent, slow application of water either directly onto land surface or into the root zone of crops. It is based on the fundamental concept of irrigating only the root zone of crops rather than the entire land surface and maintaining the water content of the root zone at near optimal level. In drip irrigation, water is conveyed under pressure through a pipe system to the fields, where it drips slowly onto the soil through emitters or drippers which are located closed to the plants. Drip irrigation is adaptable to most soils and terrain and can be used on high value crops. It is the most efficient irrigation system.

4.0 CONCLUSION

For an effective and efficient use of irrigation water, there is need to understand the different irrigation systems the nature of the soil and its topography and to an extent, the type of crop to grow. This will make you chose the irrigation system that would best suit a particular crop to minimize waste of water and enhance efficient water use by the crop.

5.0 SUMMARY

Irrigation systems consist of the three major components which are diversion methods conveyance methods and application method.
Irrigation systems are of three types namely:

- Surface irrigation system which consist of Basin furrow and Border irrigation
- Sprinkler irrigation
- Drip or trickle irrigation.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the different types of surface irrigation
2. State two crops for each of the following irrigation system.
   a. Surface
   b. Drip
3. List the two conveyance methods

7.0 REFERENCES/FURTHER READING

Agricultural Extension & Research Liaison Services A. B. U. Zaria, *Irrigation and Drainage; Extension Guide No 35 Irrigation Series No1*.

Larry, G. James. (1993). Principles of farm irrigation. John Wiley and

Ogiever Erebor (2003). Comprehensive Agricultural Science for Senior Secondary Schools A. Johnson Publisher Limited. Sons Inc.

MODULE 2 SOIL REACTION, EROSION AND DRAINAGE

UNIT 1 SALINITY, ALKALINITY AND ACIDITY

CONTENTS

1.0 INTRODUCTION

Soils are home of plants which supply them with water and nutrients necessary for their growth and development. Soils also anchor plants. Soil conditions determine the type of nutrients present in a particular soil and determine the type of crops to be planted. In this unit, you will be studying the different soil conditions, their effects on crops and soil and the measures that should be taken to correct them.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define salinity, alkalinity and acidity
- state the effects of salinity, alkalinity and acidity on crops and soil
- state the type of nutrients present in each condition
- state the control of the different soil conditions
- state crops that are tolerant to the different conditions.

3.0 MAIN CONTENT

3.1 Salinity

Salinity is a soil condition or solution that has an electrical conductivity value of 4 or more decisiemens/m at 25^oC, have exchangeable sodium percentage of less than 15% and a p^H of below 8.5. These soils are called saline soils. Saline soils usually have a surface crust of white salts especially in dry season when the net movement of moisture is upward. Salts dissolve in water move to the surface, when they are left as a crust, when the water evaporates. These white salts are mostly chlorides, sulphates, carbonate of calcium, magnesium and sodium.

3.2 Alkalinity

Alkalinity is a soil condition or solution that has an electrical conductivity value of below 4 decisiems/m at 25^oC, have exchangeable sodium percentage greater than 15% and a p^H of 8.5-10.0. This soil is called alkaline soil. Because of the high sodium, both clay and organic matter are dispersed and the result is a close packing of the soil particles and this reduces the size and amount of pore spaces and consequently, water and air will not move through the soil readily. Poor aeration and high sodium content, which is often toxic, make alkaline soils difficult and expensive to reclaim.

3.3 Formations of Saline and Alkaline Soils

Saline and alkaline soils are formed under the following conditions:

i- In the dry regions, where there is low rainfall and high temperature, there is always a tendency for the accumulation of soluble salts near the surface. During rainy season, these salts may move downward to the lower soil layers but after the rainy season, the intense evaporation brings the salts back to the surface.

ii- The ground water of dry regions usually contains considerable quantities of soluble salts. If the water table is high, large amount of water move to the surface by capillary action and are evaporated, leaving an increasing accumulation of soluble salts. This process of accumulation of soluble salts makes soils highly impregnated with salts and only salt resistant crops can grow.

iii- The salt may have originated directly from chemical weathering of rocks and have been dissolved by surface and percolating water.

iv- Under irrigation, saline and alkaline soils have developed by any one or more of the several means as follows:

a. When excessive application of water have raised the ground water level sufficiently to permit concentration of salts from saline ground water through evaporation.
b. When seepage from leaky channels and lateral channels which run at a higher level has resulted in a high water table and saline/alkaline soils.
c. When irrigation water has a high salt content
d. When poor drainage keeps the salts in the surface soil and prevents leaching of salts.
e. When the use of irrigation water is erratic that is flooding at one time followed by intense drought. When the total supply of water is limited, this would also leave the salts in the root zone.

3.4 Effects of Saline and Alkaline Soils on Crops and Soil

- Saline soils are usually barren but potentially productive soils. These soils do not support plant growth primarily because of excessive salts in the soils solution which, due to high osmotic pressure, prevents absorption of moisture and nutrients in adequate amounts. Thus, in saline soils, wilting coefficient is high and the amount of available moisture is low.
- An excess of sodium ions also exerts antagonistic effects on the absorption of calcium and magnesium.
- Under alkaline soil conditions, the damage is not due to salt concentration since the conductivity of the soil solution is low. The sodium adsorbed by clay and organic colloids causes dispersion of clay which results in a loss of desirable structure and a development of puddled effects (soil water solution). Such effect on the physical properties of soil reduces drainage, aeration and microbial activities.

- The high pH in alkaline soils causes a reduction in the solubility and availability of micro nutrients such as iron, copper manganese and zinc.

SELF-ASSESSMENT EXERCISE

i. Define salinity and alkalinity
ii. State the effects of saline soils on crops and soil

3.5 Reclamation or Control of Saline and Alkaline Soils

Before starting the reclamation of saline and alkaline soils, knowledge of the following is essential:

i. Quality of the soil
ii. Quality of the irrigation water
iii. Nature and distribution of salts in the soil root zone
iv. Level of subsoil water
v. Drainage condition

The following are technical requirements for reclamation of saline and alkaline soils:

- Adequate drainage
- Availability of sufficient water to meet crop use and also leach the salt below the root zone
- Have better than average soil management which include perfect land leveling, good bunding for irrigation and advances agronomic practices
- Good quality of irrigation water. It is imperative that the quality of irrigation water supplies be studied systematically to determine its suitability

In saline soils in which the soluble salts contain appreciable amount of calcium and magnesium do not develop into alkaline soils by the action of leaching water. The reclamation is completely easy in such soils. The main problem is thus to leach the salts, downward below the root zone and out of contact with subsequent irrigation water. It is however, important that the drainage of the soil be good. Saline soils have been reclaimed by the use of heavy application of irrigation water, usually a 60cm dose. Less than 60cm application of water was not effective and higher doses did not further reduce the salt content. In salty soils with a high water table, artificial drainage is necessary before excess salt can be removed.

In alkaline soils, the exchangeable sodium is so great as to make the soil almost impervious to water. But even if water could move downward freely in alkaline soils, the water alone would not leach down the excess exchangeable sodium. The sodium must be replaced by another cation and then leached downward and out of reach of plant roots. By cationic exchange, calcium is often used to replace sodium in alkaline soils. Calcium compounds e. g calcium sulphate (gypsum) is considered the best for this purpose. Gypsum converts sodium salts into calcium soil with a desirable pH and improvement in soil physical conditions. This also improved drainage. Flooding is then given to remove the sodium sulphate formed from the reaction with gypsum from the soil. The reactions involved are:

$2NaClay + CaSO_4 = Na_2SO_4 + CaClay$
$Na_2CO_3 + CaSO_4 = CaCO3 = Na_2SO_4$
(gypsum) (soluble)

In extreme cases of high alkalinity, the reduction in pH is brought about by the use of sulphuric acid. The reclamation process would, however, require expert handling and would usually be quite expensive.

SELF-ASSESSMENT EXERCISE

State the 4 technical requirements for the reclamation of saline and alkaline soils

3.6 Salt Tolerant Crops

Under same circumstances, it may not be feasible to reduce the salt content of soils to permit the growth of sensitive crops. The alternative is to select crops which are tolerant to salts. Of the field crops, barley for grain, sugar beet and cotton are the most tolerant to salt, while field beans cropsare the most sensitive. Other crops, mainly small grains, are intermediate in salt tolerance. Date palm is the only fruit known to be very tolerant of salty soil. Most fruit are sensitive to salt concentration in the soil.

3.7 Soil Acidity

Soil acidity refers to the concentration of hydrogen ions (H+) over hydroxyl ions (OH-) in the soil. The p^H range of acid soil is 1-6.5. The bulk of hydrogen ions are held in close association with the clay/organic colloidal complex. The causes of soil acidity includes;

i. Leaching due to heavy rainfall
ii. Soils that originated from acid parent material
iii. Use of acid forming fertilizers

iv. Microbial activities

3.8 Effects of Soil acidity on Crops

The various effects exerted on crops by soil acidity may be direct or indirect. Direct influences are:

i. Toxic effects of hydrogen ions on root tissues
ii. Influence of soil acidity on the permeability of the plant membrane for cations and
iii. Disturbance in the balance between basic and acidic constituents through the root.

The soil acidity undoubtedly exerts direct harmful effects on crops particularly by affecting the enzymic changes since the enzymes are particularly sensitive to p^H changes. It is however, increasingly being believed that it is the soil conditions created by the acidity which are harmful to plants.

Effects of Soil Acidity on Crops

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Indirect influences are:

a) Availability of various nutrients e. g phosphorus, copper and zinc
b) High solubility and availability of elements like aluminium, manganese and iron in toxic amounts due to high acidity
c) Beneficial activities of soil microorganisms are adversely affected
d) Prevalence of plant diseases
e) Due to soil acidity, nutrients such as calcium and potassium may be deficient Rice, Oats and linseed can tolerate a fairly acid soil of 5.0 p^H.

3.9 Correction of Soil Acidity

Soil acidity can be corrected using the following:

1. Use of lime materials. When lime is added to moist soil, the soil solution becomes charged with calcium ions. These active calcium ions exchange with hydrogen ions in the exchange complex. E.g of lime material to be used are;
   - ground limestone – calcic limestone ($CaCO_3$)
   - dolomitic limestone
   - quicklime (CaO)
   - hydrated lime ($Ca(OH)_2$)
   - coral shell lime
   - chalk
   - gypsum
2. Avoid the use of acid forming fertilizers e.g ammonium sulphate and ammonium nitrate

4.0 CONCLUSION

Soil condition is very critical to crop growth and development and it is imperative fro the farmer to know the soil condition of his farm to help him determine what crop to plant. Crops that tolerate acid soil should be planted in soil that is slightly acidic.

5.0 SUMMARY

Soil salinity, alkalinity and acidity are different soil conditions that connote different level of electrical conductivity value, exchangeable sodium percentage of and soil p^H and these conditions are most times detrimental to the growth of crops. The effects of these soil conditions include;

Effects of Saline and Alkaline Soils on Crops and Soil

- Saline soils are usually barren but potentially productive soils.
- An excess of sodium ions also exerts antagonistic effects on the absorption of calcium and magnesium.
- Under alkaline soil conditions, the damage is not due to salt concentration since the conductivity of the soil solution is low.

Effects of Soil Acidity on Crops

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vi. Beneficial activities of soil microorganisms are adversely affected
vii. Prevalence of plant diseases
viii. Due to soil acidity, nutrients such as calcium and potassium may be deficient Rice, Oats and linseed can tolerate a fairly acid soil of 5.0 p^H.

Reclamation or control of saline and alkaline soils

The following are technical requirements for reclamation of saline and alkaline soils:

- Adequate drainage
- Availability of sufficient water to meet crop use and also leach the salt below the root zone
- Have better than average soil management which include perfect land leveling, good bunding for irrigation and advances agronomic practices
- Good quality of irrigation water. It is imperative that the quality of irrigation water supplies be studied systematically to determine its suitability.

6.0 TUTOR-MARKED ASSIGNMENT

1. State the characteristics of saline soil
2. State the effects of soil acidity on crop growth and development
3. Explain the 2 control measures for soil acidity

7.0 REFERENCE/FURTHER READING

Chhabra, R. J. (1996). Salinity and Water Quality. Oxford & IBH Publishing Co. Pvt. Ltd.

UNIT 2 SOIL EROSION

CONTENTS

1.0 INTRODUCTION

Soil is the uppermost part of the earth crust that supports plant growth. It is a medium where plants take up nutrients for their growth and development and it also housed microorganisms that have beneficial effects on the ecosystem. Since soil is of great importance in the ecosystem, there is the need to protect it from destruction of any sort. This unit will treat soil erosion which tends to destroy soil when it is not left unchecked.

2.0 OBJECTIVES

At the end of this unit, you shall be able to:

- define soil erosion
- state the types of soil erosion
- explain the types of erosion
- state the methods of controlling soil erosion.

3.0 MAIN CONTENT

3.1 Definition of Soil Erosion

Soil erosion is the gradual removal of the top layer of the soil by moving water, wind, ice and glacier. These agents usually remove the soil particles gradually and these particles move along with the agent to a far distance. The predominant agent in the arid region is the wind and while in the humid region is water.

3.2 Types of Soil Erosion

There are four (4) types of soil erosion, these are

i. Splash soil erosion
ii. Sheet soil erosion
iii. Rill soil erosion
iv. Gully soil erosion
v. Wind soil erosion

3.2.1 Sheet Soil Erosion

Sheet erosion is the wearing away of the top layer of the soil by erosion agents on land with little or no vegetation. Sheet erosion erodes the top layer of the soil and exposes infertile sub-soil, thus leading to severe loss of plant nutrients. Sheet erosion can be recognized if sub-soil or plant roots are exposed.

3.2.2 Rill or Finger Soil Erosion

Rill erosion occurs when furrows make a path for water flows e.g a stream. They are sometimes seen as tiny finger – like channels on the land. This kind of erosion leads to gully erosion, which is refered to as the most destructive kind of erosion

3.2.3 Gully Soil Erosion

Gully erosion is an advance form of rill and sheet erosion that is unchecked. The flow of water get rapid carrying along with it moved layers of soil. It cuts channels deep into the soil until gullies are formed. Gully erosion is destructive to farmland when it's too deep and can render the farmland uncultivable.

3.2.4 Splash Soil Erosion

Splash erosion occurs when there is rain fall on a bare soil. The drops of the rain detached the soil particles and make them vulnerable to washing away by agents of erosion. Splash erosion leads to sheet erosion and wind erosion

3.2.5 Wind Soil Erosion

Wind erosion is common in arid and semi-arid desert areas with high wind and low rainfall. The wind blows and soil particles are conveyed with the wind to a distant area. This results in sheet erosion and the formation of sand dunes and drifts.

SELF-ASSESSMENT EXERCISE

i. Define soil erosion
ii. List the types of soil erosion

3.3 Factors Affecting Soil Erosion

There are several factors that affect or speed up the gravity of soil erosion in an area. These factors include the following.

- Soil structure and composition
- Vegetation cover
- Topography of the land
- Agricultural practice
- Deforestation
- Road construction and urbanization
- Climate changes (global warming)
- Bush burning

3.4 Effect of soil erosion

- Land degradation
- sedimentation of aquatic ecosystems
- water pollution
- air pollution (dust)
- leaching of soil nutrients
- reduce the size of farm land
- causes reduction in yield of crops

3.5 Control of soil erosion

Soil erosion control measures includes actions undertaken to reduce soil erosion caused by various factors such as surface water runoff, tillage operations, wind blowing, deforestation e. t. c. soil erosion control measures include; conservation tillage, contour farming, stabilization structures, terracing, mulching, cover cropping vegetated waterways, windbreaks e.t.c.

1. Terracing

Terracing is an alternative management for water conservation and erosion control. It is a combination of contouring and land shaping in which earth embankments or ridges are designed to intercept water and channel it to a specific outlet. Terraces reduces erosion by decreasing the steepness and length of the hillside slope and by preventing damage done by runoff

2. Contouring

Contouring entails performing all tillage and plating of crops across slopes. By planting across the slope rather than up and down the hill, the contour ridging slow or stop the downhill flow of water. Water is held in between these contours, thus reducing water erosion and increasing soil moisture.

3. Cover Cropping

This is the practice of planting crops who's canopy spread to cover the surface of the soil. These crops canopy help to reduce the erosive force of water and wind by intercepting rain and acting as a wind breaker. Crop residues perform similar functions mostly leguminous crops are used to cover crops.

4. Tillage Practices

One of the causes of soil erosion is improper tillage operation that exposes the soil surface to erosion agents. Proper tillage practices employed separately or in combination with crop rotation and other practices, can be very effective in reducing soil erosion losses. On sandy soils, planting can be done without any previous tillage (zero tillage) or following ploughing only. The objective with any tillage is to leave the soil surface in rough condition, and where practical, protected with crop residues. These conditions facilitate easier infiltration of water by slowing surface runoff and minimize soil erosion.

5. Strip Cropping

Strip cropping is the growing of two or more crops together in strips wide enough to permit separate crop production but close enough for the crops to interact. Strip cropping is a very effective and expansive method for controlling soil erosion. Strip cropping is a combination of contouring and crop rotation in which alternate strips of row crops and soil conserving crops are grown on the same slope, perpendicular to the wind or water flow. When soil is detached from the row crops by the force of wind or water, the dense soil conserving crops trap some the soil particles and reduce runoff and/or wind movement.

6. Mulching

Mulching is the practice of covering the surface of the soil with mulch materials such as straw, compost, wood chips, saw dust, plastics e. t. c. spread evenly onto the ground, mulch materials helps to reduce water evaporation, controls weeds and enrich the soil. By absorbing the destructive forces of rain drops and wind, mulch materials reduces erosion until the seedlings mature enough to provide their own protective cover.

7. Vegetated Waterways

This is the reduction in the velocity of water flow through the planting of vegetation on the waterways. Vegetated waterways are built to protect soil against the erosive forces of concentrated runoff from sloping lands. Usually grass linings which are planted on the water channels should be hardy, dense-growing perenials adapted to the geographical region and soil. By collecting and concentrating over land flow, waterways absorbs the destructive energy which causes channel erosion and gully formation

8. Conservation Tillage

Conservation tillage is a land management practice which can significantly reduce rill erosion in hilly areas cultivated with annual crops. The incorporation of plant residues into the soil after harvesting increases soil organic matter content and improve soil aggregate, stability and this in turn reduces soil erosion since the soil particles are not easily detachable

9. Wind Break

This is the planting of taller trees across the direction of winds in order to reduce the speed of wind. This is usually done by planting two or three rows of trees intermittently in the fields that are vulnerable to wind erosion. Wind break reduces wind speed and thereby reducing wind erosion and trap particles that have been conveyed from other areas and deposit them within the wind break shelter belt. It also provides micro climates for crops (which are sheltered for wind), habitat for beneficial bird species, carbon sequestration and aesthetic improvement to the agricultural landscape.

SELF–ASSESSMENT EXERCISE

State five causes of soil erosion

4.0 CONCLUSION

Soil erosion is a destructive phenomenon in any production that has to do with the soil. Soil erosion does not only affect crop production but also affects road construction, waterway movement, construction of building and as such all effort should be made to control it and channel water appropriately to a distant outlet to avoid it's destruction.

5.0 SUMMARY

Soil erosion is the wearing away of the top layer of the soil by agent of water, wind, ice and glacier. The causes of soil erosion includes bush burning, precipitation and wind speed, agricultural practices, vegetation cover, topography among others. The types of soil erosion are;

- Splash erosion
- Rill erosion
- Sheet erosion
- Gully erosion
- Wind erosion

Soil erosion can be control through the following practices

- Planting of wind break
- Conservation tillage
- Mulching
- Contour and strip cropping
- Vegetated waterways
- Tillage practices

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the type of soil erosion
2. State the effect of soil erosion
3. Discuss the methods of controlling soil erosion

7.0 REFERENCES/FURTHER READING

Martin, J. H., Waren H. L. and Stamp, D. L. (1976). *Principles of Field Crop Production.* (3rd ed.). New York: Macmillan Pub.

Olaitan, S. O. and Lombin, G. (1988). *Introduction to Tropical Soil Science.* London: Macmillan Pub.

Onwueme, I. C. and Sinha, T. D. (1999). *Field Crop Production in Tropical Africa.* Netherlands: CTA, Wageningen,

Rowland, J. R. J. (1993). *Dry Land Farming in Africa.* Netherlands: CTA, Wageningen.

UNIT 3 SOIL DRAINAGE

CONTENTS

1.0 INTRODUCTION

Natural rainfall and artificial rainfall (irrigation) apply water to crops for the purpose of growth and development. This water applied usually fills the pore spaces and are absorbed by plant through the root. When the pore spaces are saturated, water flood the surface of the soil and goes out of the soil through seepage, run off or drain off the field. In this unit you would be studying drainage of water from the soil either due to rainfall or irrigation.

2.0 OBJECTIVES

At the end of the unit, you should be able to:

- Define drainage
- State the importance of drainage
- List the types of drainage
- Explain the types of drainage
- State the advantages and disadvantages of each types of drainage.

3.0 Main Content

3.1 Definition of Drainage

Drainage is the removal of excess water artificially from a farm land to prevent water-logging, promote good plant growth and promote farming activities. Drainage and irrigation are complementary practices especially in arid regions where the soil are easily eroded by water because of their loose structure.

3.2 Importance of Drainage

i. It prevent water-logging in the soil
ii. It helps in early planting and ploughing
iii. It improve soil aeration
iv. The temperature of the soil is improved
v. Favours growth of soil bacteria and other soil organization
vi. It reduces soil acidity and salinity
vii. It helps in leaching of excess salt from the soil
viii. It enhances germination of seeds.
ix. It increases the depth of root zone thereby providing more available soil moisture and plant nutrients.
x. It enhance the decomposition of planted animals residues
xi. Increase water infiltration thereby reducing erosion hazards
xii. It lengthens the crop growing season.

SELF-ASSIGNMENT EXERCISE

State 10 importance of drainage

3.3 Types of Drainage

There are two major types of drainage. These are surface drainage and sub surface or under ground drainage. Drainage can also be categorized into gravity system (surface and sub surface) and pump system (wells and sumps).

3.3.1 Surface Drainage

This is the removal of the excess water from the surface of the farm land using constructed open ditches, field drains, land grading and lateral ditches. The excess water flows from the field into ditches and are conveyed to a distance outlet usually rivers or ponds. There are also called open drainage and they are constructed to a minimum depth of 1m – $1^{1/2}$ and usually have trapezoidal shape.

Advantages of Surface Drainage

1. Easy to construct
2. Low initial cost than sub surface
3. Prevent stagnant water
4. Has the ability to carry large quantities of water

Disadvantages of Surface Drainage

1. It disturb movement of machine in the farm
2. Reduce the size of land for production
3. High cost of maintenance
4. It can act as breeding place for pest and insects
5. Open ditches are prone gully erosion.

3.3.2 Sub-Surface or Underground Drainage

This is an orderly of excess water from the farm land artificially using different materials like pipes, tiles, moles and plastic tubes. The common type is the tile drains. This consist of pipes connected to form a continuous line and are laid in a narrow trench. These pipes have holes (opening) drilled around them to drain excess water toward the outlet usually filter materials are laid around the pipes to prevent clogging of the holes. Concrete and clay pipes are the commonest types of tiles used in irrigated areas Bamboo sticks are extensively used in Asia. They have been tested in many areas in Nigeria and found to be suitable.

Advantages of Sub Surface Drainage

1. It does not disturb machines movement
2. Low maintenance cost
3. No interference with farming activities
4. Does not reduces land for production
5. High value crops are grown.

Disadvantages of Sub-Surface Drainage

1. High cost of installation
2. There may be clogging which may result in erosion
3. Heavy machines may damage the tiles.

SELF-ASSESSMENT EXERCISE

i. Define drainage
ii. State two (2) advantages of surface drainage.

Other forms of sub surface or underground drainage are sumps and wells which uses pumps to remove the water from their collection point to a distance outlet or for irrigation. Sumps are built to depths of about 6m to drain small water logged areas. They can also be used as outlets for the tile system. Small pumps are used to remove the excess surface water that collects in the sumps and is pumped back up slope for reuse. It saves water, nutrients in the water and eliminates drainage hazards.

4.0 CONCLUSION

In planning irrigation, consideration for excess water has to be taken so as to avoid water logging of the irrigated land. Draining of land depends on the soil type, and the quantity of water received through irrigation and rainfall.

5.0 SUMMARY

Drainage is the removal of excess water from a farm land to create conducive atmosphere for plant growth. The benefits derived from drainage include;

- It lengthens the crop growing season
- Improve aeration
- Reduces soil acidity and salinity
- Increases microbial activities
- Leaching of excess salts
- Assures higher soil temperature

There are two major types of drainage surface and sub-surface drainage other types which are sub-surface are well and sumps where pumps are used to remove the excess water that collect in the well or sumps.

6.0 TUTOR-MARKED ASSIGNMENT

1. State the major types of drainage
2. State the importance of drainage
3. Explain the types of drainage and state three (3) advantages and two(2) disadvantages of each.

7.0 REFERENCES/FURTHER READING

Agricultural Extension & Research Liaison Services A. B. U. Zaria, *Irrigation and Drainage; Extension Guide No 35 Irrigation Series No1*.

Ogiever Erebor (2003). Comprehensive Agricultural Science for Senior Secondary Schools. A. Johnson Publisher Limited.