COURSE GUIDE

SLM 308
SOIL AND WATER MANAGEMENT

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INTRODUCTION

SLM308 is a two (2)-credit unit course on Soil and Water Management. This course covers topics in soil and water management and conservation important to students of agricultural and environmental sciences. Processes that degrade the soil- and water-resources of Nigeria (e.g. erosion, salinity, alkalinity and sodicity, as well as acidification, water repellence, and degradation of soil structure) are examined, and their measurement, avoidance and management discussed. There is a strong focus on quantitative theory and practice of measuring and managing soil water using commercially available technology, particularly in relation to interception, storage and movement of water in dryland and irrigated agro-ecosystems. Broader issues in soil and water conservation (e.g. State and Commonwealth legislation) are also covered. Practical classes consist of laboratory, computer and field exercises designed to illustrate the concepts covered in lectures.

The importance of soil and water to crop production cannot be over-emphasized. Good soil as well as water from a good source guarantees all year round production of many arable. This course is designed to intimate the students with the favorable and unfavorable conditions that may be created as a result of the use of soil and water for agricultural and other purposes. It also attempts to solve most of the problems that arises as consequences of misuse of soil and water. The course is broken into 10 units in all in six (4) modules. These units will teach and explain soil and water management study as a tool and systematic process for ensuring that soil and water considerations are taken into account in all proposed activities. This course guide defines what the course is all about as well as the course material that you will need to consult to ensure that the course is simple and within your reach. 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. The course will deal with the basic principles and selected applications of biotechnology for agricultural crops, emphasising the need for a different type of agriculture, in order to support the increasing needs for food (quantity and quality) facing climatic changes as well as increased abiotic and biotic stress conditions. The basic aspects of the major biotechnological tools and solutions will be evaluated.

WHAT YOU WILL LEARN IN THIS COURSE

You will learn:

1. Theory & measurement of soil water content, movement, storage & plant availability.
2. How to manage and measure salinity and toxicity in irrigated agricultural systems.
3. How to solve quantitative problems in soil water management, specifically how to:

    * conduct simple calculations of water content, porosity, density and hydraulic conductivity.
    * analyse and interpret data on infiltration, available water, and storage of water.
4. How to work effectively in small groups in the lab and in the field.
5. The primary causes and consequences of a wide range of soil degradation problems, including soil acidity and alkalinity, erosion, salinity and toxicity, and nutrient loss.
6. The impact of soil management on soil organic matter, soil structural stability, water quality and other important soil properties.
7. Develop an ability to collect and evaluate data in practical classes.
8. Develop writing skills through essay and report writing.
9. Learn how to provide and respond to “peer-review” feedback on a draft essay.

COURSE AIMS

The course aims and objectives are follows:

1. To expose you to the basic scientific evidence and technical aspects of the different disciplines of agricultural soil and water managements (mainly for plants and crops).
2. To clarify the major scientific, ecological and sociological aspects of soil and water in agriculture.
3. To discuss the general issues and interrelationships of science, agriculture and human well-being.

COURSE OBJECTIVES

For the aims to be achieved, there are set objectives. Each unit of this course also has its specific objectives that are found at the beginning of each unit. You will need to understand these objectives before you start working on each unit. You are encouraged to refer to them periodically to check on your progress in learning and assimilating the content. On completion of a unit, you may re-examine the objectives to ensure that you fully learn what is required. 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 to:

1. Intimate you with soil conservation methods
2. Understand causes of soil degradation
3. Understand basic principles of soil management
4. Identify good sources of water
5. Determine water requirement by crops and control the water distribution of crops.

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 is 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 12to 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 major components of this course are:

1. Course Guide
2. Study Units/Course Materials
3. Tutor-Marked Assignment (TMA)
4. References and Further Reading

COURSE GUIDE

The material you are reading now is called the course guide which introduced you to this course.

STUDY UNITS

Module 1 Background to Soil and Water Management

Unit 1 Introductory Remarks and Introduction to Soil and Water Management
Unit 2 Concept of Soil Management
Unit 3 Concept of Water Management

Module 2 Soil and Water Conservation Techniques

Unit 1 General Introduction to Concept of Soil and Water Conservation Techniques
Unit 2 Soil Conservation Techniques
Unit 3 Water Conservation Techniques

Module 3 Soil Tillage System in Soil and Water Conservation

Unit 1 Concept Soil Tillage System
Unit 2 Effects of Soil Tillage on Crop Production

Module 4 Soil Erosion in Agriculture

Unit 1 Principles of Soil Erosion
Unit 2 Soil Erodility and Erosivity

TUTOR-MARKED ASSIGNMENTS

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.

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MAIN COURSE

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MODULE 1 BACKGROUND TO SOIL AND WATER MANAGEMENT

UNIT 1 INTRODUCTORY REMARKS AND INTRODUCTION TO SOIL AND WATER MANAGEMENT

CONTENTS

1.0 INTRODUCTION

Soil and water are two important natural resources and the basic needs for agricultural production. During the last century it has been observed that the pressure of increasing population has led to degradation of these natural resources. In other words increase in agricultural production to feed the increasing population is only possible if there sufficient fertile land and water are available for farming. In India, out of 328 million hectares of geographical area, 68 million hectares are critically degraded while 107 million hectares are severely eroded. That's why soil and water should be given first priority from the conservation point of view and appropriate methods should be used to ensure their sustainability and future availability. Status of global land degradation is shown in Fig. 1.

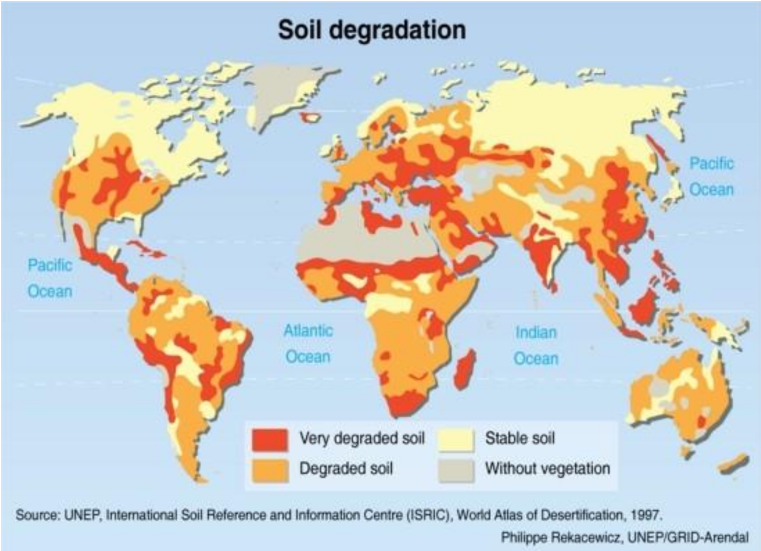

Fig. 1. Global soil degradation map.

(Source: UNEP, International Soil Reference and Information Centre (ISRIC), World Atlas of Desertification, 1997)

Water conservation is the use and management of water for the good of all users. Water is abundant throughout the earth, yet only three percent of all water is fresh water, and less than seven-tenths of freshwater is usable. Much of the usable water is utilised for irrigation. Detailed analysis will show that in about fifteen years, about two-thirds of the world's population will be living in some sort of water shortage. Water is used in nearly every aspect of life. There are multiple domestic, industrial and agricultural uses. Water conservation is rapidly becoming a hot topic, yet many people do not realise the importance of soil conservation.

Soil conservation is defined as the control of soil erosion in order to maintain agricultural productivity. Soil erosion is often the effect of many natural causes, such as water and wind. There are also human factors which increase the rate of soil erosion such as construction, cultivation and other activities. Some may argue that since it is a natural process, soil erosion is not harmful. The truth is that with the removal of the top layer of soil, the organic matter and nutrients are also removed.
Conservation is not just the responsibility of soil and plant scientists, hydrologists, wildlife managers, landowners, and the forest or mine owner alone. All citizens should be made aware about the importance of natural resources as our lives depend on that and everyone should be involved in the process of caring of these resources properly and using them intelligently.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- understand the concept of soil and water management
- know the importance and benefits of soil and water management.

3.0 MAIN CONTENT

3.1 Definition

Soil water management can be defined as active involvement in controlling soil water content at an optimal state for all given purposes, including environmental needs. An optimal state is often a compromise between competing uses and needs to account for long term sustainability of the soil water system.

3.2 Benefits of Soil and Water Management

Many nutrients and organic matter of soil is lost by soil erosion. By improving the overall soil conditions for plant growth, better conservation of water and soil can be achieved. Better land husbandry is more relevant when the land is under active crop production

3.3 Importance of Soil and Water Management

Soil erosion, sedimentation and silting in the reservoirs, land slide, gully development, water pollution etc are some of the major problems. soil conservation Techniques aim:

- to maintain soil fertility, soil productivity etc by reducing the runoff rate as well as by reducing the land slope.
- To prevent erosion of bare soil, it is important to maintain a vegetation cover, especially in the most vulnerable areas e.g. those with steep slopes, in a dry season or periods of very heavy rainfall. For this purpose, only partial harvesting forests (e.g. alternate trees) and use of seasonally dry or wet areas for pasture rather than arable agricultural land should be permitted.
- Where intensive cultivation takes place, farmers should follow crop rotation in order to prevent the soil becoming exhausted of organic matters and other soil building agents. Where soils are ploughed in vulnerable areas, contour ploughing (i.e. round the hillside rather than down the hillside) should be used. Careful management of irrigation, to prevent the application of too much or too little water will be helpful to reduce the problem of soil

salinity development. Livestock grazing must be carefully managed to prevent overgrazing.

- Construction of highways and urbanisation should be restricted to areas of lower agricultural potential. With extractive industries, a pledge must be secured to restore the land to its former condition before permission for quarries or mines is granted.

4.0 CONCLUSION

Soil conservation is defined as the control of soil erosion in order to maintain agricultural productivity. Soil erosion is often the effect of many natural causes, such as water and wind. There are also human factors which increase the rate of soil erosion such as construction, cultivation and other activities. Some may argue that since it is a natural process, soil erosion is not harmful. The truth is that with the removal of the top layer of soil, the organic matter and nutrients are also removed.
Conservation is not just the responsibility of soil and plant scientists, hydrologists, wildlife managers, landowners, and the forest or mine owner alone. All citizens should be made aware about the importance of natural resources as our lives depend on that and everyone should be involved in the process of caring of these resources properly and using them intelligently.

5.0 SUMMARY

Soil conservation is defined as the control of soil erosion in order to maintain agricultural productivity. Soil erosion is often the effect of many natural causes, such as water and wind. There are also human factors which increase the rate of soil erosion such as construction, cultivation and other activities. Some may argue that since it is a natural process, soil erosion is not harmful. The truth is that with the removal of the top layer of soil, the organic matter and nutrients are also removed.
Conservation is not just the responsibility of soil and plant scientists, hydrologists, wildlife managers, landowners, and the forest or mine owner alone. All citizens should be made aware about the importance of natural resources as our lives depend on that and everyone should be involved in the process of caring of these resources properly and using them intelligently.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is soil and water conservation.
2. State the benefits of soil and water management.
3. Highlight the importance of soil and water management.

7.0 REFERENCES/FURTHER READING

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UNIT 2 CONCEPT OF SOIL MANAGEMENT

CONTENTS

1.0 INTRODUCTION

Soil management is a key to the success of site-specific soil management. It starts with a farmer's ability to vary the depth of tillage according to soil conditions and is important in proper seedbed preparation, control of weeds, and fuel consumption, with the potential to lower production costs within an individual field, soil management for sustainable agriculture. The soil sustains most living organisms, being the ultimate source of their mineral nutrients. Soil management is important, both directly and indirectly, to crop productivity, environmental sustainability, and human health

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- understand the concept and definition of soil management
- determine the importance soil management practices
- recognise the advantages of soil management practices.

3.0 MAIN CONTENT

3.1 Definition

Soil management concerns all operations, practices, and treatments used to protect soil and enhance its performance.

3.2 Soil Management Practices

Soil management practices that affect soil quality are as follows

- Controlling traffic on the soil surface helps to reduce soil compaction, which can reduce aeration and water infiltration.
- Cover crops keep the soil anchored and covered in off-seasons so that the soil is not eroded by wind and rain.
- Crop rotations for row crops alternate high-residue crops with lower-residue crops to increase the amount of plant material left on the surface of the soil during the year to protect the soil from erosion.
- Nutrient management can help to improve the fertility of the soil and the amount of organic matter content, which improves soil structure and function.
- Tillage, especially reduced-tillage or no-till operations limit the amount of soil disturbance while cultivating a new crop, and help to maintain plant residues on the surface of the soil for erosion protection and water retention.

3.3 Advantages of Soil Management

The advantages of soil management are highlighted are below:

1. Maintain soil fertility.
2. Restore soil fertility.
3. Make the agricultural process an economic one.
4. Help increase yield.

3.3.1 Maintain Soil Fertility

An integrated soil fertility management aims at maximizing the efficiency of the agronomic use of nutrients and improving crop productivity. This can be achieved through the use of grain legumes, which enhance soil fertility through biological nitrogen fixation, and the application of chemical fertilizers. Whether grown as pulses for grain, as green manure, as pastures or as the tree components of agro-forestry systems, a key value of leguminous crops lies in their ability to fix atmospheric nitrogen, which helps reduce the use of commercial nitrogen fertilizer and enhances soil fertility. Nitrogen-fixing legumes are the basis for sustainable farming systems that incorporate integrated nutrient management. Use of nitrogen-15 lends understanding of the dynamics and interactions between various pools in agricultural systems, including nitrogen fixation by legumes and utilization of soil and fertilizer nitrogen by crops, both in sole and mixed cropping systems.

Soil fertility can be further improved by incorporating cover crops that add organic matter to the soil, which leads to improved soil structure and promotes a healthy, fertile soil; by using green manure or growing legumes to fix nitrogen from the air through the process of biological nitrogen fixation; by micro-dose fertilizer applications, to replenish losses through plant uptake and other processes; and by minimising losses through leaching below the crop rooting zone by improved water and nutrient application.

3.3.2 Restore Soil Fertility

Fertilizers restore plant nutrients lost by erosion, crop harvesting and leaching. Farmers can use either organic fertilizer from plant and animal materials or commercial inorganic fertilizers produced from various minerals. Three basic types of organic fertilizer are animal manure, green manure and compost. Animal manure includes the dung and urine of cattle, horses, poultry, and other farm animals. It improves soil structure, adds organic nitrogen, and stimulates beneficial soil bacteria and fungi. Green manure is fresh or growing green vegetation plowed into the soil to increase the organic matter and humus available to the next crop. Green manure in the form of leguminous crops is an important option to improve nitrogen load in the soil. Compost is a rich natural fertilizer and soil conditioner that aerates soil, improves its ability to retain water and nutrients, helps prevent erosion and prevents nutrients from being wasted in landfills. Farmers and homeowners produce compost by piling up alternating layers of nitrogenous rich wastes, weeds, animal manure, and vegetable kitchen scraps, carbon-rich plant wastes, and topsoil.

3.3.3 Make the Agricultural Process an Economic One

Healthy soils have high levels of microbial activity, higher levels of organic matter, and good soil structure. Because soil properties differ according to climate, geology, topography, and land use and management history on a field or farm, “healthy soil” can look very different in different places. To sustain and improve the health of their soil and reduce erosion, farmers can implement various management practices that have both costs and benefits to the farmer. When farmers make decisions about soil health practices, they are often concerned with whether a practice will improve crop yields and/or reduce agricultural input costs. Other private benefits that might be relevant to the farmer include greater resilience of crops to extreme weather (droughts and floods) and an opportunity to engage in environmental stewardship. Soil health practices can also have benefits for society, including reduced greenhouse gas emissions from agriculture, increased carbon storage, and improved water quality through reduced nutrient and sediment pollution. These public benefits have the potential to affect present and future generations, but farmers may not be considering them when they make decisions about adopting soil health practices.

3.3.4 Help Increase Yield

Erosion is caused by several factors. Slope and crop rotation play a significant role in erosion control. On moderate slopes, the reduction in erosion from uphill and downhill planting is estimated to be approximately 50 percent less than on steep slopes, where the hazard of rill erosion is increased. Row spacing is another practice, along with conservation tillage practices, that is effective in reducing soil erosion on sloping areas. Reduced row spacing can provide dense surface cover and decrease the area of soil surface exposed to water impact. Strip cropping, terracing, and grassed waterways are other ways to control erosion by dividing the slope into discrete segments. Although there is soil movement within the terrace, the majority of the detached soil stays on the terrace. These practices help remove sediment and some nutrients from the water before it leaves the field. The contribution of such practices to improving productivity and water quality is significant.

4.0 CONCLUSION

Soil management is a key to the success of site-specific soil management. It starts with a farmer's ability to vary the depth of tillage according to soil conditions and is important in proper seedbed preparation, control of weeds, and fuel consumption, with the potential to lower production costs within an individual field.
Some of advantages of soil management are highlighted are below:

1. Maintain soil fertility
2. Restore soil fertility
3. Make the agricultural process an economic one
4. Help increase yield

5.0 SUMMARY

Soil management concerns all operations, practices, and treatments used to protect soil and enhance its performance.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define soil management.
2. Outline the soil Management practices.
3. State the advantages of soil management practices and explain any two.

7.0 REFERENCES/FURTHER READING

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UNIT 3 CONCEPT OF WATER MANAGEMENT

CONTENTS

1.0 INTRODUCTION

By 2050 the world’s population will reach 9.1 billion, a 50% increase compared to 2000. Agriculture must provide this increase against the decreasing availability of and competition for land and water from other uses, whether non- food crops, urbanisation or industrial development. Most of the crop land is in fact rainfed and this is where remains the largest yield gap in crop productivity among the different Regions of the World. According to the comprehensive assessment on water management in agriculture (2007), improving rainfed farming could double or quadruple yield. One main reason why yield gaps exist is that farmers do not have sufficient economic incentives to adopt yield enhancing seeds or cropping techniques. Other reasons include lack of access to information, extension services and technical skills. Poor infrastructure, weak institutions and discouraging farm policies can also create huge obstacles to the adoption of improved technologies at farm-level. Other factors can be that available technologies have not been adapted to local conditions.

The main challenge confronting water management in agriculture is to improve water use efficiency and its sustainability. This can be achieved through (i) an increase in crop water productivity (an increased in marketable crop yield per unit of water transpired) through irrigation, (ii) a decrease in water losses through soil evaporation that could otherwise be used by plants for their growth, and (iii) an increase in soil water storage within the plant rooting zone through better soil and water management practices at farm and area-wide (catchment) scales. Tracking and quantifying water fluxes at different spatial and temporal scales within the plant rooting zone remains a formidable challenge because of the interactions between water sources from rainfall, irrigation and subsurface water on plant uptake, soil evaporation, plant transpiration (water transpired by plants) and runoff or drainage losses from crop-growing areas. The use of isotopic and nuclear techniques to investigate the relative importance of soil and irrigation management factors that influence these interactions will greatly assist in the development of water management packages that involve the consideration of soil nutrient status, type of crops grown, growth stages and the overall agro-ecosystems to minimise not only water but also nutrient losses from the farmlands and enhance water and nutrient use efficiencies in agro-ecosystems under both rain fed and irrigated conditions.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- understand the concept and definition of water management
- explain the importance water management practices
- list the advantages of soil management practices.

3.0 MAIN CONTENT

3.1 Definition

Water management is the activity of planning, developing, distributing and managing the optimum use of water resources. It is a sub-set of water cycle management. Ideally, water resource management planning has regard to all the competing demands for water and seeks to allocate water on an equitable basis to satisfy all uses and demands. As with other resource management, this is rarely possible in practice

3.2 Recommended Water Management Practices

Recommended water management practice in agriculture:

(i) Take steps to mitigate impacts on ecosystem. This may include integrated pest management, low water fertilisers but also if the farming area is located in or near a site of ecological importance.

(ii) Ensure that infrastructure for the delivery of water is adequately maintained (inter-basin transfers may pose a greater risk than intra-basin transfers).

(iii) Assess the maximum levels of water extraction above which the underlying ecosystem would get overexploited.

(iv) Ensure the adequacy of resource protection related to aquatic protection. Many farms have unused wells. Pollutants that enter these wells move quickly and without filtration to groundwater. Abandoned wells are sealed by removing pumps, piping and debris, and filling the hole with a slurry of cement or bentonite chips.

3.3 Improving Water Management Practices

The main challenge confronting water management in agriculture is to improve water use efficiency and its sustainability.

This can be achieved through:

(i) an increase in crop water productivity through irrigation,
(ii) a decrease in water losses through soil evaporation that could otherwise be used by plants for their growth, and
(iii) an increase in soil water storage within the plant rooting zone through better soil and water management practices at farm and area-wide (catchment) scales.

4.0 CONCLUSION

Agriculture must provide this increase against the decreasing availability of and competition for land and water from other uses, whether non-food crops, urbanization or industrial development. Most of the crop land is in fact rain fed and this is where remains the largest yield gap in crop productivity among the different Regions of the World. According to the comprehensive assessment on water management in agriculture (2007), improving rain fed farming could double or quadruple yield. One main reason why yield gaps exist is that farmers do not have sufficient economic incentives to adopt yield enhancing seeds or cropping techniques. Other reasons include lack of access to information, extension services and technical skills. Poor infrastructure, weak institutions and discouraging farm policies can also create huge obstacles to the adoption of improved technologies at farm-level. Other factors can be that available technologies have not been adapted to local conditions.

5.0 SUMMARY

The main challenge confronting water management in agriculture is to improve water use efficiency and its sustainability. This can be achieved through (i) an increase in crop water productivity (an increased in marketable crop yield per unit of water transpired) through irrigation, (ii) a decrease in water losses through soil evaporation that could otherwise be used by plants for their growth, and (iii) an increase in soil water storage within the plant rooting zone through better soil and water management practices at farm and area-wide (catchment) scales.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define water management in agriculture.
2. State the recommended water management given.
3 Elaborate the ways on how to improve water management practices.

7.0 REFERENCES/FURTHER READING

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MODULE 2 SOIL AND WATER CONSERVATION TECHNIQUES

UNIT 1 GENERAL INTRODUCTION TO CONCEPT OF SOIL AND WATER CONSERVATION TECHNIQUES

CONTENTS

1.0 INTRODUCTION

There are always strong links between techniques for soil conservation and Techniques for water conservation, and this applies equally in semi-arid areas. Many techniques are directed primarily to one or the other, but most contain an element of both. Reduction of surface run-off by structures or by changes in land management will also help to reduce erosion. Similarly, reducing erosion will usually involve preventing splash erosion, or formation of crusts, or breakdown of structure, all of which will increase infiltration, and so help the water conservation.

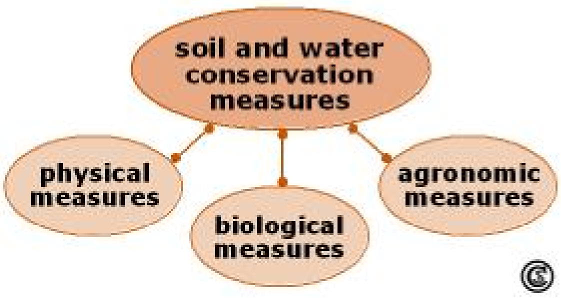


Fig 2 Types of soil and water conservation Techniques
Image Credit: after Heathcote 1998; Krüger et al. 1997

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- understand the meaning of soil and water conservation techniques
- understand the purpose soil and water conservation techniques
- explain the classification of soil and water conservation techniques
- understand the application of soil and water conservation techniques.

3.0 MAIN CONTENT

3.1 Definition

Soil and water conservation techniques are those activities at the local level which maintain or enhance the productive capacity of the land including soil, water and vegetation in areas prone to degradation through prevention or reduction of soil erosion, compaction, salinity; conservation or drainage of water.

3.2 Purpose Soil and Water Conservation Techniques

Soil and water conservation techniques are predominantly applied for the following purposes to:

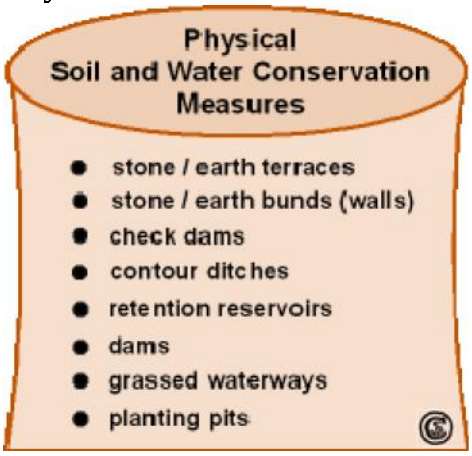
1. control runoff and thus prevent loss of soil by soil erosion, to reduce soil compaction
2. maintain or to improve soil fertility
3. conserve or drain water
4. harvest (excess) water.

3.3 Classification of Soil and Water Conservation Techniques

A variety of soil and water conservation Techniques are well known. These technologies can be differentiated either by their main purpose or by type. As many among them fulfil several functions simultaneously these are classified here by type (see figure):

physical Techniques (also termed mechanical or technical Techniques);
biological Techniques (also termed vegetative Techniques);
agronomic Techniques (sometimes called best management practices)

Physical Soil and Water Conservation Techniques



Physical techniques are structures built for soil and water conservation. Some principles should be considered. They should aim to:

- increase the time of concentration of runoff, thereby allowing more of it to infiltrate into the soil
- divide a long slope into several short ones and thereby reducing amount and velocity of surface runoff
- reduce the velocity of the surface runoff
- protect against damage due to excessive runoff.

In most systems any physical measure can be built – check dams or contour ditches, for example (see figure) (Heathcote 1998). Soil and Water Conservation Techniques in the A River catchment.
In the A River catchment, walls and terraces are used. Both serve as control structures to prevent soil erosion processes - a major problem in this drainage basin.

Terraces

Fig3:Recently constructed terraces in the A river catchment

Terraces are earthen embankments installed at right angles to the steepest slope to intercept the surface runoff. An embankment usually consists of two parts:

- an excavated channel
- a bank or ridge on the downhill side of the channel which is formed with the material excavated from the channel (Lal 1995).

Different types of terraces exist, based on the design and shape of the channel and the ridge. They should be selected in accordance with the local conditions and problems.

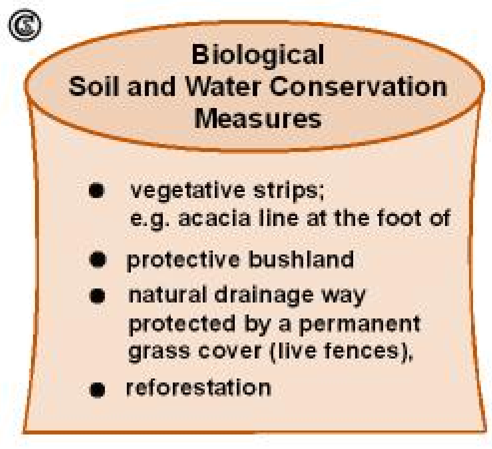
Bench terraces occur in the A River catchment (see figure 1). This type of terracing is practiced on areas of steep slope. Building only walls that reduce slope length is not sufficient here to reduce the power of the runoff. Additionally, it is necessary to modify the degree of slope by half-excavating a channel and half-filling a bank. The original ground will be converted into level, step-like fields.

The main functions of bench terraces are to:

- control erosion by reducing the degree and length of the slope;
- increase the infiltration of rain water;
- maintain soil fertility;
- allow improved irrigation where necessary

The constructed terraces (as well as the other physical Techniques) can be applied together with several biological Techniques, which are described in the following.

Biological Techniques



Biological techniques for soil and water conservation work by their protective impact on the vegetation cover. A dense vegetation cover

- prevents splash erosion;
- reduces the velocity of surface runoff;
- facilitates accumulation of soil particles;
- increases surface roughness which reduces runoff and increases infiltration;
- the roots and organic matter stabilise the soil aggregates and increase infiltration (Morgan 1999; Richter 1998; Hurni et al. 2003).

These effects entail a low soil erosion rate compared with an uncovered soil which shows in general a high soil erosion rate. Even cultivated crops in agricultural areas are a better protection against soil loss than uncovered soil (relatively high soil erosion rate) (Morgan 1999). Other positive impacts have been observed, such as improved soil moisture condition (or protection against erosion by wind). Thus, biological Techniques are an effective method of soil and water conservation, especially since they are low in cost (Heathcote 1998). Additionally, these can be used with structural and agronomic Techniques.

Several types of biological soil and water conservation Techniques exist (see figure).

Reforestation

Fig 4: Reforestation area

In highly degraded areas **reforestation** is an important measure for regeneration of the soil and water balances (see figure above). Trees fulfill many functions such as protection from erosion or conserving soil moisture. Two decisions have to be made initially when reforestation is to be done:

- should the area be completely closed for cultivation and pasture for a specific period? If so, the border must be marked clearly.
- which works better: direct seeding or planting of nursery-grown seedlings?

The answer depends on many factors such as climate, biotic factors, soil, etc. (Tidemann 1996).

Nursery practices

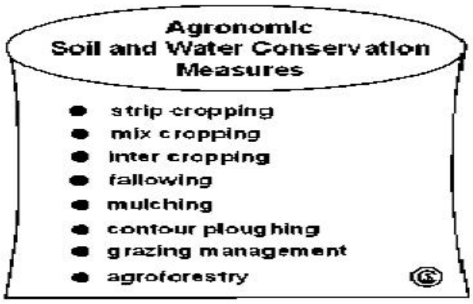
If a nursery is chosen the appropriate site has to be selected carefully. At least four criteria have to be fulfilled:

- the area of the intended nursery should be near the planting site
- the area must be large enough (about 0.5 ha for every 100,000 seedlings) (Tidemann 1996, 276)
- availability of water year-round
- the site should have a suitable soil.

The nursery can be managed commercially or by the community. Some know-how concerning soil-mixing ratios, irrigation, selection of species, etc. is required. In general, indigenous species are to be preferred, as experience with exotic species such as eucalyptus has shown in the past. When the seedlings reach an adequate size they are planted out. Later on, when the trees have grown, the forest can also be used by the people, e.g., for bee keeping.

Agronomic Techniques are the third type of soil and water conservation Techniques explained in this Watershed Management-Module.

Agronomic Soil and Water Conservation Techniques



Agronomic conservation techniques function by

- reducing the impact of raindrops through interception and thus reducing soil erosion and
- increasing infiltration rates and thereby reducing surface runoff and soil erosion (Tidemann 1998).

Some possible agronomic techniques are shown in the figure right. These Techniques can be applied together with physical or biological soil and water conservation techniques. In some systems they may be more effective than structural techniques (Heathcote 1998). Furthermore, it is the cheapest way of soil and water conservation (Wimmer 2002). The significance of land use practices becomes apparent in a comparison made by Tidemann 1996: "The differences in erosion rates caused by different land use practices on the same soil are much greater than the corresponding values from different soils under the same land use".

However, agronomic Techniques are often more difficult to implement compared with structural ones as they require a change in familiar practices (Heathcote 1998). A widely used agronomic measure is contour ploughing which is described more precisely in the next step.

Countour ploughing

FIG 5: Contour ploughing, schematic

FIG 6: Contour ploughing in the A River catchment

Contour ploughing is a well-established agronomic measure that contributes to soil and water conservation (Krüger et al. 1997) (see figure above). The soil is ploughed along the contour instead of up- and downward (see figure 1). This decreases the velocity of runoff and thus soil erosion by concentrating water in the downward furrows (see figure 2). Contour ploughing on the other hand purposely builds a barrier against rainwater runoff which is collected in the furrows. Infiltration rates increase and more water is kept in place. Contour ploughing is especially important at the beginning of the rainy season when biological conservation effects are poor (Krüger et al. 1997). The effectiveness of contour ploughing decreases with increase in slope gradient and length, rainfall intensity and erodibility of the soil (Lal 1995).

Contour ploughing in the A River catchment

In the A River catchment contour ploughing is also practiced to reduce soil erosion (see figure 2). However, it could only once be monitored due to the period of field investigation and thus was not considered in the assessment of soil erosion risk in the drainage basin.

3.4 Application of Soil and Water Conservation Techniques

These Techniques are often used in combination, especially the many traditional soil and water conservation techniques. This is increasingly considered as reasonable. Merely technical approaches are often not successful, especially without participation of the local farmers, forest managers, etc. (Bollom 1993). It has also been recognised that under modern circumstances traditional Techniques alone may often be insufficient to conserve the vital soil and water resources and have to be supplemented by modern practices to achieve a sustainable resource management(Förch and Schütt 2004 a, b).

4.0 CONCLUSION

There are always strong links between techniques for soil conservation and techniques for water conservation, and this applies equally in semi-arid areas. Many techniques are directed primarily to one or the other, but most contain an element of both. Reduction of surface run-off by structures or by changes in land management will also help to reduce erosion. Similarly, reducing erosion will usually involve preventing splash erosion, or formation of crusts, or breakdown of structure, all of which will increase infiltration, and so help the water conservation.

5.0 SUMMARY

Soil and water conservation techniques are those activities at the local level which maintain or enhance the productive capacity of the land including soil, water and vegetation in areas prone to degradation through. Prevention or reduction of soil erosion, compaction, salinity; conservation or drainage of water.

Soil and water conservation Techniques are predominantly applied for the following purposes:

1. to control runoff and thus prevent loss of soil by soil erosion, to reduce soil compaction
2. to maintain or to improve soil fertility
3. to conserve or drain water
4. to harvest (excess) water (Tidemann 1996).

A variety of soil and water conservation techniques are well known. These technologies can be differentiated either by their main purpose or by type. As many among them fulfil several functions simultaneously these are classified here by type, namely <u>physical Techniques</u> (also termed mechanical or technical Techniques);<u>biological Techniques</u> (also termed vegetative Techniques); and <u>agronomic Techniques</u> (sometimes called best management practices) (Krüger et al. 1997).

6.0 TUTOR-MARKED ASSIGNMENT

1. What types of soil and water conservation Techniques are available?
2. Which soil and water conservation Techniques are appropriate?
3. Which physical, which biological and which agronomic Techniques exist?
4. Which principles should be considered in constructing physical Techniques?
5. What are terraces?

6. How function biological Techniques in soil and water conservation?
7. How can reforestation be carried out?
8. How function agronomic Techniques in soil and water conservation?
9. What is meant by contour ploughing?
10. Why is contour ploughing an effective measure for soil and water conservation?

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UNIT 2 SOIL CONSERVATION TECHNIQUES

CONTENTS

1.0 INTRODUCTION

Soil conservation is the prevention of soil loss from erosion or reduced fertility caused by over usage, acidification, salinization or other chemical soil contamination. Slash-and-burn and other unsustainable methods of subsistence farming are practiced in some lesser developed areas.A sequel to the deforestation is typically large scale erosion, loss of soil nutrients and sometimes total desertification. Techniques for improved soil conservation include crop rotation, cover crops, conservation tillage and planted windbreaks, affect both erosion and fertility. When plants, especially trees die, they decay and become part of the soil. Code 330 defines standard methods recommended by the U.S. Natural Resources Conservation Service. Farmers have practiced soil conservation for millennia

In Many countries, policies such as the Common Agricultural Policy are targeting the application of best management practices such as reduced tillage, winter cover crops,[1]plant residues and grass margins in order to better address the soil conservation. Political and economic action is further required to solve the erosion problem. A simple governance hurdle concerns how we name and value the land and what we call it and this can be changed by cultural adaptation.[2]

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- understand soil conservation technique.

3.0 MAIN CONTENT

3.1 Definition

Soil conservation technique is the prevention of soil loss from erosion or reduced fertility caused by over usage, acidification, salinization or other chemical soil contamination. Slash-and-burn and other unsustainable methods of subsistence farming are practiced in some lesser developed areas.

3.2 Soil Conservation Techniques

The following are soil conservation techniques with their corresponding benefits;

a. Establishing and maintaining ground cover vegetation
b. No Till Cropland
c. Mulching
d. Contour Buffer Strips
e. Conservation Crop Rotation
f. Prescribed Burning

3.3 Benefits of Soil Conservation Techniques

However, the following outline corresponding benefits of the earlier mentioned conservation techniques are as follows:

a. Establishing and maintaining ground cover vegetation

- Minimise wind and water soil erosion
- Improve soil quality by selecting plants that help improve organic matter
- Improve air quality by using perennial plants including trees, shrubs, grasses, and perennial forbs
- Enhance wildlife habitat by planting native grasses, forbs, and shrubs
- Improve water quality by increasing vegetative cover.

b. No till Cropland

Managing the amount and distribution of plant residue on the soil surface and limiting soil surface disturbance. The benefits are as follows:

- Reduce surface water erosion
- Reduce wind erosion
- Improve soil organic matter
- Increase plant available moisture
- Provide food and cover for wildlife.

c. Mulching

Applying plant residues or other appropriate materials to the soil. The benefits are:

- Provide erosion control
- Minimize weed establishment and growth
- Conserve soil moisture
- Enhances vegetative cover
- Improves soil quality

d. Contour buffer strips

Narrow strips of permanent vegetative cover around hill slopes alternated down the slope with wider cropped strips that are farmed on contours. The benefits are:

- Reduce sheet and rill erosion
- Reduce transport of sediment and other water-borne contaminants downslope
- Increase water infiltration
- Reduce wind borne soil loss

e. Conservation crop rotation

Growing crops in a recurring sequence on the same field. The benefits are:

- Reduce sheet and rill erosion
- Reduce wind erosion
- Maintain the balance of nutrients
- Improve organic matter
- Reduction in water use

f. Prescribed Burning

The benefits of a controlled fire to a predetermined area is as follows:

- Control exotic weed species
- Control plant disease
- Reduce wildfire hazards
- Improve wildlife habitat
- Improve plant vigor
- Enhance seed and seedling production
- Restore and maintain ecological sites.

4.0 CONCLUSION

A sequel to the deforestation is typically large scale erosion, loss of soil nutrients and sometimes total desertification. Techniques for improved soil conservation include crop rotation, cover crops, conservation

tillage and planted windbreaks, affect both erosion and fertility. When plants, especially trees die, they decay and become part of the soil.
In Many countries, policies such as the Common Agricultural Policy are targeting the application of best management practices such as reduced tillage, winter cover crops,plant residues and grass margins in order to better address the soil conservation. Political and economic action is further required to solve the erosion problem. A simple governance hurdle concerns how we name and value the land and what we call it and this can be changed by cultural adaptation.

5.0 SUMMARY

Soil conservation technique is the prevention of soil loss from erosion or reduced fertility caused by over usage, acidification, salinization or other chemical soil contamination. Slash-and-burn and other unsustainable methods of subsistence farming are practiced in some lesser developed areas. However, the following are outline conservation techniques with their corresponding benefits; Establishing and maintaining ground cover vegetation, No till crop land, mulching, contour buffer strips, conservation crop rotation and prescribed burning. However, the following outline corresponding benefits of the earlier mentioned conservation techniques are as follows: Minimise wind and water soil erosion, improve soil quality by selecting plants that help improve organic matter, Improve air quality by using perennial plants including trees, shrubs, grasses, and perennial forbs, Enhance wildlife habitat by planting native grasses, forbs, and shrubs, and Improve water quality by increasing vegetative cover and many more.

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly define the concept of soil conservation technique.
2. List five Soil conservation techniques and State the corresponding Benefits of each.

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UNIT 3 WATER CONSERVATION TECHNIQUE

CONTENTS

1.0 INTRODUCTION

Water conservation techniques encompasses the policies, strategies and activities made to manage fresh water as a sustainable resource, to protect the water environment, and to meet current and future human demand. Population, household size, and growth and affluence all affect how much water is used. Factors such as climate change have increased pressures on natural water resources especially in manufacturing and agricultural irrigation.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- understand the definition of soil conservation techniques
- know the purpose water conservation techniques
- explain the strategies for water conservation techniques
- identify water conservation techniques for farmers.

3.0 MAIN CONTENT

3.1 Definition

Water conservation techniques encompasses the policies, strategies and activities made to manage fresh water as a sustainable resource, to protect the water environment, and to meet current and future human demand. Population, household size, and growth and affluence all affect how much water is used. Factors such as climate change have increased pressures on natural water resources especially in manufacturing and agricultural irrigation.

3.2 Purpose of Water Conservation Techniques

The goals of water conservation efforts include:

- Ensuring availability of water for future generations where the withdrawal of fresh water from an ecosystem does not exceed its natural replacement rate.
- Energy conservation as water pumping, delivery and waste water treatment facilities consume a significant amount of energy. In some regions of the world over 15% of total electricity consumption is devoted to water management.
- Habitat conservation where minimizing human water use helps to preserve freshwater habitats for local wildlife and water quality.

3.3 Strategies for Water Conservation Techniques

The key strategic activities that benefit water conservation are as follows:

1. Any beneficial deduction in water loss, use and waste of resources.
2. Avoiding any damage to water quality.
3. Improving water management practices that reduce the use or enhance the beneficial use of water.

3.4 Water Conservation Techniques for Farmers

Below, we take a look at five helpful water conservation resources for farmers.

1. **More efficient irrigation equipment**
   Irrigation equipment upgrades can be costly, but there is no question that it will be worth it in the long run. The reality of an ever-shrinking water supply in the face of growing needs will become more evident, and eventually the true cost of water will emerge. The most efficient irrigation system will depend on the type of crop, the type of soil, area climate and other factors. Gravity-flow systems and irrigation systems are just two examples of possible solutions for more efficient water use. Using water flow meters can help measure and control the amount of water being used in irrigation.

2. **Efficient weather equipment**

   Some farmers may be inclined to set an automated irrigation schedule and let it run regardless of the weather. Adjusting irrigation systems to work in better harmony with natural precipitation takes more work, but it is an inarguable way to save significant amounts of water.

   There are numerous weather apps available that provide up-to-the-second precipitation reports. Using these along with irrigation systems can help save water, which will save farmers money and reduce wear and tear on systems.

3. **Proper soil management**

   Proper soil management is a key to conserving water. It is the soil that absorbs, transmits and holds the water for crops to use and there is much a farmer can do to manipulate the nature of soil, and is especially helpful if the soil quality is compromised.

   Various techniques farmers may consider include conservation tillage, using compost and utilizing cover for crops. Again, what works the best to conserve water will depend on what kind of soil is being managed.

4. **Practice water recycling**

   Avoiding or mitigating runoff can save millions of gallons of water over the course of a growing season. Runoff can occur due to overwatering, poor soil and other factors, and in any case is a natural result of irrigation to some degree.

   Recycling runoff not only helps save water, it helps save entire ecosystems. Agricultural runoff typically contains large amounts of chemicals that can seep into groundwater and pollute rivers, streams and other bodies of water. The costs are significant, but so are the benefits.

5. **Use of organic farming methods**

   Water recycling is far less expensive when a farmer doesn't have to treat the water before reusing it. Organic farming methods that reduce or eliminate the use of chemicals are yet another way for farmers to conserve water by taking out a costly step in the recycling process.

   Using organic farming methods can arguably also lower the water-use footprint by preserving the quality of water that would otherwise be negatively affected by polluted runoff. That said, not all organic farming methods reduce the amount of water used, so conservation-minded farmers should carefully consider the options.

6. **Minimise alkaline salts**

   Management of land, water and plants to control and minimize accumulations of salts and/or sodium on the surface and root zone. This topic will be covered in detail on the Soil Restoration page.

7. **Ecological restoration and management of wildlife habitats**
This involves restoration of habitats for endangered and threatened species to conserve biodiversity. Several key points are:

- Control of invasive animal and plant species
- Incorporate native plants indigenous to the region
- Proper site preparation, planting dates, and techniques
- Conserve all undisturbed sites to sustain threatened or endangered species
- Monitor the site for at least three years and make interventions when necessary

4.0 CONCLUSION

Water conservation techniquesencompasses the policies, strategies and activities made to manage fresh water as a sustainable resource, to protect the water environment, and to meet current and future human demand. Population, household size, and growth and affluence all affect how much water is used. Factors such as climate change have increased pressures on natural water resources especially in manufacturing and agricultural irrigation.

5.0 SUMMARY

The goals of water conservation efforts include:1) Ensuring availability of water for future generations where the withdrawal of fresh water from an ecosystem does not exceed its natural replacement rate.2) Energy conservation as water pumping, delivery and waste water treatment facilities consume a significant amount of energy. In some regions of the world over 15% of total electricity consumption is devoted to water management and 3) Habitat conservation where minimizing human water use helps to preserve freshwater habitats for local wildlife and water quality. However, the Strategies for water conservation that benefit water conservation are as follows:1) Any beneficial deduction in water loss, use and waste of resources. 2) Avoiding any damage to water quality. And 3) Improving water management practices that reduce the use or enhance the beneficial use of water.

Water conservation techniques for farmers are summarised as; more efficient irrigation equipment, efficient weather equipment, proper soil management, practice water recycling, use of organic farming methods, minimise alkaline salts and ecological restoration and management of wildlife habitats.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is water conservation management?
2. Enumerate the goals and strategy of water conservation.
3. Highlight five water conservation techniques.

7.0 REFERENCES/FURTHER READING

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MODULE 3 SOIL TILLAGE SYSTEM IN SOIL AND WATER CONSERVATION

UNIT 1 CONCEPT SOIL TILLAGE SYSTEM

CONTENTS

1.0 INTRODUCTION

Some form of tillage system is involved in the production of all crops. It may be as simple as punching or digging holes in soil to plant seeds, seedlings, tubers, or other means of plant propagation, then controlling competing plants by hoeing or slashing. On the other hand, it may be a highly complex system involving primary tillage, several subsequent tillages, application of fertilizers and pesticides (includes herbicides, insecticides, etc.), and the planting operation. After plant establishment, additional operations may be used to control weeds, control erosion, or break surface crusts to enhance soil aeration or water infiltration. Between the above extremes, an infinite variety of systems has been or is being used to produce the world's supply of foods. Seldom do two producers, even within the same geographic region, use exactly the same practices with respect to such factors as type, time, depth and speed of operation. Each producer has essentially his or her own tillage system. A discussion of such seemingly endless variety of systems is beyond the scope of this report. However, some generalized tillage systems have been developed and these will be discussed relative to their effect on the conservation of soil and water resources and on crop production.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- state the definition and meaning of tillage system
- mention the objectives and benefits of tillage system
- state the types of tillage system
- explain the factors affecting the choice of tillage practices
- selection of tillage system.

3.0 MAIN CONTENT

3.1 Definition and Meaning of Tillage System

Below are some summarized definitions and meaning of tillage system from different literature:

1. Tillage includes all operations of seedbed preparation that optimise soil and environmental conditions for seed germination, seedling establishment and crop growth (Lal 1983).
2. Tillage is defined as the soil-related actions necessary for crop production (Boone 1988). According to Antapa and Angen (1990), tillage is any operation or practice taken to prepare the soil surface for the purpose of crop production.
3. The definition by Ahn and Hintze (1990) states that tillage is any physical loosening of the soil as carried out in a range of cultivation operations, either by hand or mechanised.

3.2 Objectives and Benefits of Tillage System

The overall goal of tillage is to increase crop production while conserving resources (soil and twater) and protecting the environment (IBSRAM 1990). While the benefits of tillage systems are:

1. seedbed preparation,
2. weed control,
3. evaporation suppression,
4. water infiltration enhancement, and
5. erosion control. These benefits together result in increased and sustained crop yields. The definitions of tillage, as given above, embrace the concepts and features of both conservation and conventional tillage systems.

3.3 Types of Tillage System

The types of tillage system are broadly classified into conservation and traditional tillage systems.

1. Conservation Tillage Systems

Conservation tillage as defined by the Conservation Tillage Information Center (CTIC) excludes conventional tillage operations that invert the soil and bury crop residues. The CTIC identified five types of conservation tillage systems:

1. no-tillage (slot planting),
2. mulch tillage,
3. strip or zonal tillage,
4. ridge till (including no-till on ridges) and
5. reduced or minimum tillage.

I *No-tillage*

The no-till system is a specialized type of conservation tillage consisting of a one-pass planting and fertilizer operation in which the soil and the surface residues are minimally disturbed. The surface residues of such a system are of critical importance for soil and water conservation. Weed control is generally achieved with herbicides or in some cases with crop rotation. According to Lal (1983), no-tillage systems eliminate all pre planting mechanical seedbed preparation except for the opening of a narrow (2-3 cm wide) strip or small hole in the ground for seed placement to ensure adequate seed/soil contact. The entire soil surface is covered by crop residue mulch or killed sod. A review of tillage studies in Nigeria shows that no-tillage with residue mulch is appropriate for Luvisols in the humid tropics. No-tillage is used in mechanised wheat farming in northern Tanzania and for some perennial crops, for example coffee plantations. Several studies have reported the success of no-tillage systems in many parts of the USA. Though the use of no-till is increasing, adoption has been slow.

No-till fallow is a type of no-tillage system which is used in the dryland areas in the USA. No-till fallow has been most successful in summer rainfall areas. A major goal of fallowing is to recharge the soil profile with water so that the risk of failure for the next crop is greatly reduced (Unger *et al*. 1988). The potential benefits of no-till fallow, compared with other tillage systems, are more effective control of soil erosion, increased water storage, lower energy costs per unit of production and higher grain yields. A major disadvantage of no-till fallow (sometimes referred to as chemical fallow) is its heavy use of herbicides for weed control.

II *Mulch tillage*

Mulch tillage techniques are based on the principle of causing least soil disturbance and leaving the maximum of crop residue on the soil surface and at the same time obtaining a quick germination, and adequate stand and a satisfactory yield. Lal further reported that a chisel plough can be used in the previously shredded crop residue to break open any hard crust or hard pan in the soil; care should be taken not to incorporate any crop residues into the soil. The use of live mulch and crop residue *in situ* involves special mulch tillage techniques or practices. *In situ* mulch, formed from the residue of a dead or chemically killed cover crop left in place is generally becoming an integral component of mulch tillage techniques.

Stubble mulch tillage or stubble mulch farming (sub-tillage) is a crop production system involving surface residues that was first used by a farmer in Georgia, USA, in the early 1930s for controlling water erosion. It was developed primarily for controlling wind erosion, but its value for reducing runoff and controlling water erosion was also soon apparent. This practice is carried out by small- and large-scale farmers in Tanzania for perennial crops like coffee and banana, as well as annual crops such as wheat and barley.

III *Strip or zonal tillage*

The concept of strip or zonal tillage. The seedbed is divided into a seedling zone and a soil management zone. The seedling zone (5 to 10 cm wide) is mechanically tilled to optimise the soil and micro-climate environment for germination and seedling establishment. The inter row zone is left undisturbed and protected by mulch. Strip tillage can also be achieved by chiseling in the row zone to assist water infiltration and root proliferation.

IV *Ridge till*

In this system, the soil is left undisturbed prior to planting but about one-third of the soil surface is tilled at planting with sweeps or row cleaners; planting of row crops is done on preformed cultivated ridges, while weeds are controlled by herbicides. Ridge till has been gaining popularity as a conservation practice for maize and soybean production in the USA.

V *Reduced or minimum tillage*

This system covers other tillage and cultivation systems not covered above but meets the 30% residue requirement. In Africa, the term minimum tillage is not always employed with the same meaning as in temperate countries, and may also be used differently in the different contexts of shifting cultivation (still the dominant system in most of Africa) and mechanised agriculture.

2. Conventional tillage systems

The conventional system comprised of mechanized and traditional systems;

I *Mechanised systems*

These involve the mechanical soil manipulation of an entire field, by ploughing followed by one or more harrowing. The degree of soil disturbance depends on the type of implement used, the number of passes, soil and intended crop type.

II *Traditional tillage*

In the humid and sub-humid regions of West Africa, and in some parts of South America, traditional tillage is practised mostly by manual labour, using native tools which are generally few and simple, the most important being the cutlass and hoe which come in many designs depending on function. To facilitate seedbed preparation and planting, forest undergrowth or grass is cleared with a cutlass and trees and shrubs left, but pruned. The cut biomass and residues are disposed of by burning *in situ*. This type of clearing is non-exhaustive, leaving both appreciable cover on the soil, and the root system which gives the topsoil structural stability for one or two years.

3.4 Factors Affecting the Choice of Tillage Practices

Tillage is a labor-intensive activity in low-resource agriculture practiced by small land-holders, and a capital and energy-intensive activity in large-scale mechanized farming. For any given location, the choice of a tillage practice will depend on one or more of the following factors:

1. Soil factors

- Relief (slope)
- Erodibility
- Erosivity
- Rooting depth|
- Texture and structure
- Organic-matter content
- Mineralogy

2. Climatic factors

- Rainfall amount and distribution
- Water balance
- Length of growing season
- Temperature (ambient and soil)
- Length of rainless period

3. Crop factors

- Growing duration
- Rooting characteristics
- Water requirements
- Seed

2. Socio-economic factors

- Farm size
- Availability of a power source
- Family structure and composition
- Labour situation
- Access to cash and credit facilities

3. Economic factors

- high costs of fuel, labour, tractors, and other equipment;
- high equipment inventories and maintenance costs;
- ability to use land at risk of erosion for more intensive crop production (rather than for pastures or in long-term rotations);
- the opportunities offered for more intensive cropping, avoiding long fallow periods, because of greater water conservation; and
- in many instances, higher crop yields.

4. Other factors

Government policies
Objectives and priorities

3.5 Selection of Tillage System

The tillage system selected for a particular situation depends on such variables as climatic zone, crop to be grown, soil factors, economic level of the producer, preferences of the producer, social influences, and government policies. No variable is entirely independent of the others; hence the seemingly endless variety of systems previously mentioned. Each variable, however, will be discussed in relation to its effect on the selection of tillage system and, in turn, on soil and water conservation.

4.0 CONCLUSION

Tillage operations are needed for seedbed preparation, weed con-trol, management of crop resi-dues, mixing fertilizer in the soil, improving soil aeration, alleviating compaction and optimizing soil temperature and moisture regimes. The choice of tillage practice depends on soil, climatic, crop and socio-economic factors. Conservation tillage, a crop production system involving the management of surface residues, prevents degradative processes and restores and improves soil productivity. While Conservation tillage procedures must be related to the particular site. Their successful application and use over a wide range of soil conditions depends on matching the procedure to soil type, crop cultivar, climatic factors and other aspects of the environment. Appropriate recommendations to farmers should be based on scientific data from well-designed and adequately equipped long-term experiments. The priorities for the development of conservation tillage systems include:

- development of cheap alternative methods of weed control, especially in tropical Africa for farmers with few resources
- development of effective and specific herbicides to control weeds for countries where the farmers can afford them (such herbicides should not harm subsequent crops)
- development of suitable crop rotations including cover crops, and improved cropping sequences that result in more effective storage of rainfall and efficient utilisation of soil available water,
- provision of appropriate equipment for planting and fertilizer application
- breeding of crop cultivars that are adaptable to conservation tillage systems and also have characteristics that aid in erosion control as well as improve soil fertility.

5.0 SUMMARY

Some summarised definitions and meaning of tillage system from different literature are; 1) Tillage includes all operations of seedbed preparation that optimise soil and environmental conditions for seed germination, seedling establishment and crop growth. 2) Tillage is defined as the soil-related actions necessary for crop production. According to Antapa and Angen (1990), tillage is any operation or practice taken to prepare the soil surface for the purpose of crop production. And 3) The definition by Ahn and Hintze (1990) states that tillage is any physical loosening of the soil as carried out in a range of cultivation operations, either by hand or mechanised.

The overall goal of tillage is to increase crop production while conserving resources (soil and water) and protecting the environment. While The benefits of tillage systems are: seedbed preparation, weed control, evaporation suppression, water infiltration enhancement, and erosion control. These benefits together result in increased and sustained crop yields. The definitions of tillage, as given above, embrace the concepts and features of both conservation and conventional tillage systems. The types of tillage system are broadly classified into conservation and traditional tillage systems. The conservation tillage systems are identified as; no-tillage (slot planting), mulch tillage, strip or zonal tillage, ridge till (including no-till on ridges) and reduced or minimum tillage. while The conventional system comprised of mechanised and traditional systems.

For any given location, the choice of a tillage practice will depend on one or more of the following factors:1) **Soil factors; (**Relief (slope), Erodibility, Erosivity, ,Rooting depth|, Texture and structure, Organic-matter content and Mineralogy. 2) **Climatic factors: (** Rainfall amount and distribution, Water balance, Length of growing season, Temperature (ambient and soil) and Length of rainless period). 3) **Crop factors; (** Growing duration, Rooting characteristics, Water requirements and Seed). 4) **Socio-economic factors ; (** Farm size, Availability of a power source, Family structure and composition, Labour situation and Access to cash and credit facilities). 5) **Economic factors;** (high costs of fuel, labour, tractors, and other equipment;high equipment inventories and maintenance costs;ability to use land at risk of erosion for more intensive crop production (rather than for pastures or in long-term rotations);the opportunities offered for more intensive cropping, avoiding long fallow periods, because of greater water conservation; andin many instances, higher crop yields. And 6) **Other factors;** (Government policies, Objectives and priorities).

The tillage system selected for a particular situation depends on such variables as climatic zone, crop to be grown, soil factors, economic level of the producer, preferences of the producer, social influences, and government policies. No variable is entirely independent of the others; hence the seemingly endless variety of systems previously mentioned. Each variable, however, will be discussed in relation to its effect on the selection of tillage system and, in turn, on soil and water conservation

6.0 TUTOR-MARKED ASSIGNMENT

1) Define tillage system as given.
2) What are the objectives of tillage system?
3) Enumerate five benefits of tillage system
4) List of five factors affecting the choice of tillage practices and give three examples of each.

5) what is the broad classification of tillage system? list two example each and explain.

7.0 REFERENCE/FURTHER READING

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UNIT 2 EFFECTS OF SOIL TILLAGE ON CROP PRODUCTION

CONTENTS

1.0 INTRODUCTION

Tillage has been an important aspect of technological development in the evolution of agriculture, in particular in food production. The objectives of tilling the soil include seedbed preparation, water and soil conservation and weed control. Tillage has various physical, chemical and biological effects on the soil both beneficial and degrading, depending on the appropriateness or otherwise of the methods used. The physical effects such as aggregate-stability, infiltration rate, soil and water conservation, in particular, have direct influence on soil productivity and sustainability.

Tillage technology began with the use of stick or metal jab for seeding and with gradual agricultural development the technology passed through a phase of ploughing - animal-drawn ploughs, subsequently followed by tractor-drawn implements and recently with more powerful machinery. At the centre of all this development, is the availability and employment of energy sources. In developed countries and in some developing countries today, fossil fuel is the main energy source, whilst in most developing tropical countries human labour is still predominant. However, animal draught power has been the tradition in many developing countries, particularly in the semi-arid tropics. A major constraint on the use of animals is and has been the availability of adequate fodder.

Recently, many developing countries have introduced tractors and various implements in attempts to increase food production. The general lesson learnt in most such countries is that often the machinery chosen has not been matched to the various agro-ecological zones and soil types. Furthermore, technicians engaged in the tillage operations have not been properly trained. This has resulted in widespread soil degradation and loss in soil productivity. Today there are major problems facing the modernization of African agriculture. Food production must necessarily keep pace with population growth. Many countries will soon have limited new land for agricultural development leaving no alternative other than intensifying yield per unit area. Soil management and conservation must play a major role in increasing crop yields and soil productivity on a sustainable basis.

Tillage and residue management which have direct influence on soil and water conservation are two important components of soil management in Africa, especially in the semi-arid tropics. This agro-ecological zone has a great potential for increased agricultural productivity but at the same time poses a major challenge due to the various soil and climatic constraints, and the ease with which serious soil degradation occurs if farm operations are not carefully managed. Tillage aspects of soil management, in particular, research, development and technology transfer to users to increase agricultural production in Africa are discussed and highlighted in this module.

2.0 OBJECTIVES

By the end of this unit, you will be able:

- explain the definition and meaning of tillage effects on soil and crop production
- explain the tillage effect on soil properties
- explain the tillage effect on crop yield
- discuss approach to tillage development.

3.0 MAIN CONTENT

3.1 Definition and Meaning of tillage Effects on Soil and Crop Production

One of the basic and important components of agricultural production technology is soil tillage. Various forms of tillage are practised throughout the world, ranging from the use of simple stick or jab to the sophisticated para-plough. The practices developed, with whatever equipment used, can be broadly classified into no tillage, minimum tillage, conservation tillage and conventional tillage. Energy plays a key role in the various tillage systems. An important question underlying all these practices is: why till? Much has been written on this topic and it can be summarised as follows:

- seedbed preparation
- soil and water conservation
- erosion prevention
- loosening compacted soil
- weed control

The best management practices usually entail the least amount of tillage necessary to grow the desired crop. This not only involves a substantial saving in energy costs, but also ensures that a resource base, namely the soil, is maintained to produce on a sustainable basis.

3.2 Tillage Effect on Soil Properties

Tillage affects soil physical, chemical and biological properties. Research results have been widely reported on the effects of tillage on soil aggregation, temperature, water infiltration and retention as the main physical parameters affected. The magnitude of the changes depends on soil types as well as soil composition. Changes in chemical properties are dependent mainly on the organic matter content of the soils. Tillage affects aeration and thus the rate of organic matter decomposition. Biological activities in the soil are vital to soil productivity through the activities of earthworms, termites and the many other living creatures in the soil. These influence water infiltration rates by their burrowing in the soil and their mucilage promotes soil aggregation. Tillage effects on soils are closely related to the management of crop residues in and on the surface of the soil. Unger et al. (1991) point out that the two practices with major impact on soil conservation are crop residue management and tillage. The traditional ploughing-in of crop residues is now giving way to surface soil residue management, which is more related to soil and water conservation, particularly in the semi-arid tropics.

3.3 Tillage Effect on Crop Yield

A large volume of experimental data has been published on tillage effects on crop yields under various climates, agro-ecological conditions, soils, crops and residue management systems. Under some of these conditions, the tillage effect is either closely linked to soil aggregation, hence water infiltration rate and water storage capacity, or indirectly related to soil and water conservation. Moisture conservation is particularly important in semi-arid conditions. Soil types and their various reactions to tillage are of paramount importance in determining the superiority of one practice over the other. Socio-economic considerations, however, should always be taken into account in decision making for the adoption of one practice over another.

Difficulties have arisen in the past because limited information was given on soil types when comparing one tillage treatment with another. There must be some caution with technology transfer from one agro-ecological zone or one soil type to the other. There has also been some confusion with the treatment regarded as no-tillage. Whereas in some cases, surface soil was mulched, or herbicides used to kill weeds in situ, there have been many instances in which residues were removed. In such cases comparison becomes not only difficult but conclusions are drawn which may not apply to similar agro-ecological conditions and soils.

TABLE 1: Effect of tillage system on profile water content to a depth of 1 m at two weeks after planting

Tillage system	Profile water content (mm)
No till, residues burnt	49.4
Ploughing, residues incorporated	95.8
Ploughing, residues incorporated followed by addition of external mulch	103.7

Tillage effects may differ from one agro-ecological zone to the other. In semi-arid regions moisture conservation is one of the key factors to consider. The table shows the importance of tillage and residue management on soil profile water content. The soil was mechanically tilled to a depth of 20-30 cm (Table 14). The effect of tillage systems on crop yield is not uniform with all crop species, in the same manner as various soils may react differently to the same tillage practice. The effect of tillage on yields of various crops in the West African semi-arid tropics. Cotton showed the smallest yield increase with tillage within the range of crops tested.

TABLE 2: Effect of tillage on crop yields in the West African semi-arid tropics (Nicou and Charreau 1985)

Crop	Number of annual results	Yield (kg ha-1		Yield increase (%)
		control	with tillage	
Millet Sorghum Maize Rice Cotton Groundnut	38 86 31 20 28 46	1558 1691 1893 1164 1322 1259	1894 2118 2791 2367 1550 1556	22 25 50 103 17 24

TABLE 3: Effect of cropping sequence and residue management on cowpea reproductive physiology and grain yield in the Sudan Savannah of Burkina Faso (IITA/SAFGRAD 1985)

Preceding crop	Residue management system1	Date of flowering2	Date of maturity2	Yield (kg ha-1)
Maize Crotalaria Maize	Residues removed Residues retained Residues retained LSD (0.05)	48.7 46.6 45.7 1.6	71.2 69.2 68.5 1.0	436 918 921 175

1No tillage in all treatments
2 Number of days after planting

TABLE 4: Effect of different tillage treatments on sorghum grain yield, runoff and soil loss, Luvisol (ICRISAT Centre 1983-1987) (ICRISAT 1988)

Treatment	Sorghum grain yield1	Runoff2 (mm)	Soil loss2 (t ha-1)
10 cm deep traditional ploughing	2.52	128	1.66
15 cm non inverted primary tillage	2.83	102	1.62
15 cm deep mouldboard ploughing	2.76	106	1.70
25 cm deep mouldboard ploughing	3.22	85	1.41
s.e.	+0.07	+4.9	+0.279

1Average values of four years (1983, 1984, 1986 and 1987)
2 Average values of 1986 and 1987

Tillage effects in semi-arid zones are closely linked to moisture conservation and hence the management of crop residues. Researchers emphasise the link between crop residue management and tillage and recognise them as the two practices with major impact on soil conservation in the semi-arid zones. Residue retention in a cropping system in Burkina Faso significantly increased the yield of cowpeas as shown in Table 3. Adequate quantities of residues retained increase porosity, water infiltration and water storage. Other effects of different tillage practices on sorghum yield are presented in Table 4.

On the Luvisol in this experiment, deep ploughing increased grain sorghum yield over other treatments. Many results reported in literature show crop yields under conventional tillage as superior to those under conservation tillage. There are, however, also many other results which show the reverse. In both cases the economics of the tillage input are not considered, namely energy and labour costs as well as capital investment in equipment. With tillage effect on soils, both short and long term effects must be considered in working out the economics of a system.

It is evident from the extensive published data on tillage that the effect on crop yield and soil differs with soil conditions. Generalisation and technology transfer should be treated therefore with more caution than hitherto. The choice of tillage methods depends on several factors but soil properties play an important role in determining intensity, frequency and type of tillage required. Many developing countries therefore will benefit, making full use of their soil data in acquiring tillage technology packages developed elsewhere. In addition to the soil factors, climatic factors such as soil temperature regimes, rainfall characteristics and length of growing season should be taken into account (Lal 1985). The relationship between tillage and climate underscores the importance of soil and crop specificity in determining the exact nature of tillage operations.

Under semi-arid conditions conventional tillage is superior to no tillage, reduced tillage or mulching with a number of crops - sun hemp (Crotalaria juncea), barley (Hordeum vulgare), mustard (Brassica juncea) and chickpea (Cicer arietinum) grown in the dry season. In West African semi-arid regions, soil inversion and deep ploughing superior to no tillage in increasing plant-available water and crop yields. Similar data showing greater responses to tillage than no tillage or greatly reduced tillage. Several workers in the United States and elsewhere have found conservation tillage superior and a more cost effective farming practice than conventional tillage on some soils and under certain climatic conditions. Although conservation tillage is being widely adopted, for example, in the United States, generalisation should be avoided. There is strong evidence that soils prone to surface crusting and sealing would benefit from conventional tillage once every 2 or 3 years 3.4 Factors Affecting the Choice of Tillage Practices

3.4 Approach to Tillage Development

Tillage research in developed countries has progressed alongside equipment development. In Africa, the limited range of tillage research and the neglect of small-scale tool development have had an adverse effect on food production, since the bulk of the food is produced by small scale farmers. The situation is complicated by complex factors such as increased population and food demand, exodus of youth from rural areas and the ageing farming population. It is increasingly difficult for these farmers to cope with the drudgery of work using small unimproved tools. There is urgent need therefore to establish more centres to develop and improve tillage equipment and train technicians and farmers in their efficient use. Such centres may initially be located in the savannah and semi-arid areas where the use of draught animals is traditional. Crop rotations and cropping systems will have to be improved to provide fodder for animals so that crop residues are released for soil management purposes.

Considerable work on tillage has been carried out during the past two decades in Africa, considering the limited number of research institutions. However, more intensive work is required on the different soil types, climatic conditions and cropping systems. The use of crop residue for soil management purposes must be given serious consideration. But this can be achieved only if alternative fodder and fuel sources can be developed for draught animals as well as for the provision of domestic energy supply. The development of appropriate cropping systems and inclusion of legumes in the rotation offers promising options.

Greater emphasis needs to be given to the use of soil and climatic data in developing tillage experiments. Tillage effects on different soil types need to be assessed to provide reliable guidelines to the type of conservation tillage system applicable to the various soils. Furthermore, these guidelines should be such that farmers can easily use them. One of the important approaches to the development and transfer of appropriate tillage technology in Africa is the improvement of information dissemination systems among tillage research workers. This will not only ensure effective use of the limited human and financial resources, but also avoid unnecessary repetition of research work carried out under similar ecological and climatic conditions elsewhere countries may consider cooperation and linkages of research programmes through networking systems. Such arrangements can only have their desired impact when individual countries devote adequate resources and time to the development of cooperative programmes.

4.0 CONCLUSION

Tillage work carried out in Africa has been mainly in the semi-arid and sub-humid agro-ecological zones. Relatively little data is available for the humid tropics. The semi-arid zone has the highest prospects for rapid tillage technological package development, firstly, because of the availability of animal draught power, secondly, because of the crops and cropping systems used and, thirdly, because of the urgent need for the development of soil and water conservation and management practices to increase crop production. The need for more efficient use of soil-, climatic-, and cropping system-data in developing tillage systems in the region cannot be over emphasised. Identification and classification of the soil types are necessary pre-requisites. Research methodologies should be standardised and information dissemination should be an essential component of any common tillage network programme to be developed in Africa. Lack of institutions in Africa for the development and improvement of tools suitable for small farmers is a serious drawback to increasing production on the predominantly small farms. In aiming for sustainable productivity, it is imperative that planning should take into consideration the conservation of the resources base, in particular any proposed soil, and tillage practices should be tested prior to their adoption on a wider scale.

5.0 SUMMARY

One of the basic and important components of agricultural production technology is soil tillage. Various forms of tillage are practiced throughout the world, ranging from the use of simple stick or jab to the sophisticated para-plough. The practices developed, with whatever equipment used, can be broadly classified into no tillage, minimum tillage, conservation tillage and conventional tillage. Energy plays a key role in the various tillage systems. An important question underlying all these practices is: why till? Much has been written on this topic and it can be summarised as follows:

- seedbed preparation
- soil and water conservation
- erosion prevention
- loosening compacted soil
- weed control

The best management practices usually entail the least amount of tillage necessary to grow the desired crop. This not only involves a substantial saving in energy costs, but also ensures that a resource base, namely the soil, is maintained to produce on a sustainable basis. However, the following topics were also discussed elaborately; Definition and meaning of tillage effects on soil and crop production, tillage effect on soil properties, tillage effect on crop yield and approach to tillage development in Africa.

6.0 TUTOR-MARKED ASSIGNMENT

1) Give the definition and meaning of tillage effects on soil and crop production.
2) Explain the tillage effect on soil properties.
3) Elaborate the tillage effect on crop yield given at least one example with table.
4) Briefly discussed the approach to tillage development.

7.0 REFERENCE/FURTHER READING

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MODULE 4 SOIL EROSION IN AGRICULTURE

UNIT 1 PRINCIPLES OF SOIL EROSION

CONTENTS

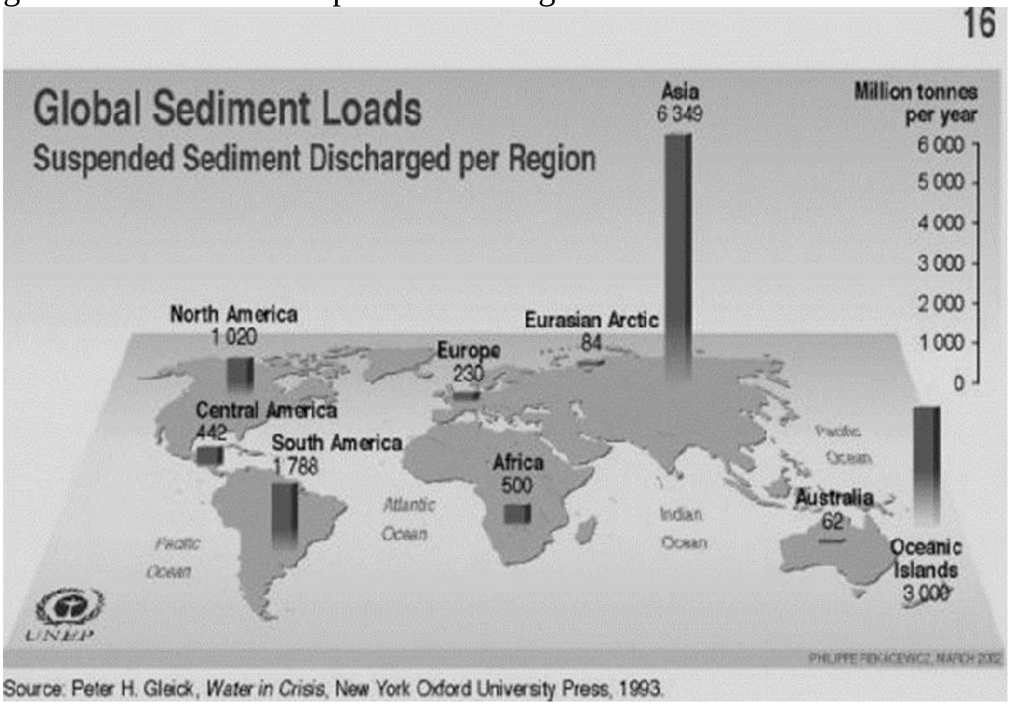
1.0 INTRODUCTION

The uppermost weathered and disintegrated layer of the earth's crust is referred to as soil. The soil layer is composed of mineral and organic matter and is capable of sustaining plant life. The soil depth is less in some places and more at other places and may vary from practically nil to several metres. The soil layer is continuously exposed to the actions of atmosphere. Wind and water in motion are two main agencies which act on the soil layer and dislodge the soil particles and transport them. The loosening of the soil from its place and its transportation from one place to another is known as soil erosion.

The word erosion has been derived from the Latin word 'erodere' which means eating away or to excavate. The word erosion was first used in geology for describing the term hollow created by water. Erosion actually is a two phase process involving the detachment of individual soil particle from soil mass, transporting it from one place to another (by the action of any one of the agents of erosion, viz; water, wind, ice or gravity) and its deposition. When sufficient energy is not available to transport a particle, a third phase known as deposition occurs. In general, finer soil particles get eroded more easily than coarse particles (silt is more easily eroded than sand). Hence soil erosion is defined as a process of detachment, transportation and deposition of soil particles (sediment). It is evident that sediment is the end product of soil erosion process. Sediment is, therefore, defined as any fragmented material, which is transported or deposited by water, ice, air or any other natural agent. From this, it is inferred that sedimentation is also the process of detachment, transportation and deposition of eroded soil particles. Thus, the natural sequence of the sediment cycle is as follows:

Soil → detachment → Transportation → Deposition

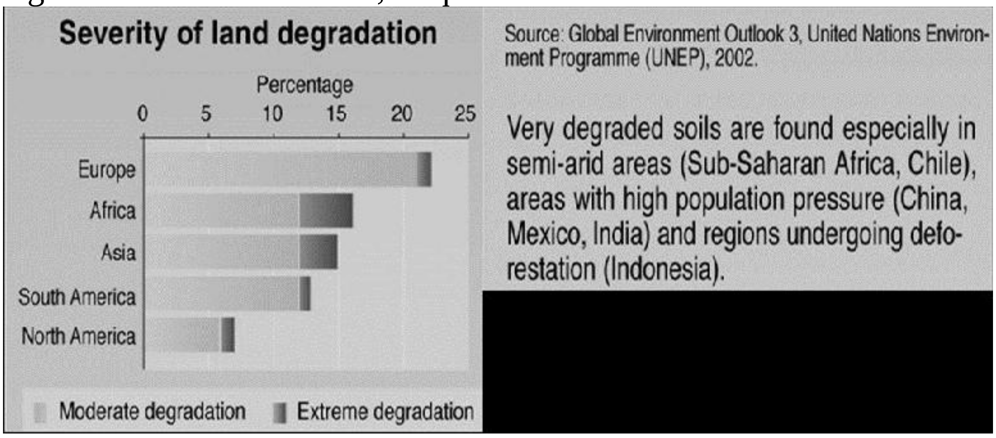
Detachment is the dislodging of the soil particle from the soil mass by erosive agents. In case of water erosion, major erosive agents are impacting raindrops and runoff water flowing over the soil surface. Transportation is the entrainment and movement of detached soil particles (sediment) from their original location. Sediments move from the upland sources through the stream system and may eventually reach the ocean. Not all the sediment reaches the ocean; some are deposited at the base of the slopes, in reservoirs and flood plains along the way. Erosion is almost universally recognized as a serious threat to human wellbeing. Erosion reduces the productivity of crop land by removing and washing away of plant nutrients and organic matter. Distribution of global sediment load is presented in Fig. 7.



Global sediment loads. Due to high monsoon rainfall, Asia has the highest suspended sediment discharge. (Source: Peter H.G., 1983)

1.1.2 Problems Arising due to Soil Erosion

Balanced ecosystems comprising soil, water and plant environments are essential for the survival and welfare of mankind. However, ecosystems have been disturbed in the past due to over exploitation in many parts of the world, including some parts of India. The resulting imbalance in the ecosystem is revealed through various undesirable effects, such as degradation of soil surfaces, frequent occurrence of intense floods etc.



Severity of land degradation at continental scale. (Source: Peter H.G., 1983)

Vast tracts of land have been irreversibly converted into infertile surfaces due to accelerated soil erosion caused by the above and other factors. These degraded land surfaces have also become a source of pollution of the natural water. Deposition of soil eroded from upland areas in the downstream reaches of rivers has caused aggradation. This has resulted in an increase in the flood plain area of the rivers, reduction of the clearance below bridges and culverts and sedimentation of reservoirs. The major land degradation problems due to sedimentation are Erosion by wind and water: Gullies and Ravines and Torrents and Riverine Lands:

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- understand the definition and meaning of soil erosion
- know the causes of soil erosion
- state the types of soil erosion
- outline the agents of soil erosion
- list the factors affecting soil erosion
- explain the mechanics of soil erosion
- discuss prevention and control of soil erosion.

3.0 MAIN CONTENT

3.1 Definition and Meaning of Soil Erosion

Soil erosion is a naturally occurring process that affects all landforms. In agriculture, soil erosion refers to the wearing away of a field's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage.

3.2 Causes of Soil Erosion

No single unique cause can be held responsible for soil erosion or assumed as the main cause for this problem. There are many underlying factors responsible for this process, some induced by nature and others by human being. The main causes of soil erosion can be enumerated as:

(1) Destruction of Natural Protective Cover by
(i) indiscriminate cutting of trees,
(ii) overgrazing of the vegetative cover and
(iii) forest fires.
(2) Improper Use of the Land
(i) keeping the land barren subjecting it to the action of rain and wind,
(ii) growing of crops that accelerate soil erosion,
(iii) removal of organic matter and plant nutrients by injudicious cropping patterns,
(iv) cultivation along the land slope, and
(v) faulty methods of irrigation

3.3 Types of Soil Erosion

3.3.1 According to Origin

Soil erosion can broadly be categorized into two types i.e. geologic erosion and accelerated erosion.

3.3.2 Geological Erosion

Under natural undisturbed conditions an equilibrium is established between the climate of a place and the vegetative cover that protects the soil layer. Vegetative covers like trees and forests retard the transportation of soil material and act as a check against excessive erosion. A certain amount of erosion, however, does take place even under the natural cover. This erosion, called geologic erosion, is a slow process and is compensated by the formation of soil under the natural weathering process. Its effect is not of much consequence so far as agricultural lands are concerned.

3.3.3 Accelerated Erosion

When land is put under cultivation, the natural balance existing between the soil, its vegetation covers and climate is disturbed. Under such condition, the removal of surface soil due to natural agencies takes places at faster rate than it can be built by the soil formation process. Erosion occurring under this condition is referred to as accelerated erosion. Its rates are higher than geological erosion. Accelerated erosion depletes soil fertility in agricultural land.

3.3.4 According to Erosion Agents

Soil erosion is broadly categorised into different types depending on the agent which triggers the erosion activity. Mentioned below are the four main types of soil erosion.

Water erosion: Water erosion is seen in many parts of the world. In fact, running water is the most common agent of soil erosion. This includes rivers which erode the river basin, rainwater which erodes various landforms, and the sea waves which erode the coastal areas. Water erodes and transports soil particles from higher altitude and deposits them in low lying areas. Water erosion may further be classified, based on different actions of water responsible for erosion, as: (i) raindrop erosion, (ii) sheet erosion, (iii) rill erosion, (iv) gully erosion, (v) stream bank erosion, and (vi) slip erosion.

1. **Sheet erosion**
   Sheet erosion is the movement of soil from raindrop splash and runoff water. It typically occurs evenly over a uniform slope and goes unnoticed until most of the productive topsoil has been lost. Deposition of the eroded soil occurs at the bottom of the slope or in low areas. Lighter-coloured soils on knolls, changes in soil horizon thickness and low crop yields on shoulder slopes and knolls are other indicators.

2. **Rill erosion**
   Rill erosion results when surface water runoff concentrates, forming small yet well-defined channels. These distinct channels where the soil has been washed away are called rills when they are small enough to not interfere with field machinery operations. In many cases, rills are filled in each year as part of tillage operations.

3. Gully erosion

Gully erosion is an advanced stage of rill erosion where surface channels are eroded to the point where they become a nuisance factor in normal tillage operations. There are farms in that are losing large quantities of topsoil and subsoil each year due to gully erosion. Surface water runoff, causing gully formation or the enlarging of existing gullies, is usually the result of improper outlet design for local surface and subsurface drainage systems. The soil instability of gully banks, usually associated with seepage of groundwater, leads to sloughing and slumping (caving-in) of bank slopes. Such failures usually occur during spring months when the soil water conditions are most conducive to the problem. Gully formations are difficult to control if corrective Techniques are not designed and properly constructed. Control Techniques must consider the cause of the increased flow of water across the landscape and be capable of directing the runoff to a proper outlet. Gully erosion results in significant amounts of land being taken out of production and creates hazardous conditions for the operators of farm machinery.

4. Bank erosion

Natural streams and constructed drainage channels act as outlets for surface water runoff and subsurface drainage systems. Bank erosion is the progressive undercutting, scouring and slumping of these drainage ways. Poor construction practices, inadequate maintenance, uncontrolled livestock access and cropping too close can all lead to bank erosion problems. Poorly constructed tile outlets also contribute to bank erosion. Some do not function properly because they have no rigid outlet pipe, have an inadequate splash pad or no splash pad at all, or have outlet pipes that have been damaged by erosion, machinery or bank cave-ins.
The direct damages from bank erosion include loss of productive farmland, undermining of structures such as bridges, increased need to clean out and maintain drainage channels and washing out of lanes, roads and fence rows.

Effects of water erosion

On-site

1. The implications of soil erosion by water extend beyond the removal of valuable topsoil.
2. Crop emergence, growth and yield are directly affected by the loss of natural nutrients and applied fertilizers.
3. Seeds and plants can be disturbed or completely removed by the erosion.
4. Organic matter from the soil, residues and any applied manure, is relatively lightweight and can be readily transported off the field, particularly during spring thaw conditions.
5. Pesticides may also be carried off the site with the eroded soil.
6. Soil quality, structure, stability and texture can be affected by the loss of soil. The breakdown of aggregates and the removal of smaller particles or entire layers of soil or organic matter can weaken the structure and even change the texture. Textural changes can in turn affect the water-holding capacity of the soil, making it more susceptible to extreme conditions such as drought.

Off-site

The off-site impacts of soil erosion by water are not always as apparent as the on-site effects. Eroded soil, deposited down slope, inhibits or delays the emergence of seeds, buries small seedlings and necessitates replanting in the affected areas. Also, sediment can accumulate on down-slope properties and contribute to road damage. Sediment that reaches streams or watercourses can accelerate bank erosion, obstruct stream and drainage channels, fill in reservoirs, damage fish habitat and degrade downstream water quality. Pesticides and fertilizers, frequently transported along with the eroding soil, contaminate or pollute downstream water sources, wetlands and lakes. Because of the potential seriousness of some of the off-site impacts, the control of "non-point" pollution from agricultural land is an important consideration.

Wind Erosion: Wind erosion is most often witnessed in dry areas wherein strong winds brush against various landforms, cutting through them and loosening the soil particles, which are lifted and transported towards the direction in which the wind blows. The best example of wind erosion is sand dunes and mushroom rocks structures, typically found in deserts.

Effects of wind erosion

- Wind erosion damages crops through sandblasting of young seedlings or transplants, burial of plants or seed, and exposure of seed.

- Crops are ruined, resulting in costly delays and making reseeding necessary.
- Plants damaged by sandblasting are vulnerable to the entry of disease with a resulting decrease in yield, loss of quality and market value.
- Also, wind erosion can create adverse operating conditions, preventing timely field activities.
- Soil drifting is a fertility-depleting process that can lead to poor crop growth and yield reductions in areas of fields where wind erosion is a recurring problem. Continual drifting of an area gradually causes a textural change in the soil. Loss of fine sand, silt, clay and organic particles from sandy soils serves to lower the moisture-holding capacity of the soil. This increases the erodibility of the soil and compounds the problem.

The removal of wind-blown soils from fence rows, constructed drainage channels and roads, and from around buildings is a costly process. Also, soil nutrients and surface-applied chemicals can be carried along with the soil particles, contributing to off-site impacts. In addition, blowing dust can affect human health and create public safety hazards.

Tillage erosion

Tillage erosion is the redistribution of soil through the action of tillage and gravity. It results in the progressive down-slope movement of soil, causing severe soil loss on upper-slope positions and accumulation in lower-slope positions. This form of erosion is a major delivery mechanism for water erosion. Tillage action moves soil to convergent areas of a field where surface water runoff concentrates. Also, exposed subsoil is highly erodible to the forces of water and wind. Tillage erosion has the greatest potential for the "on-site" movement of soil and in many cases can cause more erosion than water or wind.

Effects of tillage erosion

- Tillage erosion impacts crop development and yield.
- Crop growth on shoulder slopes and knolls is slow and stunted due to poor soil structure and loss of organic matter and is more susceptible to stress under adverse conditions.
- Changes in soil structure and texture can increase the erodibility of the soil and expose the soil to further erosion by the forces of water and wind.

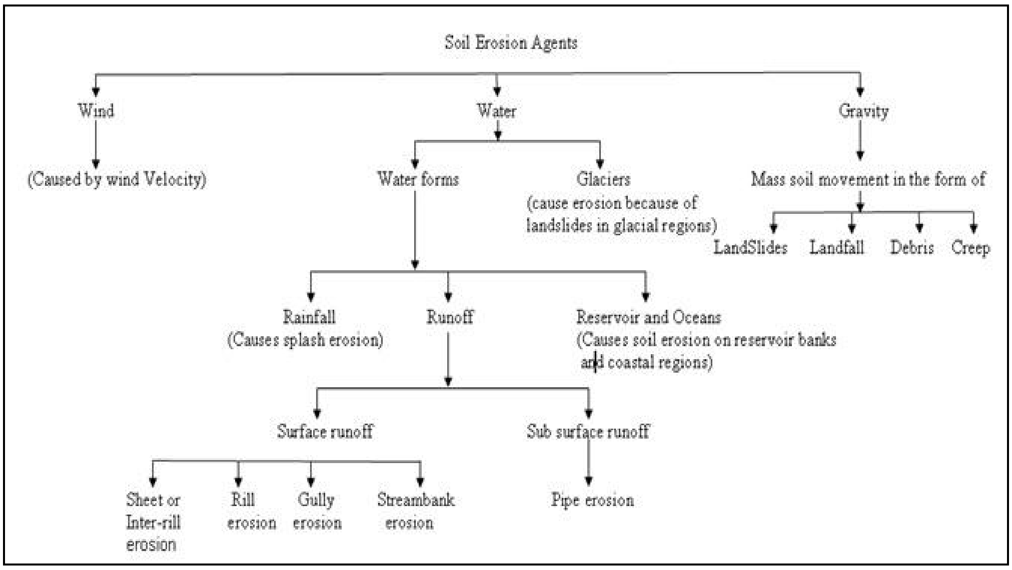
In extreme cases, tillage erosion includes the movement of subsurface soil. Subsoil that has been moved from upper-slope positions to lower-slope positions can bury the productive topsoil in the lower-slope areas, further impacting crop development and yield. Research related to tillage-eroded fields has shown soil loss of as much as 2 m of depth on upper-slope positions and yield declines of up to 40% in corn. Remediation for extreme cases involves the relocation of displaced soils to the upper-slope positions.

Glacial erosion: Glacial erosion, also referred to as ice erosion, is common in cold regions at high altitudes. When soil comes in contact with large moving glaciers, it sticks to the base of these glaciers. This is eventually transported with the glaciers, and as they start melting it is deposited in the course of the moving chunks of ice.

Gravitational erosion: Although gravitational erosion is not as common a phenomenon as water erosion, it can cause huge damage to natural, as well as man-made structures. It is basically the mass movement of soil due to gravitational force. The best examples of this are landslides and slumps. While landslides and slumps happen within seconds, phenomena such as soil creep take a longer period for occurrence.

3.4 Agents of Soil Erosion

Soil erosion is the detachment of soil from its original location and transportation to a new location. Mainly water is responsible for this erosion although in many locations wind, glaciers are also the agents causing soil erosion. Water in the form of rain, flood and runoff badly affects the soil. Soil is in fact a composite of sand, silt and clay. When the rain falls along the mountains and bare soil, the water detaches the soil particles, and takes away the silt and clay particles along with the flowing water. Similarly, when wind blows in the form of storms, its speed becomes too high to lift off the entire soil upper layer and causes soil erosion. Other factors responsible for soil erosion are human and animal activities. Vegetation is the natural cover of soil. When the animals continuously graze in the pastures, the vegetation is removed due to their walking and grazing. Bare lands left behind are easily affected by soil erosion. Activities of human like forest cutting, increased agriculture, and clearing of land for different purposes are the other agents that cause erosion of the soil. The soil erosion agent can be classified and summarised as shown in Figure below:



Soil erosion agents, processes and effects. (Sources: Das, 2000)

3.5 Factors Affecting Soil Erosion

Soil erosion includes the processes of detachment of soil particles from the soil mass and subsequent transport and deposition of those soil/sediment particles. The main factors responsible for soil erosion, in India, are excessive deforestation, overgrazing and faulty agricultural practices. Soil erosion is a very complicated problem as many complex factors affect the rate of erosion and therefore it is difficult to solve. These factors include:

1. **Climatic factor**: The climatic factors that influence erosion are rainfall amount, intensity, and frequency. During the periods of frequent or continuous rainfall, high soil moisture or saturated field conditions are developed, a greater percentage of the rainfall is converted into runoff. This in turn results in soil detachment and transport causing erosion at high rate.

2. **Temperature**: While frozen soil is highly resistant to erosion, rapid thawing of the soil surface brought about by warm rains can lead to serious erosion. Temperature also influences the type of precipitation. Although falling snow does not cause erosion, heavy snow melts in spring can cause considerable runoff damage. Temperature also influences the amount of organic matter that gets collected on the ground surface and get incorporated with the topsoil layer. Areas with warmer climates have thinner organic cover on the soil. Organic matter cover on the surface protects the soil by shielding it from the impact of falling rain and helping in the infiltration of rainfall that would otherwise cause more runoff. Organic matter inside the soil increases permeability of the soil to cause more percolation and reduce runoff.

3. **Topographical Factors:** Among the topographical factors, slope length, steepness and roughness affect erodibility. Generally, longer slope increases the potential for erosion. The greatest erosion potential is at the base of the slope, where runoff velocity is the greatest and runoff concentrates. Slope steepness, along with surface roughness, and the amount and intensity of rainfall control the speed at which runoff flows down a slope. The steeper the slope, the faster the water will flow. The faster it flows, the more likely it will cause erosion and increase sedimentation. Slope accelerates erosion as it increases the velocity of flowing water. Small differences in slope make big difference in damage. According to the laws of hydraulics, four times increase in slope doubles the velocity of flowing water. This doubled velocity can increase the erosive power four times and the carrying (sediment) capacity by 32 times.

4. **Soil:** Physical characteristics of soil have a bearing on erodibility. Soil properties influencing erodibility include texture, structure and cohesion. Texture refers to the size or combination of sizes of the individual soil particles. Three broad size classifications, ranging from small to large are clay, silt, and sand. Soil having a large amount of silt-sized particles is most susceptible to erosion from both wind and water. Soil with clay or sand-sized particles is less prone to erosion.

Structure refers to the degree to which soil particles are clumped together, forming larger clumps and pore spaces. Structure influences both the ability of the soil to absorb water and its physical resistance to erosion. Another property is the cohesion which refers to the binding force between the soil particles and it influences the structure. When moist, the individual soil particles in a cohesive soil cling together to form a doughy consistency. Clay soils are very cohesive, while sand soils are the least cohesive.

5. **Vegetation:** Vegetation is probably the most important physical factor influencing soil erosion. A good cover of vegetation shields the soil from the impact of raindrops. It also binds the soil together, making it more resistant to runoff. A vegetative cover provides organic matter, slows down runoff, and filters sediment. On a graded slope, the condition of vegetative cover will determine whether erosion will be stopped or only slightly halted. A dense, robust cover of vegetation is one of the best protections against soil erosion.

6. **Biological Factors of Soil Erosion**: Biological factors that influence the soil erosion is the activities like faulty cultivation practices, overgrazing by animals etc. These factors may be broadly classified into following three groups:(i) Energy factors, (ii) Resistance factors, and (iii) protection factors.

(i) Energy Factors: They include such factors which influence the potential ability of rainfall, runoff and wind to cause erosion. This ability is termed as erosivity. The other factors which directly reduce the power of erosive agents are reduction in length/degree of slope through the construction of terraces and bunds in case of water eroded areas and creation of wind breaks or shelter belts in case of wind eroded areas.

(ii) Resistance Factors: They are also called erodibility factors which depend upon the mechanical and chemical properties of the soil. Those factors which enhance the infiltration of water into the soil reduce runoff and decrease erodibility, while any activity that pulverizes the soil increases erodibility. Thus, cultivation may decrease the erodibility of clay soils but increases that of sandy soil.

(iii) Protection Factors: This primarily focuses on the factors related to plant cover. Plant cover protects the soil from erosion by intercepting the rainfall and reducing the velocity of runoff and wind. Degree of protection provided by different plant covers varies considerably. Therefore, it is essential to know the rate of soil erosion under different land uses, degrees of length and slope, and vegetative covers so that appropriate land use can be selected for each piece of land to control the rate of soil erosion. The quantity of soil moved past a point is called soil loss. It is usually expressed in unit of mass or volume per unit time per unit area.

Specific Factors that influence tillage erosion

The rate and magnitude of soil erosion by tillage is controlled by the following factors:

a. Type of tillage equipment

Tillage equipment that lifts and carries will tend to move more soil. As an example, a chisel plow leaves far more crop residue on the soil surface than the conventional moldboard plow but it can move as much soil as the moldboard plow and move it to a greater distance. Using implements that do not move very much soil will help minimize the effects of tillage erosion.

b. Direction

Tillage implements like a plow or disc throw soil either up or down slope, depending on the direction of tillage. Typically, more soil is moved while tilling in the down-slope direction than while tilling in the up-slope direction.

c. Speed and depth

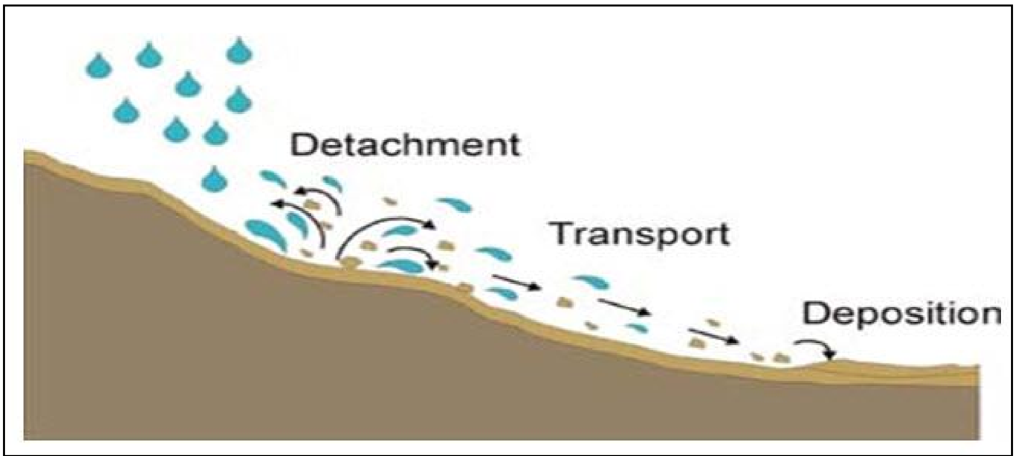
The speed and depth of tillage operations will influence the amount of soil moved. Deep tillage disturbs more soil, while increased speed moves soil further.

d. Number of passes

Reducing the number of passes of tillage equipment reduces the movement of soil. It also leaves more crop residue on the soil surface and reduces pulverization of the soil aggregates, both of which can help resist water and wind erosion.

3.6 Mechanics of Soil Erosion

Soil erosion is initiated by detachment of soil particles due to action of rain. The detached particles are transported by erosion agents from one place to another and finally get settled at some place leading to soil erosion process. Different soil erosion processes are shown in Figure below.



Process of water erosion by the impact of raindrops.
(Source: www.landfood.ubc.ca)
Mechanics of soil erosion due to water and wind is discussed below.

3.7 Mechanics of Water Erosion

There are three steps for accelerated erosion by water:

i) Detachment or loosening of soil particles caused by flowing water, freezing and thawing of the top soil, and/or the impact of falling raindrops,

ii) Transportation of soil particles by floating, rolling, dragging, and/or splashing and
iii) Deposition of transported particles at some places of lower elevation.

Rain enhances the translocation of soil through the process of splashing as shown in Fig.2.2. Individual raindrops detach soil aggregates and redeposit them as particles. The dispersed particles may then plug soil pores, reducing water intake (infiltration). Once the soil dries, these particles develop into a crust at the soil surface and runoff is further increased.

3.7.2 Mechanics of Wind Erosion

Wind erosion occurs where soil is exposed to the dislodging force of wind. The intensity of wind erosion varies with surface roughness, slope and types of cover on the soil surface and wind velocity, duration and angle of incidence. Fine soil particles can be carried to great heights and for (may be) hundreds of kilometers. The overall occurrence of wind erosion could be described in three different phases. These are initiation of movement, transportation and deposition.

1. Initiation of Movement: The initiation of the movement of soil particles is caused by several factors acting separately in combination. In the course of collision of grains rolling and bumping on the surface, some particles may be bounced up. It occurs when the wind force or the impact of moving particles is strong enough to dislodge stationary soil particles.
2. Transportation: The transportation of the particles once they are dislodged take place in three ways:

i) Saltation – In saltation soil particles of medium size (0.10-0.15 mm diameter) are carried by wind in a series of short bounces. These bounces are caused by the direct pressure of the wind on soil particles.
ii) Soil Creep – saltation also encourages soil creep (rolling or sliding) along the surface of the particles (0.5-1.0 mm diameter). The bouncing particles carried by saltation strike the large aggregates and speed up their movement along the surface.
iii) Suspension – When the particles of soil are very small (less than 0.1 mm) they are carried over long distances. Finer suspended particles are moved parallel to the ground surface and upward.

3. Deposition: Deposition of the particles occurs when the gravitational force is greater than the forces holding the particles in air. Deposition could occur when the wind velocity is decreased due to surface obstructions or other natural causes.

3.8 Prevention and Control of Soil Erosion

1. Increase of vegetation

When the land is covered with vegetation, the roots of the plants and trees interlock and interlace to bind the soil particles. This helps in two ways:

- does not allow the soil particles to be carried away by wind or water
- does not allow free flow of water over the soil which prevent erosion of soil by flowing water
- the falling leaves of the plants get converted to humus by decomposing action of the soil microbes. This enriches the soil.

Several methods can be employed to increase the vegetation cover of land. Some of them are as follows:

2. Crop rotation

The practice of growing different crops at different times on the same land is called crop rotation. This keeps the topsoil covered with vegetation. Rotation of cereal crops with legumes also keeps the soil enriched with nitrogen (from the legumes).

3. Reforestation

Slopes are more subject to soil erosion by running water. Growing trees on lands which have lost their vegetation is called reforestation. Trees like Albizia, Cassia, Butia, etc. are suitable for this.

4. Strip cropping

It involves growing of crops in strips. The most common method followed is the contour farming where the strips of crop are at right angles to the slope. Wind-strip cropping is when the strips of crop are place at right angles to the direction of wind.

5. Control of grazing

Covering the land with small plants and grasses helps the topsoil to remain in place as the roots of these plants bind with the soil particles. Cattle graze on these plants and expose the topsoil Thus, grazing should be allowed only on the land meant for the purpose and other areas should be protected from grazing.

6. Terracing

Fields are cut at right angles to the slope. This slows down the flowing water and allows it to irrigate the crops, as well.

7. Dam building

With the dams the speed and amount of water flowing can be controlled. This will control the soil erosion of the river banks.

8. Wind breakers

Trees are planted across the wind direction to protect against the high velocity winds. These rows of trees are called shelter belts or wind breakers.

4.0 CONCLUSION

The uppermost weathered and disintegrated layer of the earth's crust is referred to as soil. The soil layer is composed of mineral and organic matter and is capable of sustaining plant life. The soil depth is less in some places and more at other places and may vary from practically nil to several metres. The soil layer is continuously exposed to the actions of atmosphere. Wind and water in motion are two main agencies which act on the soil layer and dislodge the soil particles and transport them. The loosening of the soil from its place and its transportation from one place to another is known as soil erosion.

The word erosion has been derived from the Latin word 'erodere' which means eating away or to excavate. The word erosion was first used in geology for describing the term hollow created by water. Erosion actually is a two phase process involving the detachment of individual soil particle from soil mass, transporting it from one place to another (by the action of any one of the agents of erosion, viz; water, wind, ice or gravity) and its deposition. When sufficient energy is not available to transport a particle, a third phase known as deposition occurs. In general, finer soil particles get eroded more easily than coarse particles (silt is more easily eroded than sand). Hence soil erosion is defined as a process of detachment, transportation and deposition of soil particles (sediment). It is evident that sediment is the end product of soil erosion process. Sediment is, therefore, defined as any fragmented material, which is transported or deposited by water, ice, air or any other natural agent. From this, it is inferred that sedimentation is also the process of detachment, transportation and deposition of eroded soil particles. Thus, the natural sequence of the sediment cycle is as follows:

Soil → detachment → Transportation → Deposition

5.0 SUMMARY

Soil erosion is a naturally occurring process that affects all landforms. In agriculture, soil erosion refers to the wearing a way of a field's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage.

The main causes of soil erosion can be enumerated as:(1) Destruction of Natural Protective Cover by (indiscriminate cutting of trees, overgrazing of the vegetative cover and forest fires), (2) Improper Use of the Land (keeping the land barren subjecting it to the action of rain and wind, growing of crops that accelerate soil erosion, removal of organic matter and plant nutrients by injudicious cropping patterns, cultivation along the land slope, and faulty methods of irrigation).

Soil erosion can broadly be categorized into two types i.e. geologic erosion and accelerated erosion. And also into different types depending on the agent which triggers the erosion activity. However, the four main types of soil erosion; *(1) Water Erosion:* (2) Wind Erosion: 3). Tillage Erosion, (4) Glacial Erosion: and (5) Gravitational Erosion:

Soil erosion is the detachment of soil from its original location and transportation to a new location. Mainly water is responsible for this erosion although in many locations wind, glaciers are also the agents causing soil erosion.

The main factors responsible for soil erosion, include:*1. Climatic Factor*: *2. Temperature*: *3. Topographical Factors: 4. Soil:5. Vegetation: 6. Biological Factors of Soil Erosion*: and Other Specific

Factors that influence tillage erosion are Type of Tillage Equipment, Direction, Speed and Depth and Number of Passes Soil erosion is initiated by detachment of soil particles due to action of rain. The detached particles are transported by erosion agents from one place to another and finally get settled at some place leading to soil erosion process. Some of Prevention and Control of Soil Erosion are summarised as; Increase of Vegetation, Crop Rotation, Reforestation, Strip Cropping, Control of Grazing, Terracing, Dam Building and Wind Breakers

6.0 TUTOR-MARKED ASSIGNMENT

1) Give the definition and meaning of soil erosion.
2) State the causes of soil erosion.
3) What are the types of soil erosion?
4) Outline the agents of soil erosion.
5) List the factors affecting soil erosion.
6) Explain the mechanics of soil erosion.
7) Discuss prevention and control of soil erosion.

7.0 REFERENCES/FURTHER READING

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UNIT 2 SOIL ERODILITY AND EROSIVITY

CONTENTS

1.0 INTRODUCTION

Soil degradation is indicated by lowering of the fertility status, by a reduction of the nutrient level or by physical loss of topsoil. The latter condition, mostly occurs in regions prone to soil erosion where during heavy rainfall considerable amounts of soil, rock debris and organic matter are transported down slope to rivers and eventually to the sea. Soil erosion control can be attained by knowing soils' susceptibility and the factors responsible for the susceptibility. Generally, the quantity of erosion yield is dependent upon the ability of rain to detach the soil particles (i.e., erosivity of rainfall) and at the same time the susceptibility of soil to withstand against the raindrop (i.e., erodibility of soil). Thus, the soil erosion is the function of both erosivity and erodibility. When rainfall erosivity exceeds the soil erodibility, soil erosion occurs. Erodability (or erodibility) is the inherent yielding or nonresistance of soils and rocks to erosion. A high erodability implies that the same amount of work exerted by the erosion processes leads to a larger removal of material. Because the mechanics behind erosion depend upon the competence and coherence of the material, erodability is treated in different ways depending on the type of surface that eroded. Erosivity is the term used to describe the potential of raindrop impact, runoff from snowmelt, or water applied with an irrigation system rainstorm to detach and erode soil.

When rainfall erosivity exceeds the soil erodibility, soil erosion occurs. Erosivity of rainfall. Rainfall erosivity is a term that is used to describe the potential for soil to be washed off from disturbed, de-vegetated areas and move with into surface waters during storms.

2.0 OBJECTIVES

By the end of this unit, you will be able to:

- understand the definition and meaning of soil erodilibity
- explain the soil erodility factors and determinants
- understand the definition and meaning of erosivity of rainfall
- state the factors affecting rainfall erosivity
- discuss the estimation of erosivity from rainfall data

3.0 MAIN CONTENT

3.1 Definition and Meaning of Soil Erodibility

Soil erodibility is an estimate of the ability of soils to resist erosion based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils (Fig. 17.2). On the basis of erodibility, a soil can be compared quantitatively with the other soils for a given rainfall condition. Bouyoucos (1935) suggested that the soil erodibility depends on mechanical composition of soil, such as sand, silt, and clay, presented by the ratio as:

$$Erodibility, E = \frac{\%\, sand\ + \%\, silt}{\%\, clay}$$

The range of particle diameter of clay, sand and silt is:
Clay = < 0.002 mm
Silt = 0.002 – 0.006 mm
Sand = 0.06 - 2.0 mm.

This indicator is reliable only in some cases.
Tillage and cropping practices which lower soil organic matter levels, cause poor soil structure, and result in soil compactness contribute to increases in soil erodibility. Decreased infiltration and increased runoff can be a result of compacted subsurface soil layers. A decrease in infiltration can also be caused by a formation of a soil crust, which tends to "seal" the surface. On some sites, a soil crust might decrease the amount of soil loss from sheet or rain splash erosion, however, a

corresponding increase in the amount of runoff water can contribute to greater rill erosion problems.

Past erosion has an effect on soil erodibility for a number of reasons. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were, because of their poorer structure and lower organic matter. The lower nutrient levels often associated with subsoils contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil.

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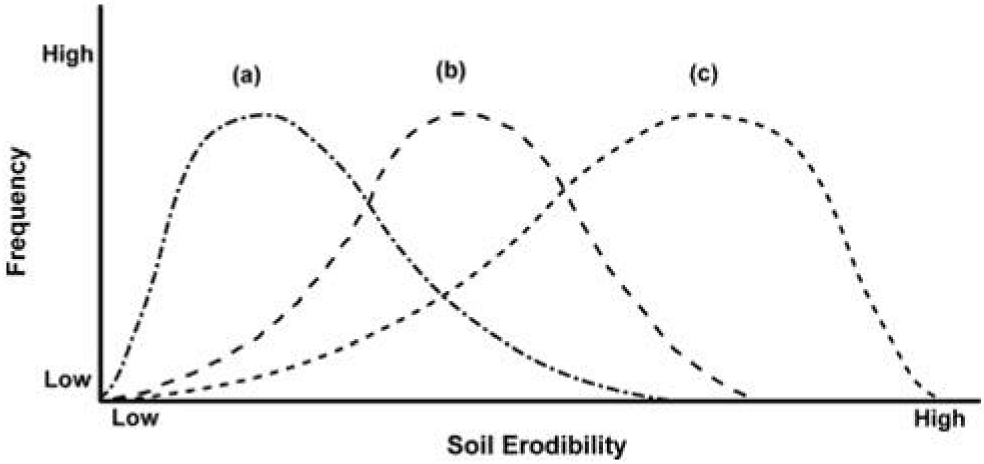

Conceptual Diagram Showing the Frequency Distributions of Three Soils in the Erodibility Continuum. These could Represent the Same Soil Type under Three Levels of Disturbance Intensity, for example Under Low (a), Moderate (b) or High (c) Stocking Rates or the Responses of Three Different Soils, for example A Clay (a), A Loam (b) and A Sand (c) to A Similar Level of Disturbance.

3.1.1 Soil Erodibilty Factor and Determinants

3.1.1.1 Soil Erodibility Factors

Soil erodibility factors (Kw) and (Kf) quantify soil detachment by runoff and raindrop impact. These erodibility factors are indexes used to predict the long-term average soil loss from sheet and rill erosion under crop systems and conservation techniques. Factor Kw applies to the whole soil and factor Kf applies only to the fine-earth (less than 2.0 mm) fraction. The procedure for determining the Kf factor is outlined in Agriculture Handbook 703, Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE), USDA, Agricultural Research Service, 1997. The K factors for soils in Hawaii and the Pacific Basin were extrapolated from local research. The nomograph, shown in Part 618, Subpart B, Exhibits, Section 618.91, was not used to determine K factors for soils in Hawaii. Soil erodibility factors Kw or Kf are used in the erosion prediction equations USLE and RUSLE. Soil properties that influence rainfall erosion are those that affect:

Infiltration rate, movement of water through the soil, and water storage capacity. Dispersion, detachability, abrasion, and mobility by rainfall and runoff. Some of the most important properties are texture, organic matter content, structure size class, and the saturated hydraulic conductivity of the subsoil.

Source: U.S. Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. Available online. Accessed 9/13/2012.

3.1.1.2 Erodibility Determination

Erodibility is defined as the resistance of the soil to both detachment and transport. It varies with soil texture, aggregate stability, shear strength, infiltration capacity and organic and chemical content. Erodibility of a soil is designated by the soil erodibility factor K. There are several approaches to determine K and the three major ones are discussed as given below.

1) Use of in situ erosion plots
2) Measuring K under a simulated rainstorm
3) Predicting K using regression equations describing the relationship between K and soil physical and chemical properties.

1) In Situ Erosion Plots

Erosion plots enable measurement of K under field conditions. They make use of a standard condition of bare soil with no conservation practice and 7° slope of 22.13 m length of plots. This approach is costly and time consuming.

2) Measuring K under a Simulated Rainstorm

This approach is less time consuming but relatively costly. The main drawback is that none of the rainfall simulators built to date can recreate all the properties of natural rain. Nevertheless this method is being used more extensively in erosion studies.

The rainfall simulator, generally used in this study, is made of Duction bars. It measures 1.80 m both in length and width and is 3.80 m high. Several kinds of nozzle are tested and the one that produces water droplets close to natural rain is chosen. Water is released at a low pressure. A wooden tray of dimension 1 m by 2 m and 15 cm deep is placed under the simulator with the slope adjusted to 7°. A collecting structure is placed at the downslope end to gather runoff and sediment. Soil samples collected from different erosion-sensitive regions are placed in the wooden tray. The soil is then subjected to simulated rainstorm of different intensities. Since, it is difficult to set predetermined rainfall intensity, the nozzle is adjusted to low and high levels and the depth of water reaching the wooden tray is measured using a beaker throughout the experiment. Total volume of runoff and sediment are collected and measured.

3) Predicting K

K may be predicted using regression equations describing the relationships between K and soil chemical and physical properties.

3.1.1.3 Relationship between Rainfall Energy and Soil Erosion

It is well-established that the amount of soil that is detached by a particular depth of rainfall is related to the intensity at which this rain falls. The results of various studies further suggest that soil splash rate is a combined function of rainfall intensity and some measure of raindrop fall velocity (Ellison, 1944).

The relationship is given by:

$$S \alpha V^{4.3}.D^{1.07}.I^{0.65} \quad S \propto V^{4.3}.D^{1.07}.I^{0.65} \quad ($$

where, S = quantity of soil splashed in 30 minutes duration, V = velocity of raindrop, ft./s, D = diameter of raindrop, mm and I = intensity of rainfall, inch/h.

Raindrop diameter in storms of varying intensity can be observed for each region, resulting in regressions such as: energy of a storm = energy of each segment of rain falling at a given intensity multiplied by the number of millimeters fallen at this intensity (Bisal, 1960).

The expression is given by:

$$G = K.D.V^{1.4} \qquad G = K.D.V^{1.4} \qquad ($$

where, G = weight of soil splashed in gm, K = constant, depends upon the soil type, D = drop diameter in mm, and V = impact velocity in m/s.

This impact energy is dissipated in four ways:

- Compression of the soil under the rain's impact, following rapid moistening of the soil surface;

- Crushing and shearing stress: separation of aggregated particles;
- Projection of elementary particles in a crown formation on flat soil and transport in all directions but most effectively downhill on slopes.
- Noise of the impact of the drops on resistant material.

3.2 Definitions and Meaning of Erosivity

Erosivity is the term used to describe the potential of raindrop impact, runoff from snowmelt, or water applied with an irrigation system rainstorm to detach and erode soil. Rainfall erosivity is a term that is used to describe the potential for soil to be washed off from disturbed, de-vegetated areas and move with into surface waters during storms.

3.2.1 Erosivity of Rainfall

Rainfall erosivity is a term that is used to describe the potential for soil to be washed off from disturbed, de-vegetated areas and move with into surface waters during storms. It may also be defined as the potential ability of rain to cause the erosion. It is dependent upon the physical characteristics of rainfall, which include raindrop size, drop size distribution, kinetic energy, terminal velocity, etc. For a given soil condition, the potential of two storms can be compared quantitatively, regarding soil erosion to be caused by them. The power of overland runoff flow to erode soil material is partly a property of the rainfall, and partly of the soil surface. Rainfall erosivity is highly related to soil loss. Increased rain erosivity indicates greater erosive capacity of the overland water flow. Soil erosion by running water occurs where the intensity and duration of rainstorms exceeds the capacity of the soil to infiltrate the rainfall. The potential for erosion is based on many factors which include including soil type, slope, and the energy or force of precipitation expected during the period of surface disturbance.

Fig12: Tilled Farmland Very Susceptible to Erosion from Rainfall.

3.2.2 Factors Affecting Rainfall Erosivity

The various factors, which affect the erosivity of rain storm, are given as under:

1) **Rainfall Intensity**
   Rainfall intensity refers to the rate of rainfall over the land surface. It is one of the most important factors responsible for the erosive nature of rainfall. The rainfall intensity is assumed as the force, by which an individual water droplets strikes over the soil surface.

2) **Drop Size Distribution**
   The drop size distribution in a particular rainstorm influences the energy, momentum and erosivity of the rain in cumulative way. The increases in median drop size, increases the rainfall intensity.

3) **Terminal Velocity**
   The effect of terminal velocity of falling raindrops is counted in terms of kinetic energy of respective rain drops at the time of their impact over the soil surface. It is the function of drop size. A rainstorm composed of large proportion of bigger size raindrops, has greater terminal velocity and vice-versa. The kinetic energy of rain storm has following relationship with terminal velocity, as:

$$E_k = \frac{IV^2}{2}$$

where,
Ek = rainfall energy (watts /m2)3, I = Intensity of rainfall (mm/s), and V = Terminal velocity of rainfall before impact (m/s).

4) **Wind Velocity**

Wind velocity affects the power of rainfall to cause soil detachment, by influencing the kinetic energy of rain storm. Tropical regions experience the occurrence of windy storm most of the times. Wind driven storms are more effective than anticipated for breaking the aggregates. The effect of wind velocity on soil detachment by rain storm is shown in Table 1.

Effect of Wind Velocity on Soil Detachment at Different Intensities of Rain Storm. (Source: Lyles et.al, 1969)

Wind Velocity (m/s)	Intensity of Rain (cm/h)		
	1.6	2.84	5.61
	% Soil Detachment (arbitrary unit)		
0	56	93	97
6.7	95	98	97
13.4	97	100	100

5) **Direction of Slope**

The direction of land slope also develops significant effect on rainfall erosivity. Slope direction in the direction of the rain storm, effectively alters the actual kinetic energy of the rain drop. It increases the impact force of the raindrop as the velocity component in the direction of slope becomes more.

3.2.3 Estimation of Erosivity from Rainfall Data

The rainfall erosivity is related to the kinetic energy of rainfall. The following two methods are widely used for computing the erosivity of rainfall.

1. EI30 Index method and
2. KE > 25 Index method.

1. **EI30 Index Method**

This method is based on the fact that the product of kinetic energy of the storm and the 30-minute maximum rainfall intensity gives the best estimation of soil loss. The greatest average intensity experienced in any 30 minute period during the storm is computed from recording rain gauge charts by locating the maximum amount of rain which falls in 30 minute period and later converting the same to intensity in mm/hour. This measure of erosivity is referred to as the EI30 index and can be computed for individual storms, and the storm values can be added over periods of time to give weekly, monthly or yearly values of erosivity.

2. **KE > 25 Index Method**

This is an alternate method introduced by Hudson for computing the rainfall erosivity of tropical storms. This method is based on the concept that erosion takes place only at threshold value of rainfall intensity. From experiments, it was obtained that the rainfall intensities less than 25 mm/h are not able to yield the soil erosion in significant amount. Thus, this method takes care of only those rainfall intensities, which are greater than 25 mm/h. That is why the name is K.E. > 25 Index method. It is used in the same manner as the EI30 index and the calculation procedure is also similar.

Calculation Procedure

The estimation procedure is same for both the methods. However, K.E. > 25 method is more advantageous, because it sorts out many data less than 25 mm/h, hence uses less rainfall data. For both the methods, it is important to have data on rainfall amount and its intensity. The procedure involves the multiplication of rainfall amounts in each class of intensity to the computed kinetic energy values and then all these values are added together to get the total kinetic energy of the storm. The K.E. so obtained, is again multiplied by the maximum 30-minute rainfall intensity to determine the rainfall erosivity value.

4.0 CONCLUSION

When rainfall erosivity exceeds the soil erodibility, soil erosion occurs. Erosivity of Rainfall. Rainfall erosivity is a term that is used to describe the potential for soil to be washed off from disturbed, de-vegetated areas and move with into surface waters during storms.

5.0 SUMMARY

Soil degradation is indicated by lowering of the fertility status, by a reduction of the nutrient level or by physical loss of topsoil. The latter condition, mostly occurs in regions prone to soil erosion where during heavy rainfall considerable amounts of soil, rock debris and organic matter are transported down slope to rivers and eventually to the sea. Soil erosion control can be attained by knowing soils' susceptibility and the factors responsible for the susceptibility. Generally, the quantity of erosion yield is dependent upon the ability of rain to detach the soil particles (i.e., erosivity of rainfall) and at the same time the susceptibility of soil to withstand against the raindrop (i.e., erodibility of soil). Thus, the soil erosion is the function of both erosivity and erodibility. When rainfall erosivity exceeds the soil erodibility, soil erosion occurs. Erodability (or erodibility) is the inherent yielding or nonresistance of soils and rocks to erosion. A high erodability implies that the same amount of work exerted by the erosion processes leads to a larger removal of material. Because the mechanics behind erosion depend upon the competence and coherence of the material, erodability is treated in different ways depending on the type of surface that eroded. Erosivity is the term used to describe the potential of raindrop impact, runoff from snowmelt, or water applied with an irrigation system rainstorm to detach and erode soil.

6.0 TUTOR-MARKED ASSIGNMENT

1. Give the definition and meaning of soil erodilibity.
2. Explain the soil erodility factors and determinants.
3. Give the definition and meaning of erosivity of rainfall.
4. State the factors affecting rainfall erosivity.
5. Discuss the estimation of erosivity from rainfall data.

7.0 REFERENCES/FURTHER READING

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