NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF CROP AND SOIL SCIENCE

COURCE CODE: SLM 506

COURSE TITLE: INTEGRATED SOIL MANAGEMENT

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SLM 506: Integrated Soil Management (2 Units)

COURSE GUIDE

AGR 205:

INTRODUCTION TO AGRO-CLIMATOLOGY

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INTRODUCTION:

Soil is the most fundamental and basic natural resource for all life to survive. The key to good agricultural soil is good soil management; hence integrated soil management. To undertake the study on 'Integrated Soil Management', sub units to be studied include problem soils:- Soil erosion, Soil is too dry, Soil is acidic (acid soils), Soil is alkaline (salt affected soils) or Soil has excess salinity (salt content) or sodicity (sodium content), Soil is too wet (wetland soils); polluted soils, organic soils or Soil lacks organic matter, regosols etc., their characteristics and use, soil organic carbon sequestration; Soil nutrient dynamics.

What you will learn in this Course:

In-depth knowledge of problem soils, causes and effects, their characteristics and use for sustainable agricultural production will be elucidated.

COURSE AIM:

The course aims to provide a good understanding of soil problems to better management soils for agricultural use.

COURSE OBJECTIVES:

After going through this course, you should be able to:

- Explain the nature and scope of soil erosion
- Explain the nature, scope, cause and effects of soil erosion
- Explain cause, effects and management of acid and salt affected soils,
- Explain and manage too wet or dry soils,
- Identify and manage organic and lack of organic matter soils,
- organic carbon sequestration
- Explain soil nutrient dynamics.
- Explain and manage wetland soils

WORKING THROUGH THIS COURSE

This course has been carefully put together bearing in mind the fact that it is an introductory course. However, efforts have been made to ensure adequate explanation of the concepts and issues treated in the work. Tables have been used where necessary to enhance your understanding. You are advised to spend good time to study the work and ensure that you attend tutorial sessions where you can ask questions and compare your knowledge with that of your classmates.

COURSE MATERIALS

You will be provided with the following materials:

A Course guide

In addition, the course comes with a list of recommended reference materials which are not compulsory for you to acquire or read, but are essential to give you more insight into the various topics discussed

STUDY UNITS:

The course is divided into 17 units. The following are the study units contained in this course:
Module 1

Unit 1 Soil erosion: causes and effects

Unit 2 Soil erodibility

Unit 3 Effect of Water Erosion

Unit 4 Wind Erosion

Module 2

Unit 1 Organic Soils

Unit 2. Soil Organic Carbon Sequestration

Unit 3. Carbon Sequestration in Soils: The Opportunities and Challenges

Unit 4. Regosol

Module 3

Unit 1. Problem Soils

Unit 2. Sandy Soils

Unit 3. Polluted Soils

Unit 4. Reclamation nd Management of Polluted Soils

Module 4:

Unit 1. Bioremediation of Polluted Soil Sites with Crude Oil Hydrocarbons

Unit 2. Soil Nutrient Dynamics

Unit 3. Nutrients Cycle In Soils: (P, S, Ca, K & Minor Elements)

Unit 4**.** Roles of Animals in Nutrient Cycling In Soils

Module 5

Unit 1. Wetland Soils

TEXT BOOKS AND REFERENCES

The following textbooks and references are suggested for further reading.

OMAFRA Factsheet, Universal Soil Loss Equation (USLE), Order No. 12-051

BMP 06, Soil Management

BMP 26, Controlling Soil Erosion on the Farm. *Soil Erosion- Causes and Effects*. Available from: https://www.researchgate.net/publication/314500264_Soil_Erosion-_Causes_and_Effects [accessed Jun 22 2019].

Fredrick, R. Troeh, J. Arthur Hobbs, and Roy L. Donahue (2004). Soil and Water Conservation for Productivity and Environmental Protection. Fourth Edition. Pearson Education, Prentice Hall, Upper Saddle River, New Jersey 07458. P 641

Glenn, O Schwab, Richard, K. Frevert, Talcott, W. Edminster and Kenneth, K. Barnes (1981). Soil and Water Conservation Engineering. Third Edition. John Wiley & Sons. New York.

Kim H Tan (2000). Environmental Soil Science. Second edition, Revised and expanded. Marcel Dekker, Inc. New York. Pp 421.

ASSESSMENT

There are two components of assessment for this course. They are the Tutor-Marked Assignment (TMA) and the end of course examination.

TUTOR-MARKED ASSIGNMENT

The TMA is the continuous assessment component of your course. It accounts for 30% of the total score. The TMAs will be given to you by your facilitator and you will return it after you have done the assignment.

FINAL EXAMINATION AND GRADING

This examination concludes the assessment for the course. It constitutes 70% of the whole course. You will be informed of the time for the examination.

SUMMARY

This course intends to provide you with the knowledge of key to good agricultural soil is good soil management; hence integrated soil management as it affects agricultural production and environment. By the end of this course you will be able to answer the following:

- explain the nature and scope of soil erosion
- explain the nature, scope, cause and effects of soil erosion
- explain cause, effects and management of acid and salt affected soils,
- explain and manage too wet or dry soils,
- Identify and manage organic and lack of organic matter soils,
- organic carbon sequestration
- explain soil nutrient dynamics.
- explain and manage wetland soils

We wish you success in this course and hope that you will have a better understanding of the integrated soil management as it affects agricultural production and environment. I wish you best of luck.

Module 1:

In unit one you will be taken through the definition of soil erosion and the activities of man's influence on this phenomenon. You will also be taken through the causes and effects of soil erosion as well as the types of soil erosion. In the next unit, you will be taken through the soil erodibility and its causes, including rainfall effects. Units three and four will focus on water and wind erosion causes and processes. You will be taken through the form and nature of soil erosion and factors that influence soil erodibility.

Module 2:

In unit one, you will be taken through the organic soils; their types, characteristics and management, while unit 2 will dwell on carbon sequestration; basic concepts and its challenges. Unit three dealt with soil carbon sequestration; its opportunities and challenges, while unit four discussed details on Regosols; properties and management.

Module 3:

Unit one of this module explained problem soils; their types, properties and management. Some problem soils discussed include acid sulphate soils, organic soils and salt affected soils; saline and alkaline soils. In unit two, sandy soils, skeletal soils, too dry or too wet soils were explained, to show their use and management practices. Unit three of this module explained polluted soils while unit four showed measures for reclaiming polluted soils.

Module 4:

Unit one of module four discussed bioremediation of hydrocarbon polluted soils and unit two explained soil nutrient dynamics while unit four discussed nutrients dynamic (P, S, Ca, K & minor elements).

Module 5:

This is a single unit module devoted to wetland soil discussion. It gave details on tropical wetlands; their potentials and limitations.

MODULE 1: Soil Erosion – Causes and Effects

UNIT 1 CONTENTS

UNIT 1. SOIL EROSION – CAUSES AND EFFECTS

Introduction:

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. Erosion, whether it is by water, wind or tillage, involves three distinct actions – individual grains of soil are detached from the mass, detached grains are then transported over the land surface and deposited on new sites. Topsoil, which is high in organic matter, fertility and soil life, is relocated elsewhere "on-site" where it builds up over time or is carried "off-site" where it fills in drainage channels. Soil erosion reduces cropland productivity and contributes to the pollution of adjacent watercourses, wetlands and lakes.

Soil erosion can be a slow process that continues relatively unnoticed or can occur at an alarming rate, causing serious loss of topsoil. Water and wind erosion are two main agents that degrade soils. Soil compaction, low organic matter, loss of soil structure, poor internal drainage, salinization and soil acidity problems are other serious soil degradation conditions that can accelerate the soil erosion process. Runoff washes away the soil particles from sloping and bare lands while wind blows away loose and detached soil particles from flat and unprotected lands.

Geologic erosion is a normal process of weathering that generally occurs at low rates in all soils as part of the natural soil while accelerated erosion is that resulting from anthropogenesis.
-forming processes.
The magnitude and impact of soil erosion on productivity depends on nature of soil profile and horizonation, terrain, soil management and climate characteristics. Many factors and processes are responsible for soil erosion. The major objective of studying this lesson is to understand the causative factors of soil erosion and their effects. This unit will therefore study water erosion: forms of water erosion, effects of water erosion; wind erosion: effects of wind erosion; Tillage erosion: effects of tillage erosion; Conservation measures.

2.0 **Objectives**:
At the end of this unit, you should be able to:
- define soil erosion
- identify types of soil erosion
- understand the principles of the different erosion types.

3.0 Water Erosion: Causes and Effects
Most water erosion is classified as sheet erosion, rill erosion, gully erosion or streambank erosion. The widespread occurrence of water erosion combined with the severity of on-site and off-site impacts have made water erosion the focus of soil conservation efforts in Nigeria and elsewhere.

3.1 Sheet Erosion:
Sheet erosion is the removal of a thin layer of soil over an entire soil surface and is therefore 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 lying areas. Lighter-coloured soils on knolls, changes in soil horizon thickness and low crop yields on shoulder slopes and knolls are other indicators. Raindrop splash and surface flow cause sheet erosion, with splash providing most of the detaching energy and flow providing most of the transporting capacity. Sheet erosion is insidious because it is difficult to see. The first sign is when subsoil colour begins to show, as cultivation mixes surface soil and subsoil.

3.2. Rill Erosion:
Runoff water tends to concentrate in streamlets as it passes downhill. This water is more turbulent and has greater scouring action than sheet flow and cuts small channels by removing soil from the edges and beds of the streamlets. These small channels frequently occur between crop rows and along tillage marks but some channels follow the slope across plant rows and break through tillage ridges as they pass downhill. The channels that follow the slope are called ephemeral gullies, because they tend to form repeatedly in the same place in the fields and if not managed carefully they can grow into full-fledged gullies. The crop-row channels are called rills.

Rill erosion therefore 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.

3.3. 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 Nigeria that have loose large quantities of topsoil and subsoil each year due to gully erosion. Surface water runoff, causing gully formation or 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 rainy season months when the soil water conditions are most conducive to the problem.

Gully formations are difficult to control if corrective measures are not designed and properly constructed. Control measures 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.

Erosion channels too large to be erased by ordinary tillage are therefore called gullies. Deep relatively straight-sided channels develop where the soil material is uniformly friable throughout the profile. The channel in deep loess soils is U-shaped with almost vertical walls. Broad V-shaped channels often develop where friable surface soils overlie cohesive, tight, non-erodible subsoils. Gullies are described as ‘active” when their walls are free of vegetation and “inactive” when they are stabilized by vegetation. Gullies are also classified as small, medium and large according to depth, with medium-sized gullies measuring 1 to 5 m deep.

Gully erosion sometimes expands by a process of internal erosion. Here, water enters the soil in cracks or other large openings and flow for a considerable distance beneath the surface, erode soil along the way and emerge with deposits on a slope or gully. Enlargement of the underground channel eventually causes the surface to cave-in and convert to a gully.

3.4. Bank /Streambank 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.

Removal of soil materials from sides of running streams is usually greatest along the outsides of bends, but inside meanders may be scoured intensively during severe floods. Streambank erosion often removes the entire soil profile of very productive soil. Also, streams that are ‘unloaded’ pick up sediment from their beds and banks such that streambank and bed erosion are increased when the sediment load brought into the stream is reduced due to conservation measures on uplands, upstream sediments are caught in reservoirs or other traps.

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

4.0. Conclusion:

Erosion, whether it is by water, wind or tillage, involves three distinct actions – individual grains of soil are detached from the mass, detached grains are then transported over the land surface and deposited on new sites. Topsoil, which is high in organic matter, fertility and soil life, is relocated elsewhere "on-site" where it builds up over time or is carried "off-site" where it fills in drainage channels. The control of soil erosion is very pertinent in agricultural landuse management to attain sustainable production and food security.

5.0 Summary:

In this unit we have learnt that:

1. Soil erosion can occur naturally and is called geologic erosion
2. Soil erosion can be caused by the activities of man (anthropogenic) is referred to as accelerated erosion.
3. Soil erosion can be caused by rainfall and runoff
4. Erosion can occur in water/stream courses
5. Eroded soil materials can be deposited in floodplains

6.0 Tutor-Marked Assignment:

What possible damages would bank erosion cause?

7.0 References/Further Readings:

OMAFRA Factsheet, Universal Soil Loss Equation (USLE), Order No. 12-051

BMP 06, Soil Management

BMP 26, Controlling Soil Erosion on the Farm

Soil Erosion- Causes and Effects. Available from: https://www.researchgate.net/publication/314500264_Soil_Erosion-_Causes_and_Effects [accessed Jun 22 2019].

Fredrick, R. Troeh, J. Arthur Hobbs, and Roy L. Donahue (2004). Soil and Water Conservation for Productivity and Environmental Protection. Fourth Edition. Pearson Education, Prentice Hall, Upper Saddle River, New Jersey 07458. P 641

Glenn, O Schwab, Richard, K. Frevert, Talcott, W. Edminster and Kenneth, K. Barnes (1981). Soil and Water Conservation Engineering. Third Edition. John Wiley & Sons. New York

UNIT 2: SOIL ERODIBILITY**:**

UNIT 2 CONTENTS

1.0 Introduction:

Soil erodibility is related to the soil's detachability and transportability. Any property that deters soil detachment or transportation reduces soil erodibility. Soil texture and structure affects size of soil grains exposed to erosive elements. Runoff must occur for rapid erosion to take place, so soil properties that affect infiltration rate and permeability must also affect rate of erosion.

2.0. Objectives:

The objectives in this unit include to:

- Explain soil erodibility
- Explain physical factor that would influence soil erodibility
- Explain chemical factors influencing soil erodibility
- Explain cementing agents in soil
- Explain the role of organic matter in erosion control
- Explain tillage as it relates to soil erodibilty

3.0 Soil Erodibility: Causes and effects.

Soil erodibility is an estimate of the ability of soils to resist erosion, based on physical characteristics of each soil. Texture is a principal characteristic affecting erodibility, but structure, organic matter and permeability also contribute. 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.

Tillage and cropping/landuse practices that reduce soil organic matter levels, cause poor soil structure, or result in soil compaction, contribute to increases in soil erodibility. For example, compacted subsoil layers can decrease infiltration and increase runoff. Also, soil crusts which tend to "seal" the surface, decreases infiltration rate. On some sites, a soil crust might decrease the amount of soil loss from raindrop impact and splash, but a corresponding increase in amount of runoff water can contribute to more serious erosion problems.

Past erosion also has effect on a soil's erodibility. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils 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.

3.1. Soil Texture:

Sand particles are easy to detach because they lack cohesiveness, but they are difficult to transport because they are relatively large and heavy. Clay particles tend to stick together and are difficult to detach, but are easily transported to great distances once detached from the soil mass. Silty soils are frequently well aggregated but the aggregates readily break down when wetted, and the individual particles are readily transported.

Infiltration rate and permeability of water are related to soil texture in part because water moves rapidly through macropores, but slowly through micropores. Large pores between sand particles permit rapid water movement. Fine to very fine pores common in medium and fine texture soils such as loams, clay loams and clay restrict water movement. Therefore, a moderate rainstorm would produce more runoff and erosion from the finer textured soils than from sandy ones.

3.2 Soil Structure:

Large, stable aggregates make a soil difficult to detach and transport; thus making it more permeable to water. However, soils high in clay usually have low permeability and low infiltration rates, while a well-aggregated clay soil permits faster water movement than a poorly aggregated clay. Factors that influence the size and stability of aggregates include texture, cation on the exchange complex, type of clay mineral, organic matter content, cementing materials other than clay and organic matter and cropping history.

3.2.1. Texture:

Sand has a weakening and loosening effect on structure. Clay is a cementing and aggregating agent. The higher the clay content, up to about 40%, the larger and more stable the aggregates. Clay contents above 40% promote development of very small aggregates that erode easily, especially where surface soil freeze and thaw frequently during winter. Some soil aggregates, particularly those high in silt and very fine sand, are relatively unstable. Raindrops destroy these aggregates and the fine grains flow into and plug surface pores to produce a dense compact layer at the soil surface. Slow infiltration into this compacted layer causes increased runoff and erosion.

3.2.2. Type of Cation on the Exchange complex:

If the cation-exchange complex is occupied mainly by H^+ or trivalent cations, the colloid will be flocculated and individual soil particles will aggregate. Large stable aggregates resist both detachment and transportation. On the other hand, soil colloids with large amounts of Na^+ and K^+ or with very large amounts of Mg^{2+} on the exchange sites will deflocculate. Deflocculated colloids prevent aggregate formation and cause low permeability and high erodibility.

3.2.3. Type of Clay:

Aggregation of soils is influenced by the type of clay mineral. Tropical and subtropical soils, which are high in hydrous oxides of iron aluminum and in the 1:1 type lattice clay; kaolinite, tend to be better aggregated than soils high in the 2:1 type lattice clays; smectite and illite.

3.2.4. Organic Matter Content:

Soil structure improves and the individual aggregates become more stable as organic matter content increases. This is accompanied by increased permeability and decreased runoff and erosion. These effects are mostly related to decomposable organic matter such as dying roots and fresh plant residues incorporated into the soil. Perhaps, the high degree of microbial activity producing sticky exudates and hyphae that bind the soil particles into aggregates can be credited with this.

3.2.5. Cementing agencies:

Secondary lime is a cementing agent and helps to hold particles in aggregates. Some iron compounds band clays and other soil grains together in stable forms in many strongly leached, temperate-region soils and in numerous tropical soils. These soils may be quite resistant to erosion.

3.2.6. Cropping History:

Soils plowed from native vegetation or cultivated pasture resist erosion because they tend to have excellent structure and relatively large, stable aggregates. Roots permeate the aggregates and large amounts of incorporated crop residue add to stabilize the soil. Actively decomposing plant materials help to develop resistant structure and humus, which resist further decomposition. Aggregates may become less stable and more subject to breakdown and erodililty increases unless decomposable organic matter content are incorporated in the soil to enhance aggregate stability by promoting decomposition and erosion.

3.2.7: Rainfall and Runoff:

The greater intensity and duration of a rainstorm, the higher erosion potential is the rainfall event. Impact of raindrops on the soil surface can break down soil aggregates and disperse aggregate materials. Lighter aggregate materials; such as very fine sand, silt, clay and organic matter are easily removed by the raindrop splash and runoff water. Greater raindrop energy or runoff amounts are required to move larger sand and gravel particles.

Soil movement by rainfall (raindrop splash) is usually greatest and most noticeable during short-duration, high-intensity thunderstorms. Although the erosion caused by long-lasting and less-intense storms is not usually as spectacular or noticeable as that produced during thunderstorms, the amount of soil loss can be significant, especially when compounded over time.

Surface water runoff occurs whenever there is excess water on a slope that cannot be absorbed into the soil or is trapped on the surface. Reduced infiltration due to soil compaction or crusting increases runoff. Runoff from agricultural land is greatest before crop establishment, when soils are typically bare of sufficient canopy/ vegetative cover.

3.2.8 Slope gradient and Length:

The steeper and longer a slope of field, the higher is the risk for erosion. Soil erosion by water increases as slope length increase due to the greater accumulation of runoff and suspended sediments. Consolidation of small fields into larger ones often results in longer slope lengths with increased erosion potential, due to increased velocity of water, which permits a greater degree of scouring (carrying capacity for sediment).

3.2.9 Cropping and Vegetation:

The potential for soil erosion increases if the soil has no or very little vegetative cover of plants and/or crop residues. Plant and residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of runoff water and allows excess surface water to infiltrate. The erosion-reducing effectiveness of plant and/or crop residues depends on the type, extent and quantity of cover. Vegetation and residue combinations that completely cover the soil and intercept all falling raindrops at and close to the surface are the most efficient in controlling soil erosion (e.g., forests, permanent grasses). Partially incorporated residues and residual roots are also important as these provide channels that allow surface water to move into the soil. The effectiveness of any protective cover also depends on how much protection is available at various periods during the year, relative to the amount of erosive rainfall that falls during these periods. Crops could provide a full protective cover for a major portion of the year (e.g., row crops), particularly during periods of highly erosive rainfall events. Crop management systems that favour contour farming and strip-cropping techniques can further reduce the amount of soil erosion that would occur. To reduce most of the erosion on annual row-crop land, leave a residue cover greater than 30% after harvest and over the dry season months, or inter-seed a cover crop (e.g., *Desmodium intortum* or *uncinatum*, *Centrosema pascuorum*, *Macrotyloma unflorum* etc., after silage corn). Herbaceous legumes like *D. intortum*, *D uncinatum*, etc., cover crops can reduce erosion much more than can crops that leave the soil bare for a longer period of time (e.g., row crops), particularly during periods of highly erosive rainfall events.

3.2.10. Tillage Practices:

The potential for soil erosion by water is affected by tillage operations, depending on the depth, direction and timing of plowing, the type of tillage equipment and the number of passes. Generally, less disturbance of vegetation or residue cover at or near the surface, results to more effective tillage practice in reducing water erosion. Minimum till or no-till practices are effective in reducing soil erosion by water. Tillage and other practices performed up and down field slopes create pathways for surface water runoff and can accelerate the soil erosion process. Cross-slope cultivation and contour farming techniques discourage the concentration of surface water runoff and limit soil movement.

4.0. Conclusion:

Soil erodibility is an estimate of the ability of soils to resist erosion, based on physical characteristics of each soil. Texture is a principal characteristic affecting erodibility, but structure, organic matter and permeability also contribute. Therefore, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion; hence management measures to mitigate degradation should be adopted for use of these soils.

5.0. Summary:
Erodibility of any soil would therefore be influenced by the physical, chemical, biological properties of the soil, as well as tillage practices, cropping history and vegetation, rainfall and runoff, slope pattern and length and organic matter content.

6.0 Tutor-Marked Assignment
Explain the effect of tillage on soil erodibility

7.0 References/Further Readings.
OMAFRA Factsheet, Universal Soil Loss Equation (USLE), Order No. 12-051

BMP 06, Soil Management

BMP 26, Controlling Soil Erosion on the Farm. *Soil Erosion- Causes and Effects*. Available from: https://www.researchgate.net/publication/314500264_Soil_Erosion-_Causes_and_Effects [accessed Jun 22 2019].

Fredrick, R. Troeh, J. Arthur Hobbs, and Roy L. Donahue (2004). Soil and Water Conservation for Productivity and Environmental Protection. Fourth Edition. Pearson Education, Prentice Hall, Upper Saddle River, New Jersey 07458. P 641

Glenn, O Schwab, Richard, K. Frevert, Talcott, W. Edminster and Kenneth, K. Barnes (1981). Soil and Water Conservation Engineering. Third Edition. John Wiley & Sons. New York.

Kim H Tan (2000). Environmental Soil Science. Second edition, Revised and expanded. Marcel Dekker, Inc. New York. Pp 421.

UNIT 3. EFFECT OF WATER EROSION:
UNIT 3 CONTENTS

1.0. Introduction**:**
The implication of soil erosion by water extends beyond removal of valuable topsoil. On-site effects would include negative impacts on crop performance and soil quality. Off-site, effects may

not be apparent in the short time period, but may damage culverts, building etc in the long run. However, eroded soil materials will sediment at a deposition site.

2.0. **Objectives**:

In this unit, effects of water erosion on-site, off-site and at deposited environment will be explained. Therefore, aim of the unit includes:

- To identify soil erosion problems on-site
- To identify soil erosion occurrence off-site
- To identify erosion sedimentation effects
- To identify erosion control measures

3.0. Effect of Water Erosion: Problems and control

3.1 On-Site:

The implication of soil erosion by water extends beyond removal of valuable topsoil. Crop emergence, growth and yield are directly affected by loss of natural nutrients and applied fertilizers. Seeds and plants can be disturbed or completely removed by erosion. Organic matter from the soil, residues and any applied manure is relatively lightweight and can be readily transported off the field; particularly during rainy conditions. Pesticides may also be carried off the site with the eroded soil. Soil quality, structure, stability and texture can be affected by the loss of soil. Breakdown of soil aggregates and 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 water-holding capacity of the soil, making it more susceptible to extreme conditions such as dry spells.

3.2 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.

3.3. Water Erosion and Sedimentation:

Sedimentation is a part of the erosion process. Repeated detachment, transportation and deposition move soil from the highest uplands to ocean beds. Not all sediment comes from cultivated lands or upland sites. Bottomland even stream banks and beds lose materials to erosion. Using every practical means to control erosion on cultivated land, range and forest will reduce but not prevent sedimentation.

Sedimentation is both beneficial and harmful. Alluvial soils are among the world's most productive soils: they develop in sediments eroded from rich surface soils on the uplands. Subsoil deposited on fertile bottomland soils reduces their productivity. Erosion from denuded mountain slopes often deposits several layers of soils, stones and other coarse materials on the land at the foot of the slopes.

Sedimentation damages all types of vegetation. Even large trees may be killed. Highways, railroads, commercial buildings and residences may be covered by layers of flood-borne sediment. Sedimentation is a continuing process. Sediments from upland areas and streambeds is deposited on the bed when flow velocity decreases. This raises the level of the river bed and reduces channel capacity so that subsequent floodwater overtops the banks and causes increased damage.

Levees have been built to control river flow. Their effectiveness is seldom permanent because sedimentation raises channel beds in the levee systems so much that many river beds are actually above much of the surrounding land. Storms eventually cause overflow that results in extreme losses on the alluvial plains the levees were built to protect.

Siltation of stream channels form shallow areas and sandbars that must be cleared from navigable streams. Dredging operations are expensive and may be needed at frequent intervals. Most alluvial soils have water tables at shallow depths that feed seepage water into the nearby stream or river. As sediments raise river beds, water tables also rise. Higher water tables reduce crop growth by reducing depth of well-aerated soil. Some of these areas become swamps with no commercial value, though they may have value as wetlands for wildlife.

Sedimentation of reservoirs is costly also. Silt and coarse clay carried by streams are deposited when velocity slows as they enter lakes and reservoirs. The finest clay passes through the lakes and out the spillways. Excessive sedimentation and a short useful life are likely where stream gradient is steep, catchment area soils are erodible, watershed area is small (less than 100 m^2 or 250 km^2), and the ratio of watershed area to volume of storage is less than 80 mi^2:1 ac-in (200 km^2:1 ha-cm). When a reservoir is filled with sediment, its value for recreation, flood control and /or irrigation is gone forever.

3.4. **Principles of Water Erosion Control**:

Water erosion occurs when conditions are favourable for the detachment and transportation of soil material. Climate, soil erodibility, slope gradient and length and surface and vegetative conditions influence how much erosion will take place.

Many different practices have been developed to reduce water erosion, but not all practices are applicable in all regions. However, the principles of water erosion control are the same wherever serious erosion occurs.

These principles are:

1. Reduce raindrop impact on the soil
2. Reduce runoff volume and velocity
3. Increase the soil's resistance to erosion

4.0 Conclusion:

The implication of soil erosion by water extends beyond removal of valuable topsoil. Crop emergence, growth and yield are directly affected by loss of natural nutrients and applied fertilizers. Seeds and plants can be disturbed or completely removed by erosion. Organic matter from the soil, residues and any applied manure, is relatively lightweight and can be readily transported off the field; particularly during rainy conditions, It is therefore expedient that appropriate conservation measures are put in place to forestall soil degradation by erosion; in particular, in cultivated fields.

5.0. Summary:

Organic matter from eroded soil, residues and any applied manure is relatively lightweight and can be readily transported off the field to degrade soil quality of the site. 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. Water erosion therefore occurs when conditions are favourable for the detachment and transportation of soil material. Climate, soil erodibility, slope gradient and length and surface and vegetative conditions influence how much erosion will take place when erosion is induced by rainfall and runoff.

6.0. Tutor-Marked Assignment:

How would soil erosion affect soil quality and fertility of arable lands?

7.**0 References/Further Readings**:

Troeh F R, Hobbs J A, Donahue R L 2004. Soil and water conservation for productivity and environmental protection. Fourth edition. Prentice Hall. Upper Saddle, New Jersey. Pp 641

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UNIT 4. WIND EROSION:

UNIT 4 CONTENTS

1.0. **INTRODUCTION**:

Wind erosion is the process of detachment, transportation and deposition of soil material by wind. It is a cause for of serious soil deterioration that has both geologic and human caused components. Loess deposits provide evidence that much of the geologic component came from outwash plains associated with continental glaciations, from large desert areas and beaches. Wind erosion occurs commonly in the extreme northern fringes of Nigeria where dune sand conveyance and deposition is witnessed in the months of March to June, just before the on-set of rains.

2.0: **Objectives**:

Objectives of this unit include:

- Explain wind erosion
- Explain soil erodibility causes and effects
- Identify causes of wind erosion
- Identify effects of wind erosion
- Identify conservation measure for control of wind erosion

3.0. Wind erosion: Causes, effects and conservation measures

Wind erosion is usually considered to be a problem of dryland areas, but even in humid zones, wind can cause severe damage to sandy soils, particularly along seacoasts to muck soils and to medium and fine textured soils that are stripped of their vegetative cover. Soil particles move in three ways, depending on soil particle size and wind strength – suspension, saltation and surface creep. The rate and magnitude of soil erosion by wind is controlled by the following factors:

3.1. Soil Erodibility, causes and effect:

Very fine soil particles are carried high into the air by wind and transported great distances (suspension). Fine-to-medium size soil particles are lifted a short distance into the air and drop back to the soil surface, damaging crops and dislodging more soil (saltation). Larger-sized soil particles that are too large to be lifted off the ground are dislodged by the wind and roll along the soil surface (surface creep). The abrasion that results from windblown particles breaks down stable surface aggregates and further increase the soil erodibility.

3. 2. Soil Surface Roughness:

Soil surfaces that are not rough offer little resistance to the wind. However, ridges left from tillage can dry out more quickly in a wind event, resulting in more loose, dry soil available to blow. Over time, soil surfaces become filled in, and the roughness is broken down by abrasion. This results in a smoother surface susceptible to the wind. Excess tillage can contribute to soil structure breakdown and increased erosion.

3.3. Climate:

The speed and duration of the wind have a direct relationship to the extent of soil erosion. Soil moisture levels are very low at the surface of excessively drained soils or during periods of drought, thus releasing the particles for transport by wind. This effect could occur in freeze-drying of the soil surface during winter months. Accumulation of soil on the leeward side of barriers such as fence rows, trees or buildings are indicators of wind erosion.

3.4. Unsheltered Distance:

A lack of windbreaks (trees, shrubs, crop residue, etc.) allows the wind to put soil particles into motion for greater distances, thus increasing abrasion and soil erosion. Knolls and hilltops are usually exposed and suffer the most.

3.41. Vegetative Cover:

The lack of permanent vegetative cover in certain locations results in extensive wind erosion. Loose, dry, bare soil is the most susceptible; however, crops that produce low levels of residue (e.g., soybeans and many vegetable crops) may not provide enough resistance. In severe cases, even crops that produce a lot of residue may not protect the soil. The most effective protective vegetative cover consists of a cover crop with an adequate network of living windbreaks in combination with good tillage, residue management and crop selection.

3.4.2. 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.

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

3.4.4. Type of Tillage Equipment:

Tillage equipment that lifts and carries will tend to move more soil. For 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.

3.4.5. 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.

3.4.6. 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.

3.4.7. 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.

3.4.8. 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 erodibility of the soil and expose it to further erosion by 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.

3.5. Conservation Measures:

The adoption of various soil conservation measures reduces soil erosion by water, wind and tillage. Tillage and cropping practices, as well as land management practices, directly affect the overall soil erosion problem and solutions on a farm. When crop rotations or changing tillage practices are not enough to control erosion on a field, a combination of approaches or more extreme measures might be necessary. For example, contour plowing, strip-cropping or terracing may be considered. In more serious cases where concentrated runoff occurs, it is necessary to include structural controls as part of the overall solution – grassed waterways, drop pipe and grade control structures, rock chutes, water and sediment control basins.

3.6. Types of soil Movement:

Wind carries soil in three ways, namely

1. Suspension. Soil particles and aggregates less than 0.05 mm in diameter (silt size and smaller) are kept suspended by the turbulence of air current. Suspended dust does not drop out of the air in quantity unless rain washes it out or the velocity of the wind is drastically reduced.

2. Saltation. Intermediate-sized grains, approximate 0.05 to 0.5 mm in diameter (very fine, fine and medium sand sizes), move in a series of short leaps. The jumping grains gain a great deal of energy and may knock other grains into the air or bounce back themselves. These saltation grains are the key to wind erosion and drastically increase the number of both smaller and larger grains that move in suspension and in surface creep.

3. Surface creep. Soil grains larger than 0.5 mm in diameter cannot be lifted into the wind stream, but those smaller than about 1 mm may be bumped along the soil surface by saltating grains.

   Aggregates, clods and particles larger than 1 mm in diameter remains in place on the eroding surface and form a protective covering, often called ‘desert pavement’ or ‘lag gravel’

3.7. Erosion Damage:

Wind erosion damage includes loss of soil depth, textural change and productivity losses, abrasion, air pollution and sedimentations. Precise measurements are scarce and difficult to make, but quantitative observations are abundant.

3.8. Loss of soil

Annual losses higher than 300 ton/ha have been estimated for highly erodible, bare sandy soils. Entire furrow slice could be blown away in three or four years at this rate if soil was removed uniformly from the entire surface. Actual losses are usually less than this because land is seldom left bare and unprotected for a whole year, but greater losses have occurred.

3.9. Textural Change

Wind winnows soil much as it sifts chaff from threshed grain. Fine soil grains are carried great distances in suspension, saltating grains move to the fence rows or other barriers at the edge of fields and coarser grains stay where they are or move relatively short distances within the eroding field. Winnowing action can make texture coarser from glacial till, mixed residuum and other materials having a wide range of particle sizes. Largest change would occur in more erodible sandy soils. Medium and fine textured soils suffer less from texture change.

3.10. Nutrient Losses

Colloidal clay and organic matter are the seat of most of the soil's fertility. Colloidal materials lost in dust storms contain a lot of fertility. Fertility loss is particularly severe in coarse –textured soils that become coarser as erosion progresses, but it is also important in medium-textured soils that lose surface soil but do not change texture.

3.11. Productivity Losses

Soils become less productive as winds erode them. Soils developed from glacial till and other mixed-textured materials lose productivity mostly because of lowered nutrient content and reduced water-holding capacity. Soils developed from loess or other relatively uniform materials lose productivity because of friable, productive surface soil and the exposure of more clayey, less permeable, less fertile subsoil material. Loss of soil depth reduces crop production by making the root zone shallower and /or less favourable for root growth.

3.12. Abrasion

Soil grains carried by wind have etched automobile windows and sandblasted paints on houses, cars, and machinery, though this type of damage is costly, but they are insignificant compared to damage done to young, growing plants. Severe damage is done to young growing plant; especially when erosive wind carries abrasive soil material across panted fields. The damage could range from delayed growth to reduced yield and could result in death of plants in cases, where seedlings are buried by dune sand deposits that cover the crops over a long time.

3.13. Air Pollution

Most dust originates from deserts or in dryland areas bared of vegetative cover by overgrazing, cultivation, uncontrolled tree felling and/or bush fire. Dune sands or atmospheric dust storm causes discomfort some distances for the source. Near the source, discomfort could be more severe, even fatal to humans and dangerous for vehicular movement. In addition to the physical hazard produced by dust in the air, chemical hazards may also be encountered as windblown from mine-spoil and waste-disposal sites often contain unusual chemicals, some of which could be hazardous. Many of these contaminants are adsorbed on soil surfaces of fine soil particles and are carried into air by erosive forces to add to the inconvenience and hazard of living in and breathing dust-laden air. Dust resulting from farming activities seldom cause death directly, but can and does cause accidents and respiratory ailments that could prove fatal

3.14. Deposition (Sedimentation)

Suspended dust is carried long distances and deposited as a thin film over exposed surfaces. It constitutes a nuisance that can be demoralizing to those who try to keep surfaces dust free, but it generally does no great physical damage. Some soils may also gain from added nutrients and organic matter. Crops can be buried by drifting soil, particularly when they are planted in furrows. Young plants are most likely to be damaged, but even mature plants on the windward edges of fields next to eroding areas can be completely covered. Sand dunes can move into windbreaks and tree shelterbelts, eventually kill them if the drift gets too deep. Highways and other engineering works can be covered with windblown soil and such deposits are expensive to remove or damages repaired.

4.0. Conclusion:

Wind erosion is usually considered to be a problem of dryland areas, but even in humid zones, wind can cause severe damage to sandy soils, particularly along seacoasts to muck soils and to medium and fine textured soils that are stripped of their vegetative cover. To mitigate adverse effects of wind erosion, appropriate site specific conservation measure is advocated for sustainable agriculture, environmental health and food security.

5.0. Summary:

Wind erosion, though usually considered to be a problem of dryland areas, can occur even in humid zones, causing severe damage; in particular, to sandy soils. Even ridges left from tillage can dry out more quickly in a wind event, resulting in more loose, dry soil available to can blow out by wind pressure. Commonly however, most dust originates from deserts or in dryland areas bared of vegetative cover by overgrazing, cultivation, uncontrolled tree felling and/or bush fire. Appropriate conservation measures are necessary to mitigate effects of wind erosion.

6.0. Tutor-Marked Assignment:

a. Enumerate three types of soil movement under wind erosion.
b. Discuss any one type of the movements

7.0 References/Further Readings:

Troeh F R, Hobbs J A, Donahue R L 2004. Soil and water conservation for productivity and environmental protection. Fourth edition. Prentice Hall. Upper Saddle, New Jersey. Pp 641

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MODULE 2:

UNIT 1: ORGANIC SOILS:

UNIT 1 CONTENTS

1.1. INTRODUCTION

Soil can be classified into groups as mineral and organic, on the basis of organic matter content. In the mineral soils, organic matter content may vary from 0-20 per cent. Organic soils occupy less than 1% of the world's land area. Generally, in these soils, organic matter content is more than 20%; such that organic soils are defined as those organic mucks and peats consisting of more than 20% organic matter by weight and 18 inches (45 cm) or greater in thickness. Organic soils are highly productive soils particularly for vegetables and flowers, provided properly managed. Organic deposits accumulate in marshes, bogs and swamps by decaying of water loving plants like mosses, grasses, pondweeds, shrubs and trees since generations. Microorganisms break down the organic tissues and aid in the synthesis of organic matter and humus

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2.0 **Objectives**:

3.0. Main Content: Organic Soil: Classification, characteristics and management

3.1 Classification of Organic Soils:

On the basis of stage of breakdown of original plant and animal materials, organic soils have been classified into following two groups:

3.1.1. **Peat soil:**

These are organic soils that have slightly decayed or non-decayed plant and/or animal materials and are called 'peat soils'. In peat soils, original plant and/or animal deposits can be identified, especially in the upper horizons. Peat soils are coarse textured or fine- textured depending on the nature of deposited plant residues.

3.1.2. **Muck soil:**

These are organic soils having markedly decomposed original materials and are termed 'muck soil'. Muck soils are usually fine- textured because of well decomposition of original plant deposits.

3.2. Characteristics of Organic (Peat and Muck) Soils:

3.2.1. Physical Characteristics:

3.2.1.1. Colour:

The colour of cultivated organic soils is dark brown to deep black.

3.2.1.2. Bulk density:

The bulk density of organic soils is quite low when compared with mineral soils. Bulk density of well composed organic soil is only 0.20-0.30 compared to 1.3-1.5 for mineral soils. Thus, organic soils are light weight when dry.

3.2.1.3. Soil structure:

The surface layer of organic soils is granular or crumby. Its cohesion and plasticity are low compared to mineral soils. Organic soils are therefore, porous, open and easy to cultivate.

3.2.1.4 Water-holding capacity:

When compared to mineral soils, organic soils have high water-holding capacity. Therefore, a given layer of organic soil at optimum moisture will supply only slightly more water to plants than a comparable mineral soil.

3.3. Chemical Characteristics:

3.3.1. Cation exchange capacity:

Cation exchange capacity (CEC) of organic colloids is higher than those for inorganic colloids (Table 1).

Table 1: Cation Exchange Capacity of representative Organic and Mineral Soils

Exchange Characteristics	Weight Basis	
	Organic soil	Mineral soil
Exchangeable Ca($cmolkg^{-1}$)	150	8
Other exchangeable Mg etc($cmolkg^{-1}$)	40	3
Exchangeable H and Al($cmolkg^{-1}$)	60	5
Cation exchange capacity ($cmolkg^{-1}$)	250	16
Percentage base saturation (%)	76	69
pH	5.0-5.2	5.6-5.8

3.3.2 Soil pH:

The pH of an organic soil at a given percentage base saturation is generally lower than that of a representative mineral soil. Organic soils are highly acidic with a pH value less than 5.5.

3.3.3 Buffering capacity:

Histosols have a higher buffering capacity than mineral soils.

3.3.4 Carbon-Nitrogen ratio:

The representative organic soil possesses a high carbon-nitrogen ratio (20:1) compared to 12:1 for a representative mineral soil. Even so organic soils show vigorous nitrification (nitrate release) in spite of their high C/N ratio. Apparently some of the carbon in peats is very resistant to microbial attack and is not readily usable by general purpose decay organisms. Consequently, these organisms are not excessively encouraged, and they do not tie up the nitrates.

3.3.5 Availability of nutrients in organic soils.

- Nitrogen: Nitrogen content in organic soils are high in comparison with a mineral soil.
- Phosphorus and Potassium:

Both the phosphorus and potassium content of an organic soil are low compared to a mineral soil. Unlike mineral soils, organic soils do not fix phosphorus and potassium.

- Calcium:

Organic soils are comparatively high in calcium. In-spite of this high lime content, the majority of organic soils are distinctly acidic. Owing to high cation adsorption capacity of organic soils that they may be at a low percentage base saturation and carrying large amounts of exchangeable calcium. At the same time, the percentage base saturation is such as to assure a decidedly acid condition (Table 2).

Table 2: Organic matter and Nutrient contents for representative peak (organic soil) and a Mineral surface soil

Constituents	Peat	Mineral
	g/100 g soil	g/100 g soil
Organic matter	80	4.00
Nitrogen	2.50	0.15
Phosphorus	0.15	0.05
Potassium	0.10	1.70
Calcium	2.00	0.40
Magnesium	0.30	0.30
Sulphur	0.60	0.04

3.4. Management of Organic Soils:

The productivity of organic soils depends upon proper management. All sorts of crops can be grown on organic soils but it is especially suitable for vegetable, flowers and pasture.

3.4.1 Tillage operation:

Organic soils are porous and open, therefore, generally needs packing rather than loosening. A soil compacting roller is an important implement in management of organic soils. The compacting of soils allows the roots to come into closer contact with the soil and facilitate the capillary movement. Compacting of soil also tends to reduce the blowing of the soil during dry weather.

3.4.2. Water management:

A reasonably high water table (between 45 and 75 cm from the soil surface) assures a ready water supply for vegetables and other shallow- rooted crops grown on organic soils. It also reduces wind erosion and oxidation of organic matter from the soil surface.

3.4.3 Use of lime:

Ordinarily, use of lime in organic soils is less when compared to mineral soils because organic soils are usually adequately supplied with calcium. But acidic muck soils contain high inorganic matter and result in dissolution of iron, aluminum and manganese to the extent of toxicity. Under these conditions, liming is necessary to obtain normal plant growth.

3.4.4 Use of fertilizers:

Organic soils are very low in phosphorus and potassium elements. Therefore, phosphatic and potassic fertilizers should be applied to augment these nutrients for sustainable crop production.

Nitrogen is needed in organic soils when succulent vegetables are grown.

3.4.5 Use of micronutrients:

Organic soils need some of the micronutrients such as copper, zinc, manganese and boron.

4.0. Conclusion:

Soil can be classified into groups as mineral and organic, on the basis of organic matter content. In the mineral soils, organic matter content may vary from 0-20 per cent. Organic deposits accumulate in marshes, bogs and swamps by decaying of water loving plants like mosses, grasses, pondweeds, shrubs and trees since generations. The use of organic soils for agricultural production purposes will largely be limited to water loving plants or when drained.

5.0. SUMMARY:

Generally, in these organic soils, organic matter content is more than 20%; such that organic soils are defined as those organic mucks and peats consisting of more than 20% organic matter by weight and 18 inches (45 cm) or greater in thickness. Organic soils are highly productive soils particularly for vegetables and flowers, provided they are properly managed**.** Most crops can be grown on organic soils but it is especially suitable for vegetable, flowers and pasture.

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Allison, F. E. (1973). Soil organic matter and its role in crop production. Developments in Soil Science, 3, U. S. Department of Agriculture, Washington, D. C. U. S. A. Elsevier Scientific Publishing Company. New York Pp 631

UNIT 2: **SOIL ORGANIC CARBON SEQUESTRATION:**

UNIT 2 CONTENTS

1.0 Introduction:

Increase in atmospheric concentration of carbon dioxide (CO_2) (from 280 parts per million (ppm) in the pre-industrial era to 390 ppm in 2010, an enrichment of 39 percent) and other greenhouse gases (GHGs, such as nitrous oxide [N_2 O] and methane [CH_4], may accentuate radiative forcing and alter the Earth's mean temperature and precipitation (IPCC, 2007). The atmospheric concentration of CO_2 at 390 ppm as a volume is equivalent to ~590 ppm as a mass The mass of the atmosphere is 5.14 x 1018 kg (Trenberth *et al*., 1988). Therefore, the total mass of CO_2 is 3 030 Pectagrams+ (Pg), which is equivalent to 825 Pg of carbon that has strong impact compelling the increasing emphasis on identifying strategies that will reduce the rate of enrichment of atmospheric CO_2 by offsetting anthropogenic emissions.

2.0 Objectives:

The focus therefore, is on sequestration of CO_2 from the atmosphere or point sources. Anthropogenic sources include the combustion of fossil fuel, cement manufacturing, deforestation and the burning of biomass and land-use conversion including drainage of peatlands, soil tillage, animal husbandry, etc. (FAO and Lal, 2008). The aim therefore is to stabilize the atmospheric abundance of CO_2 and other GHGs to mitigate the risks of global warming and to increase soil carbon.

The objectives of this unit therefore is to

1. Understand the concept of carbon sequestration
2. Understand the technical potential of soil carbon sequestration
3. Identify challenges of enhancing soil carbon storage

3.0 . Main Content: Soil Organic Carbon Sequestration: Concepts, potential and challenges

3.1 **Basic concepts of carbon sequestration**:

What is Carbon Sequestration:

Carbon is found in all living organisms and is the major building block for life on Earth. Carbon exists in many forms, predominately as plant biomass, soil organic matter and as the gas carbon dioxide (CO_2) in the atmosphere and dissolved in seawater. Carbon sequestration is the long-term storage of carbon in oceans, soils, vegetation (especially forests) and geologic formations. Although oceans store most of the Earth's carbon, soils contain approximately 75% of the carbon pool on land; three times more than the amount stored in living plants and animals. Therefore, soils play a major role in maintaining a balanced global carbon cycle.

How is Carbon Sequestered in Soils:

Through the process of photosynthesis, plants assimilate carbon and return some of it to the atmosphere through respiration. The carbon that remains as plant tissue is then consumed by animals or added to the soil as litter when plants die and decompose. The primary way that carbon is stored in the soil is as soil organic matter (SOM). Soil organic carbon (SOM) is a complex mixture of carbon compounds, consisting of decomposing plant and animal tissue, microbes (protozoa, nematodes, fungi, and bacteria) and carbon associated with soil minerals. Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere. Climatic conditions, natural vegetation, soil texture and drainage all affect the amount and length of time carbon is stored.

Between 1750 and 2003, anthropogenic emissions were estimated at 292 Pg from the combustion of fossil fuels (Holdren, 2008), and at 136 ±30 Pg from land-use change, deforestation and soil cultivation (IPCC, 2001). Currently, approximately 8.3 Pg C yr^{-1} is emitted by fossil fuel combustion (IPCC, 2007; WMO, 2010) and 1.6 Pg C yr^{-1} by deforestation, land-use change and soil cultivation. The total for anthropogenic emissions is 9.9 Pg C yr^{-1}, of which 4.2 Pg C yr^{-1} is absorbed by the atmosphere and 2.3 Pg C yr^{-1} by the ocean. Atmospheric enrichment of GHGs can be moderated by either reducing anthropogenic emissions, or sequestering C in plant biomass or the soil. Transfer of atmospheric CO_2 into other pools with a longer mean residence time (MRT), in such a manner that it is not re-emitted into the atmosphere in the near future, is called sequestration. Three processes for lowering CO_2 emissions to mitigate climate change are:

(i) reducing global energy use;

(ii) developing low or no-C fuel; and

(iii) sequestering CO_2 from point sources or atmosphere using natural and engineering techniques.

Depending on the processes and technological innovations, there are three main types of C sequestration:

(i) those based on the natural process of photosynthesis and conversion of atmospheric CO_2 into biomass, soil organic matter or humus and other components of the terrestrial biosphere;

(ii) those involving engineering techniques; and

(iii) those involving chemical transformations (Lal, 2008).

The rate of enrichment of atmospheric CO_2 concentration can be reduced and moderated by its transfer to other pools by mitigative and adaptive options. Mitigative strategies involve those options that either reduce emissions or sequester C. Emission reduction includes those technologies that enhance energy-use efficiency and involve low-C or no-C fuel sources. In general, natural processes of sequestering C into terrestrial and aquatic ecosystems are more cost-effective and have numerous co-benefits; such as enhancement of ecosystem services, as compared with engineering techniques and conversion of CO_2 into carbonates.

Sequestration of CO_2 by plants occurs both in terrestrial and inland aquatic ecosystems (or wetlands). Atmospheric carbon dioxide (CO_2) sequestration in terrestrial ecosystems is significant in protected areas and in extensively and intensively managed landuse systems, but to different degrees depending on vegetation, soil types and conditions. Managed ecosystems include the world's croplands, grazing lands, forest lands and urban lands. Restoration of degraded/desertified lands and drastically disturbed ecosystems (i.e. mined lands) comprise important sink for atmospheric CO_2. Important strategies for aquatic ecosystems are the management and restoration of wetlands (peat soils and their permanent vegetation). Although fertilization of oceans using iron is technically possible, there are environmental concerns (Kintisch, 2001). Natural processes of C sequestration in terrestrial and aquatic ecosystems (e.g. soils, vegetation, wetlands) contribute to increased biomass, improved soil health and function, including nutrient cycling, water infiltration, soil moisture retention as well as water filtration and buffering in wetlands. Thus, these processes enhance resilience of ecosystems and adaptation of the systems to climatic disruptions with the attendant changes in temperature, precipitation frequency and intensity of extreme events. Most soils under managed ecosystems contain a lower soil carbon stock (SOC) pool than their counterparts under natural ecosystems owing to depletion of the SOC pool in cultivated soils. The most rapid loss of SOC pool occurs in the first 20-50 years of conversion from natural to agricultural ecosystems in temperate regions and 5-10 years in the tropics (Lal, 2001). In general, cultivated soils normally contain 50-75 percent of the original SOC pool. The depletion of SOC pool is caused by oxidation or mineralization, leaching and erosion. Thus, soil C sequestration implies increasing the concentration/pools of SOC and soil inorganic carbon (SIC) as secondary carbonates through landuse conversion and adoption of recommended management practices (RMPs) in agricultural, pastoral and forestry ecosystems and restoration of degraded and drastically disturbed soils. Formation of charcoal and use of biochar for soil amendment is another option. In contrast with geological sequestration, which implies injecting CO_2 at a depth of 1–2 km, the SOC sequestration involves putting C into the surface layer at a depth of 0.51 m using the natural processes of humification.

3.2. **Technical potential of soil carbon sequestration using recommended management practices**:

Transfer of atmospheric CO_2 into the pedologic pools by use of judicious management of soils and vegetation, involves numerous agronomic interactions. Principal agronomic techniques include:

- reduction or elimination of mechanical tillage and adoption of no-till (NT) or minimum till;
- use of crop residues or synthetic materials as surface mulch in conjunction with incorporation of cover crops into the rotation cycle;
- adoption of conservation-effective measures to minimize soil and water losses by surface runoff and accelerated erosion bioengineering;
- enhancement of soil fertility through integrated nutrient management (INM) that combines practices for improving organic matter management (in situ), enhancing soil biological processes involving biological nitrogen fixation (BNF), mycorrhizae and additions of organic wastes (biosolids, slurry) and synthetic fertilizers;
- conservation of water in the root zone to increase the green water component by reducing losses through runoff (blue water) and evaporation (grey water), and increasing use efficiency through application of drip irrigation/fertigation techniques;
- adopting grazing systems that improves the diet of livestock and reduce their enteric emissions;
- better use of complex farming systems including mixed crop-livestock and agroforestry techniques that efficiently use resources, enhance biodiversity and mimic the natural ecosystems.

Objective of these agronomic interactions is to create a positive C budget and improve the quality and productivity of natural resources. The overall goal of sustainable management of soil, water and biological resources is to strengthen and accelerate the coupled cycles of H_2O, C, N,P, and S. Strengthening of these interlinked cycles enhances the resulting ecosystem services by increasing the soil C pool, improving soil biological activity, increasing net primary productivity (NPP), decreasing losses from erosion, leaching and increasing the humification efficiency in soil.

There exists a wide range of degraded soils with a depleted SOC pool. Important among these are those degraded by erosion, nutrient depletion, acidification and leaching, structural decline and pollution/contamination. Restoring degraded soils and ecosystems is a strategy with multiple benefits for water quality, biomass productivity and for reducing net CO_2 emissions. Grainger (1995) estimated that there are approximately 750 million ha of degraded land in the tropics with the potential for afforestation and soil quality enhancement. The sequestration potential is approximately 0.5 Megagram (Mg) ha^{-1} yr^{-1} as SOC and an additional 1.0 Mg ha^{-1} yr^{-1} as biomass, a terrestrial C sequestration potential of 750 million ha is approximately 1.1 Pg C yr^{-1}. Lal (2001) estimated the SOC sequestration potential of 0.4-0.7 Pg C yr^{-1} through desertification control in soils of arid and semi-arid regions. Similar estimates were provided by Squires *et al*. (1995)

Application of manure and other organic amendments is another important SOC sequestration strategy. The data from Morrow plots in Illinois indicated that manure plots contained 44.6 Mg ha^{-1} more SOC than unmanured control (Anderson *et al*., 1990). Several long-term experiments in Europe have shown that the rate of SOC sequestration is greater with application of organic manure than with chemical fertilizers. Increase in the SOC pool in the 0–0.3 m depth after long-term use of manure when compared with chemical fertilizers was 10 percent over 100 years in Denmark (Christensen, 1996), 22 percent over 90 years in Germany (Korschens and Muller, 1996), 100 percent over 144 years at Rothamsted, United Kingdom (Jenkinson, 1990) and 44 percent over 21 years in Sweden (Witter *et al*., 1993).

3.3. **Challenges of enhancing soil carbon storage**:

Carbon sequestration in soils and other terrestrial ecosystems have both mitigation and adaptation implications. The mitigation impacts of innovative agricultural systems accrue from the net reduction in GHG emissions. The adaptation impacts of adopting improved soils and crop management systems are based on the reduction of the adverse effects of projected climate change. Yet, there are numerous challenges to realizing the mitigation and adaptation benefits of adopting agricultural innovations. The importance of applying crop residues as an amendment to enhance the SOC pool has long been recognized (Melsted, 1954; Tisdale and Nelson, 1966). Himes (1998) observed that additional amounts of N, P and S are required to convert biomass C into humus. Jacinthe and Lal (2005) also showed that application of N increased the humification efficiency of wheat straw in a long-term mulching experiment conducted in central Ohio. Drinkwater *et al*. (1998) showed that in organic systems (without use of chemical fertilizers), legume-based cropping systems reduced C and N losses, presumably because of an increase in N availability after biological N fixation (BNF). Soil-specific and demand-specific (yield of grains and biomass and desired rates of SOC sequestration) rates of N application are required to minimize losses, reduce environmental pollution (leaching of nitrates and emission of N_2O) and maximize energy efficiency.

Innovative techniques must be developed to deliver water and nutrients directly to plant roots at the right time (and in the right formulation and amount) so that their use efficiency is high. An increase in the SOC pool is essential to advancing global food security, especially for increasing agronomic yields in the developing countries of sub-Saharan Africa and South Asia (Lal, 2004a; 2006). However, despite the multiple benefits, the total sink capacity of biotic/terrestrial C sequestration is low and estimated at about 50–100 Pg over 50 to 100 year period (by the end of the twenty-first century). The sink capacity is limited by several interactive factors including the magnitude of historic C loss, higher rate of decomposition because of change in climate, and the more severe problems of erosion and leaching (Lal, 2009c).

There is also concern regarding temperature-sensitivity of soil C with global warming and the positive feedback to climate change. There are associated C costs of farm operations related to fertilizers and pesticide use, tillage, irrigation and other farm operations (Lal, 2004b) in terms of fuel/energy, emission from the manufacture of nitrogenous fertilizers and so forth. This highlights the need for both sound cost/ benefit analysis at the farming system level and assessment of value chain and opportunities in improving C balance for the main commodities. Significant advances in understanding the processes leading to SOC sequestration can be made using modern innovations in nanotechnology, biotechnology and information technology. A combination of nanotechnology and biotechnology can provide useful tools for restoring degraded soils, ecosystems and enhancing the SOM pool.

Some possible innovations include nano-enhanced products (e.g. nanofertilizers and nanopesticides) with a nanobased smart delivery system (use of halloysite) to provide nutrients at the desired site, time and rate to optimize productivity. Using such nanoscale formulations of agricultural chemicals can enhance the use efficiency of input, and minimize losses into the environment. Nanoporous materials (e.g. hydrogels and zeolites) can store water in the soil during the rainfall season and release it slowly during the dry season; thus minimizing the adverse effects of drought stress. With remote sensing of edaphic conditions, automatic release of targeted input (nanoscale precision farming) can effectively and efficiently alleviate soil-related constraints. Similar to nanotechnology, biotechnology has numerous applications that assist understanding and management of pedospheric properties and processes. Relevant examples of such applications include:

• enhancing the SOC pool in terrestrial ecosystems (soils, trees and wetlands) by using genetically modified (GM) plants characterized by a favourable root:shoot ratio and harvest index with a large biomass production, and a deep root system containing recalcitrant compounds (e.g. phenolics);

• expanding the land base by bringing new land under production, which was hitherto not been cultivable, by growing specifically improved crops/cultivars and restoring degraded ecosystems through bioremediation of contaminated soils;

• growing efficient plants with high BNF capacity, built-in resistance to dry spell (aerobic rice), anaerobiosis, nutrient/elemental imbalance, unfavorable soil pH/reaction, etc.; and

• developing plants that emit chemical stress signals that can be remotely sensed and treated with targeted inputs to alleviate the stress prior to severe adverse effects on production.

4 0. **Conclusion:**

The sequestration of CO_2 from atmosphere or point sources and the anthropogenic sources; combustion of fossil fuel, cement manufacturing, deforestation and the burning of biomass and land-use conversion including drainage of peatlands, soil tillage, animal husbandry is aimed at stabilizing the atmospheric abundance of CO_2 and other GHGs to mitigate the risks of global warming as well as improving soil quality/health for sustainable agricultural production and food security. Three strategies deployed for lowering CO_2 emissions to mitigate climate change include: reducing global energy use, developing low or no-C fuel; and sequestering CO_2 from point sources or atmosphere using natural and engineering techniques.

5.0 Summary:

In summary therefore, carbon sequestration is the long-term storage of carbon in oceans, soils, vegetation (especially forests) and geologic formations. Though oceans store most of the Earth's carbon, soils contain approximately 75% of the carbon pool on land; three times more than the amount stored in living plants and animals. The primary way that carbon is stored in soil is as soil organic matter (SOM), which is a complex mixture of carbon compounds, consisting of decomposing plant and animal tissue, microbes (protozoa, nematodes, fungi, and bacteria) and carbon associated with soil minerals. Therefore, soils play a major role in maintaining a balanced global carbon cycle and sequestration of CO_2 by plants occur both in terrestrial and inland aquatic ecosystems (or wetlands). However, atmospheric carbon dioxide (CO_2) sequestration in terrestrial ecosystems is significant in protected areas and in extensively and intensively managed landuse systems, but to different degrees depending on vegetation, soil types and conditions. Managed ecosystems include the world's croplands, grazing lands, forest lands and urban lands. Restoration of degraded/desertified lands and drastically disturbed ecosystems (i.e. mined lands) comprise important sink for atmospheric carbon dioxide (CO_2).

2.0 Tutor-Marked Assignment

i). Mention three strategies deployed for lowering CO_2 emissions to mitigate climate change?

ii). what are the contribution of the natural processes of C sequestration in terrestrial and aquatic ecosystems?

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UNIT 3: **CARBON SEQUESTRATION IN SOILS: THE OPPORTUNITIES AND CHALLENGES**

UNIT 3 CONTENTS

1.0 INTRODUCTION:

Over the past 150 years, amount of carbon in the atmosphere has increased by 30%. Most scientists believe there is a direct relationship between increased levels of carbon dioxide in the atmosphere and rising global temperatures. One proposed method to reduce atmospheric carbon dioxide is to increase global storage of carbon in soils. The role of soil ecosystem is increasingly being recognized with the realization that it has the capacity of reducing concentration of carbon dioxide (CO_2) in the atmosphere through sequestration of organic carbon in the soil and also by releasing this CO_2 back into the atmosphere through mineralization of soil organic matter. It has been reported that mineralization of only 10% of the soil organic carbon pool globally can be equivalent to about 30 years of anthropogenic emissions (Kirschbaum, 2004; Jobbágy and Jackson, 2000; Stockmann *et al*., 2013) . This underscores the need to prevent carbon loss (emission) from the soil resource.

2.0. Objectives:

The objective of this unit therefore is to:

- Identify the genesis of carbon sequestration idea in terrestrial systems
- Identify evidence that carbon is sequestered in soil and terrestrial ecosystems
- Identify mechanisms of carbon capture and sequestration
- Understand how Carbon sequestration occurs in different ecosystems
- Identify the role of soil carbon in different ecosystems

3.0 Carbon Sequestration in soils: The opportunities and challenges:

Globally, soil contains a large carbon pool estimated at approximately 1500 Gt of organic carbon in the first 1 m of the soil profile and is much higher than the 560 Gt of carbon (C) found in biotic pool and twice more than atmospheric CO_2 (Lal, 2008; IPCC, 2013). By holding this huge carbon stock, the soil is preventing carbon dioxide build up in the atmosphere which will compound the problem of global warming and climate change.

There is huge opportunity for sequestering atmospheric carbon in soil for a long period of time because already 24% of global soils and 50% of agricultural soils are degraded globally. Because most of agricultural soils are already degraded, they are estimated to have the potential of sequestering up to 1.2 billion tonnes of carbon per year. Carbon sequestration in soils can be a short term solution of reducing CO_2 concentration in the atmosphere. Despite the huge carbon deposit in soil ecosystem globally, research efforts in sequestration has been primarily focused on geological and vegetation carbon capture and storage while giving less attention on the role of soil as a viable carbon sink.

Finally, some proven management practices and strategies used in enhancing the soil carbon stock under forest and agricultural ecosystems will be discussed while emphasizing the need for the scientific community to resolve most challenges making widespread adoption of this initiative difficult.

3.1. **Genesis of carbon sequestration idea in terrestrial systems**.

The idea that a strategy was needed for reducing CO_2 emission without 'drastic shutdown of industrial civilization' was proposed by Dyson (1997), that the excess CO_2 could be absorbed by trees in a large scale plantation as a potential strategy for halting the continuous CO_2 build up in the atmosphere. This is in light of evidence that photosynthetic turnover is 20 times larger than the annual increase in atmospheric CO_2 (Dyson, 1997). He therefore concluded that by planting of fast growing trees on a massive scale on marginal land or growing and harvesting swamp-plants and converting them into humus or peat the concentration of CO_2 in the atmosphere could be minimized. This could be a short gap measure to hold the atmospheric CO_2 level down until alternatives to fossil fuels are found.

3.2. **Evidence that carbon is sequestered in the soil and terrestrial ecosystems**:

Soil is reputed to contain the largest terrestrial carbon pool estimated at approximately 2344 Gt (1 gigaton = 1 billion tonnes) of organic carbon in the first 3 m, 1500 Gt in the first 1 m and 615 Gt stored in the top 20 cm of the soil profile (Jobbágy and Jackson, 2000; Stockmann *et al*., 2013). By holding this huge carbon stock, soil is preventing or delaying carbon dioxide build up in the atmosphere which will compound the problem of climate change. Considering the fact that only 9 Gt of C is added to the atmosphere yearly through anthropogenic activities from fossil fuels and ecosystem degradation, soil can be counted on as an effective carbon sink that renders vital climate regulation services. Conversely, soil also emits CO_2 back to the atmosphere following SOM decomposition estimated at 150 Gt which leaves a vacuum that could be filled if the lost carbon can be captured back and stored in the soil. The realization that the terrestrial systems (including soil) have the capacity to sequester as much as 4.9 Gt C/year has generated interest in the potential of these systems to sequester and store carbon in long-lived pools, thereby preventing its accumulation in the atmosphere. Just like the way soil sequesters and stores organic carbon, thereby reducing CO_2 amount in the atmosphere, it can equally release carbon (through CO_2) into the atmosphere to raise concentration of carbon dioxide in atmosphere. Over the last few decades, soil has lost considerable quantity of carbon as a result of anthropogenic activities; such as deforestation and agricultural activities. Managed ecosystems such as agriculture are believed to have already lost 30–55% of their original soil organic carbon stock since conversion (Batjes, 2013). The lost productivity of agricultural and degraded lands together offers opportunity for recovering 50–60% of the original carbon content through adoption of carbon sequestration strategies (Lal, 2004). This situation creates opportunity for the replenishment of lost carbon stock through adoption of deliberate strategies and policies of carbon sequestration. This may likely reduce the amount of CO_2 in the atmosphere.

3.3. **Mechanisms of carbon capture and sequestration:**

Soil carbon is originally derived from the CO_2 assimilated by plants through photosynthesis and converted to simple sugars and eventually returned to the soil as soil organic matter. Photosynthesis is the process where plants produces organic compounds such as carbohydrate by using solar energy to convert CO_2 and water into organic compounds such as carbohydrates. These organic compounds are then used in making the plants structural components (also known as biomass) and generating the energy needed for metabolic activities. The maximum amount of carbon that can be produced, otherwise known as gross primary productivity (GPP), depends on the plant's ability to produce these compounds through photosynthesis. The biomass produced through photosynthesis is utilized by the plants themselves in generating the energy needed for metabolic activities in a process called respiration. The difference between the GPP and respiration is called the net primary productivity (NPP) which is generally believed to be 45% of GPP (Gifford, 2003). Net primary productivity (NPP) is determined by the potion of solar radiation captured by the plants and used for photosynthesis (also known as photosynthetically active radiation (PAR), the leaf area index, the light use efficiency (the ratio of primary productivity to absorbed PAR) of the vegetation and autotrophic respiration (Sanderman *et al*., 2018). The higher the NPP, the more carbon is transferred to stable pools in the soils (Sitch *et al*., 2008).

3.4. **Carbon sequestration**:

Carbon sequestration is the process of transferring carbon dioxide (CO_2) from the atmosphere into stable terrestrial carbon (C) pools. The process can be driven naturally or anthropogenically. The anthropogenically driven sequestration ensures that there is no net gain in the atmospheric C pool because the CO_2 sequestered comes from the atmosphere. There are basically two types of sequestration: abiotic and biotic. The abiotic techniques involve injection of CO_2 into deep oceans, geological strata, old coal mines and oil wells. The biotic component on the other hand, involves managing higher plants and micro-organisms to remove more CO_2 from the atmosphere and fixing this C into stable soil pools.

Biotic sequestration is further subdivided into oceanic and terrestrial sequestration. Oceanic sequestration involves C capture by photosynthetic activities of organisms such as phytoplankton, which converts the C into particulate organic material and deposits such on the ocean floor. Terrestrial sequestration involves transfer of CO_2 from the atmosphere into the biotic and pedologic C pools. This is accomplished by the transfer or sequestration of CO_2 through photosynthesis and storage in live and dead organic matter. The major terrestrial C sinks include: forests, soils and wetlands.

3.4.1. **Carbon sequestration in soil ecosystem**

Soil carbon sequestration could be defined as the process of transferring carbon dioxide from atmosphere into the soil of a land unit through plants, plant residues and other organic solids, which are stored or retained in the unit as part of the soil organic matter (humus). According to the Soil Science Society of America, it is the storage of carbon in a stable solid form in the soil as a result of direct and indirect fixation of atmospheric CO_2 (Burras *et al*., 2001). The direct fixation involves natural conversion of CO_2 into soil inorganic compounds such as calcium and magnesium carbonates while the indirect sequestration takes place when plants produce biomass through the process of photosynthesis. This biomass is eventually transferred into the soil and indirectly sequestered as soil organic carbon after decomposition. Subsequently, some of this plant biomass is indirectly sequestered as soil organic carbon (SOC) during decomposition processes. The amount of carbon sequestered in the soil reflects the long term balance between carbon uptake and release mechanisms. Many agronomic, forestry and conservation practices, including best management practices lead to a beneficial net gain in carbon fixation in soil. The carbon sequestered under direct fixation is also referred to as soil inorganic carbon (SIC) while C fixed indirectly is called soil organic carbon (SOC) (Lal, 2008). Carbon can also be sequestered in soil through the accumulation of humus onto the surface layers (usually 0.5–1 m depth) of soil or anthropogenically through land use change or adoption of right management practices (RMPs) in agricultural, pastoral or forest ecosystems. Soils under managed ecosystems tend to have a lower SOC pool than those in natural ecosystems due to oxidation or mineralization, leaching and erosion. Globally, soils are reported to the have the capacity of sequestering 0.4–0.8 Pg (IPCC, 2001). The sequestration of carbon in soil depends on a number of factors, whether abiotic or biotic. Abiotic soil C sequestration depends on clay content, mineralogy, structural stability, landscape position, soil moisture and temperature regimes (Jimenez *et al*., 2007). Biotic soil C sequestration on the other hand depends on management practice, climate and activities of soil organisms (Lal *et al*., 2007; Abdullahi *et al*, 2014).

3.4.2. **Carbon stock in forest soils**:

Carbon is stored in forest ecosystems mainly in biomass, soil and to a reduced extent in coarse woody debris. The carbon stock in forest soils play important role in global carbon cycle due to the large expanse of forest ecosystems estimated at 4.1 billion hectares globally (Dixon and Wisniewsk, 1995). The forest ecosystems contain more than 70% of global soil organic carbon (SOC) and forest soils are believed to hold about 43% of carbon in the forest ecosystem to 1 m depth (Jobbágy and Jackson, 2000). However, unfortunately this high carbon content inherent in natural forest soils is easily depleted by decrease in the amount of biomass (above and below ground) returned to the soil, changes in soil moisture and temperature regimes and degree of decomposability of soil organic matter (due to difference in C:N ratio and lignin content) (Post and Kwon, 2000). Anthropogenic activities such as conversion of forests to agricultural land also deplete the soil organic carbon (SOC) stock by 20–25% (Lal, 2005). Deforestation is reported to emit about 1.6–1.7 Pg C/year (about 20% of anthropogenic emission (Watson *et al*., 200).

3.4.3 Carbon Sequestration in Soils:

According to IPCC, agricultural soils have the potential of sequestering up to 1.2 billion tonnes of carbon per year. However, it has been estimated that already about 50% of agricultural soils have been degraded globally, a situation that creates opportunity for sequestering atmospheric carbon in the soil for a long period of time. The potential of sequestering carbon in agricultural land is huge as over one third of the world’s arable land is in agriculture (World Bank, 2018). Agricultural land could sequester at least 10% of the current annual emissions of 8–10 Gt/year (Hansen *et al*., 2013).

3.5. **The role of soil carbon in different ecosystems:**

The carbon in soil plays significant roles in different ecosystems. Some of these include:

3.5.1. Mitigation of climate change

The continuous increase in concentration of carbon dioxide (CO_2) and other GHGs in the atmosphere largely due to anthropogenic sources is believed to be responsible for climatic changes and related consequences being experienced across the globe. This situation has generated interest in developing strategies for reducing GHGs build up in the atmosphere. Out of the approximately 8.7 Gt C/year being emitted into the atmosphere, from anthropogenic sources, only 3.8 Gt C/year remains (Lal, 2008; Denman *et al*., 2007). The unaccounted difference of 4.9 Gt C/year is believed to be sequestered in terrestrial (oceans, forests, soils, etc.) bodies referred to as the 'missing sink' (Denman *et al*., 2007; Battle *et al*., 2000). This realization has generated interest on the potential of terrestrial sector (including soil) to sequester carbon in long-lived pools thereby reducing the amount that is present in the atmosphere.

3.5.2. Sustainable land management

Apart from reducing the concentration of greenhouse gases (GHGs) in the atmosphere, soil carbon sequestration also complements efforts geared at improving land (forest or agricultural land) productivity. This is because all strategies that sequester carbon in soil also improve soil quality and land productivity by increasing organic matter content of the soil. Organic matter improves soil's structural stability, water-holding capacity, nutrients availability and provide favorable environment for soil organisms. Carbon sequestration activities offer opportunity for regaining lost productivity, especially under agricultural systems. It has been reported that managed ecosystems such as agriculture have lost 30–55% of their original soil organic carbon stock since conversion (Batjes, 2013). The lost productivity of agricultural and degraded lands together offers opportunity for recovering 50–60% of the original carbon content through adoption of carbon sequestration strategies (Lal, 2004).

3.5.3. Ancillary benefits

Apart from climate change mitigation and improving forest land productivity, carbon sequestration in soils (of different ecosystems) also have several ancillary benefits. Some of these include: improvement in water holding capacity and infiltration, provision of substrate for soil organisms, serving as a source and reservoir of important plant nutrients, improvement of soil structural stability among others (Lal, 2004). According to Fung (2000), the environmental benefits associated with soil carbon sequestration is 40–70% higher than the productivity benefits. Based on these reasons therefore, any policy, strategy or practice that increases soil carbon sequestration also generates these benefits.

3.6 **Challenges of carbon sequestration in soils**

Although there are lot of opportunities in leveraging carbon stock and sequestration potential in the soil of different ecosystems, there are numerous challenges making this difficult in reality. Some of these challenges include:

a. Measurement and verification: the stock of carbon in soils is difficult, time-consuming and expensive to measure. Changes within the range of 10% are very difficult to detect due to sampling errors, small-scale variability and uncertainties with measures and analysis (Sparling *et al.*, 2006). The annual incremental stock of carbon in soil is very small usually within 0.25–1.0 t/ha (Ravindranath and Ostwald, 2008). It is even more difficult to account for little gains or losses in soil carbon at various scales due to methodological difficulties such as monitoring, verification, sampling and depth (Trumbore and Torn, 2003). Even if these small changes (gains or losses) are detected, it is not easy to link such changes to management or land use practice in a given context. The capacity of the soil to sequester and retain carbon is also finite as it reaches a steady state after sometime.

b. Carbon pools: sequestered carbon exists in the soil in different pools with varying degree of residence time in the ecosystem. These pools include:

i. Passive, recalcitrant or refractory pool: organic carbon held in this pool has a very long residence time ranging from decades to thousands of years.

ii. Active, labile or fast pool: carbon held in this pool stays in the soil for much shorter period due to fast decomposition. The residence time normally ranges from 1 day to a year. Carbon Sequestration in Soils:

iii. Slow, stable or humus pool: carbon held in this pool has long turnover time due to slow rate of decomposition. The residence time typically ranges from 1 year to a decade.

c. Permanence: another challenge of carbon sequestration in soil is non-permanence of the sequestered carbon as it can be released back to the atmosphere as easily as it is gained as a result of decomposition or mineralization. It is for this reason that sequestered carbon is considered a short-term option for removing carbon from the atmosphere. The rate of carbon loss depends on several climatic, land use and management factors.

d. Separation: it is very difficult to isolate and differentiate the portion of carbon sequestered in the soil as a result of management activities or land use and that which occurred naturally. The principle of separation requires that carbon sequestered or GHGs emission prevented as a result of management intervention to be distinguished from that which would have occurred due to natural causes.

3.7. **Strategies of increasing carbon stock in soils**

There are proven practices and strategies that lead to increase in soil carbon stock in different terrestrial ecosystems. Most of these strategies increases the carbon stock in biomass through photosynthesis and indirectly builds up below ground and soil carbon through increased deposition of organic matter. Organic carbon level of soil can be improved by increasing amount of organic matter input, changing the decomposability of organic matter, placing organic matter in deep layer and enhancing better physical protection of soil aggregates or formation of organo-mineral complexes in soils. In the forest ecosystem, the following have been widely reported.

• Afforestation

• Reforestation

• Natural regeneration

• Enrichment planting

• Reduced impact logging (RIL)

• Increasing the carbon stock of existing forests using several silvicultural techniques among others (Walcot *et al*., 2009; Boer, 2001).

In the agricultural ecosystem, some strategies that enhance carbon capture and storage in the soil include:

• Manuring and fertilizing

• Conservation tillage (minimum, zero/no-till) 10 Carbon Capture, Utilization and Sequestration

• Crop residue management

• Cover cropping

• Application of farmyard manure

• Application of inorganic fertilizers

• Rotational grazing

• Perennial cropping systems

4.0. Conclusion:

Globally, soil contains a large carbon pool estimated at approximately 1500 Gt of organic carbon in the first 1 m of the soil profile. By holding this huge carbon stock, the soil is preventing carbon dioxide build up in the atmosphere which will compound the problem of climate change. Soil is also the basic foundation of soil health/quality. Efforts to improve on and maintain high soil quality is dependent on the amount of carbon sequestered by the landuse system. Therefore agricultural practices that will combine soil quality improvement drive with environmental health considerations are advocated for adoption.

There is huge opportunity for sequestering atmospheric carbon in soil for a long period of time because already 24% of global soils and 50% of agricultural soils are degraded globally.

5.0 SUMMARY:

There exists opportunity for sequestering atmospheric carbon in soil for a long period of time because already 24% of global soils and 50% of agricultural soils are degraded globally. Hence, most agricultural soils are already degraded and are estimated to have the potential of sequestering up to 1.2 billion tonnes of carbon per year. Soil carbon sequestration also complements efforts geared at improving land (forest or agricultural land) productivity, because all strategies that sequester carbon in soil also improve soil quality and land productivity by increasing organic matter content of the soil.

6.0 Tutor-Marked Assignment:

Carbon pools: sequestered carbon exists in the soil in different pools. Explain the pools.

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UNIT 4.0 REGOSOL

UNIT 4 CONTENTS

1.0. INTRODUCTION:

A **Regosol** in the World Reference Base for Soil Resources (WRB) is very weakly developed mineral soil in unconsolidated materials. Regosols are extensive in eroding lands, in particular in arid and semi-arid areas and in mountain regions. Internationally, Regosols correlate with soil taxa that are marked by incipient soil formation such as Entisols in the USDA soil taxonomy or Rudosols and possibly some Tenosols in the Australian Soil Classification.

2.0. Objectives:

Objectives of this unit include:

1. define the soil order Regosols
2. identify the genesis of Regosols
3. understand the characteristics of Regosols
4. identify management and use of Regosols

3.0. Main Content: Regosol: Description, genesis, characteristics and management

The group of Regosols is a taxonomic rest group containing all soils that could not be accommodated in any of the other groups. Excluded from the Regosols are weakly developed soils that classify as Leptosols (very shallow soils), Arenosols (sandy soils) or Fluvisols (in recent alluvial deposits). These soils have AC-profiles. Profile development is minimal as a consequence of young age and/or slow soil formation.

3.1. Definition of Regosols:

Regosols are defined in terms of their properties, but particularly in terms of the properties they do not have. Regosols are soils in unconsolidated mineral materials of some depths, excluding coarse textured materials and materials with fluvic properties and have no diagnostic horizons other than ochric epipedon horizon

3.2. Summary description of Regosols:

Connotation: soils in weathered shell of the earth

Parent material: unconsolidated, finely grained weathering material

Environment: all climate zones without permafrost and at all elevations. They are particularly common in arid areas, in the dry tropics and in mountain regions.

Profile development: AC-profiles with no other diagnostic horizon than ochric epipedon/surface horizon. Profile development is minimal as a consequence of young age and/or slow soil formation e.g., because of prolonged drought

Use: land use and management vary widely. Some Regosols are used for capital-intensive irrigated farming, but the most common landuse is low volume grazing. Regosols in mountain areas are best left under forest.

3.2. Distribution of Regosols

Regosols occur in all climate zones without permafrost and at all elevations, but are particularly common in arid areas, in the dry tropics and in mountain regions.

Regosols cover an estimated 260 million hectares worldwide, mainly in arid areas in the mid-western United States, Northern Africa, the Near East and Australia. Some 50 million hectares of Regosols occur in the wet/dry tropics, most especially in northern Australia, and another 36 million hectares in mountain areas.

3.3. Genesis of Regosols:

Soil forming properties have had minimal effect on properties of Regosols. This may have been caused by:

1. Conditions which retard soil formation, such as dry and hot desert climate
2. Recent truncation/exposure of the soil material or
3. Steady rejuvenation of the soil materials.

Profile development is limited to formation of a thin ochric surface horizon over unaltered parent material. The paucity of pedogenetic transformation products explains the low coherence of the matrix material and makes the soil colour normally still determined by the composition of mineral soil fraction. In regions with considerable evaporation surplus over precipitation, some lime and/or gypsum may accumulate at shallow depths in the profile but not to the extent of having a calcic or gypsic horizon present. Soil in recent deposits of mine wastes, urban wastes, dredging and landfill that are still too young for soil formation to occur, are included in the Reference Soil Group of Regosols.

3.4. Characteristics of Regosols:

The central concept of a Regosol is a deep, well drained, medium textured, non-differentiated mineral soil that has minimal expressions of diagnostic horizon; except for an ochric surface horizon, properties or materials.

Some general observations include:

a. Parent material and climate dominate the morphology of Regosols. The content of weatherable minerals vary from low to extremely high (little transformation)

b. In cool climates, the surface contains poorly decomposed organic matter whereas (ochric) surface horizon tend to be thin, low in organic matter and generally weakly expressed in hot, dry climate

c. Regosols in dry regions have generally a high base status than Regosols in more humid (mountain) regions.

d. Low coherence of the matrix material makes most Regosols in sloping regions prone to erosion

e. Low water holding capacity of most Regosols and their high permeability to water makes them sensitive to drought and/or dry spell.

f. Many Regosols in colluvial materials are prone to slaking; in particular those in loes. This makes them sensitive to erosion in wet periods. Many Regosols form hard surface crust early in dry season: the crusts hinder emergence of seedlings and infiltration of rain and irrigation water in the dry season.

3.5. Management and use of Regosols:

Land use and management of Regosols vary widely. Some Regosols are used for capital-intensive irrigated farming but the most common land use is low volume grazing. Regosols in mountain areas are best left under forest.

Regosols in desert areas have minimal agricultural significance. Regosols in steppe region with 500 to 1000 mm of rainfall per year need irrigation for satisfactory crop production. The low moisture holding capacity of the Regosols calls for frequent application of irrigation water; sprinkler or trickle irrigation can solve this problem though rarely economic. Where rainfall exceeds 750 mm per year, the entire profile is raised to its (low) water holding capacity early in the season; improvement of dry farming practices and/or cover cropping may be an option at this instance.

Many Regosols are used for extensive grazing. Regosols on colluvial deposits of loess belts of northern Europe and north America are mostly cultivated; they are planted to small grains, sugar beets or fruits trees. Regosols in mountain areas are quite delicate to manage and are best left under forest.

4.0. Conclusion:

Regosols are extensive in eroding lands, in particular, in arid and semi-arid areas and in mountain regions. Many Regosols are used for extensive grazing and mostly cultivated for the production of small grains, sugar beets or fruits trees. Regosols landuse requires appropriate conservation measures to ensure its use for sustainable agricultural production.

5.0. **Summary**:

Regosols are soils in unconsolidated mineral materials of some depths, excluding coarse textured materials and materials with fluvic properties and have no diagnostic horizons other than ochric epipedon horizon. The paucity of pedogenetic transformation products explains the low coherence of the soil matrix material and makes the colour normally still determined by the composition of mineral soil fraction. Land use and management of Regosols vary widely, but some Regosols are used for capital-intensive irrigated farming but common land use is low volume grazing.

4.0 Tutor-Marked Assignment:
i). What conditions pre-dispose soils to be classified as Regosols
ii). Of what agricultural use are Regosols?

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MODULE 3:

Unit 1: **PROBLEM SOILS** 1:

UNIT 1 CONTENTS

1.0. INTRODUCTION:

'Problem soil' in the context of this discussion implies 'soil that has agricultural problems due to the soil's unsuitable physical and chemical properties, or less suitable for cultivation, resulting in that crops are not able to grow and produce yields normally. These soils always occur naturally, including saline soil, acid sulfate soil and organic soil. If these lands are used for agricultural purpose, then it may cause some severe effects on the ecology and environment.

2.0 Objectives:

The objectives of this unit were to identify problems conditions in soils among which include:
i). identify acid sulfate soils and their utilization
ii). identify organic soils and their utilization
iii). identify salt affected soils and their utilization

3.0 Main Content: Problem Soils:

3.1. **Acid sulfate soils:**

This refers to the soil with very high acidity because it may currently have or used to have sulfuric acid, which is a consequence of the occurrence of pyrite mineral in the soil profile and the amount of sulfuric acid formed is large enough to cause changes of certain soil properties and to affect growth of plants in that vicinity.

Acid sulfate soils occur in areas with marine or brackish water sediment as parent materials, pyrite mineral may be formed. Upon oxidization of pyrite, a substance called jarosite will be obtained, which will finally release sulfuric acid to the soil. The distinguished characteristic of acid sulfate soil is the presence of the straw-yellow mottles in the subsoil, with strong acidity – a pH below 4.0

3.1.1. Problem arising from acid sulfate soils:

The strong acidity of an acid soil affects availability of various nutrients such as nitrogen, phosphorus, potassium, sulfur, calcium and magnesium to the plants and results in the shortage of these elements in plants, so they cannot grow normally. In strongly acid soil, iron and aluminum may dissolve in the soil to the levels that are toxic to many crops as well as soil microorganisms. Water in an acid sulfate soil area is normally astringent (sour) and unsuitable for agriculture and consumption. In a fish pond, there might be the toxicity of hydrogen sulfide gas, carbon dioxide and organic acids.

Soil acidity is common to areas of high rainfall, poor drainage, heavy nitrogen-fertilizer use and high evergreen-tree population. To remedy this soil problem, add dolomitic lime or wood ash. .

Amendments to add**:** dolomitic lime, wood ash. For soils with low pH, lime is many farmers' go-to amendment. Lime is best incorporated into the soil, but if you're applying it to an already-established area, it can be watered in by rainfall or irrigation. The application rate for lime varies based on your soil's pH and type. Soils in Nigeria are however poorly buffered with organic matter and do not therefore support farmer use of lime or gypsum to remediate soil acidity. Use of farm yard manure to enhance the soil buffering capacity and reverse acidity is recommended. When wood ash is used, it should be applied at a rate of no more than 2 pounds per 100 square feet, as excess wood ash will raise the potassium level in the soil, thus preventing plants from absorbing other nutrients. In low-pH areas, you can still grow many acidic-soil-loving crops, including radishes, sweet potatoes, potatoes, blueberries, cranberries, raspberries and apples.

3.1.2 Utilization guidelines for acid sulfate soils:

Acid sulfate soil management for crop cultivation; it is important that acidity of the soil must be controlled, so it will not increase. For soils with low acidity, a dilution method may be used, i.e. by keeping freshwater on the land for a long time and drain it off before cultivation. Additional treatment is to select plants that tolerate soil acidity. For severe acid sulfate soils, applying calcium carbonate ($CaCO_3$) materials such as marl, lime, crushed limestone or limestone dust to the surface soil at an appropriate rate can effectively reduce soil acidity. However, applying $CaCO_3$, combined with washing with water and groundwater control, is the most complete and most effective method to use in areas where the soil is very strongly acid and has been abandoned for a long time.

3.2. ORGANIC SOILS

Organic soil or peat soil means a soil mixed with organic matter in the uppermost part of a soil profile, at a depth of 40 cm or thicker. This is mainly caused by the deposition of organic materials, especially deriving from the vegetation that grows naturally in an environment of a closed shallow basin, with water inundating for a long time, causing the rotting process to proceed slowly, making the organic soil layer thicker and thicker

3.2.1 The problem of organic soil

An organic soil is the soil that has many plant parts as its component, mostly located in an inundated area. If the water is entirely drained out, the soil will subside, with a light density and the cultivated plants cannot stand upright and the soil itself is sensitive to fire. The soil is mostly composed of organic materials; both being completely decomposed and partly decayed plant parts such as branches, stems or roots. The presence of this non-uniformly mixed organic material makes it difficult to plow. Besides, in the area of organic soil, there is often a layer of clay with potential to become acid. In such case, when the area is drained out to dryness, the result will be a strongly acid soil.

3.2.2. Utilization guidelines

In general, organic soil is classified as a problem soil, not recommended to use for growing economic crops. It should be left to maintain the natural ecosystem; therefore, a still undisturbed area should be reserved to maintain its natural forest condition. But for an area along the border of a swamp that has already been disturbed and turned to be beds and (small) canals, an acid soil might have occurred. In such case, lime or marl is required to reduce the acidity and the sour or salty water in the area has to be controlled, so it will not affect the growth of the plants.

3.3. SALT-AFFECTED SOILS:

‘Salt-affected soil’ refers to a soil having too high amount of salt dissolved in soil solution that consequently affects the growth and productivity of plants. Generally, if the electric conductivity (EC) of a soil solution extracted from a water-saturated soil is in the range of between 2 and 4 dSm^{-1}, the soil is considered saline. The general characteristics of salt-affected soils are similar to non-problem soils, but contain more easily soluble salts than normal. The result from an EC measurement will tell us whether or not the soil is a salt-affected soil. However, we can observe condition of the area and the types of vegetation growing there. The area with salt-affected soils would show a thin film of white salt especially in the dry season. Also, as the distribution of salt is not uniform, each area may possess different salinity levels. In the saltiest area the condition may not allow any crop to grow on or there may be some salt-tolerant plants only. For the areas with low salinity there may be some plants, but their growth will not be impressive. Therefore, for such a plot of land, one may see many empty patches or some salt crusts appearing on the surface in some spots.

3.3.1. The problem of saline soils

Too much soluble salt in the soil can harm the plant growth because the plants can suffer lack of water (dehydration) and from receiving excessive amounts of elements that are constituents of the salt that are accumulated in the soil, particularly sodium and chloride, causing crop failure, crop yield reduction and low quality produce.

3.3.2. Utilization guidelines

3.3.2.1. The management of coastal saline soil:

This may be carried out in two ways; namely,

(a) Management to suit existing natural conditions, such as preservation or rehabilitation of mangrove forest. For the area that has been transformed to be salt farm or shrimp farm, a preventive measure must be exercised so the salt water will not spread to other agricultural areas.

(b) Modification of natural conditions, such as building a dam to block the sea water so the area will become permanent farmland or raising the beds to grow crops and using water to wash the salt out and apply soil improving materials such as rice husk, compost and manure. If there is an acid soil layer beneath, digging of the bed has to be done very carefully and not to dig the small canal down to the layer of acid soil. If some part of the acid soil layer is dug up to fill the beds, acidity of the soil must be corrected with lime or marl.

3.3.2.2**.** Management of inland saline soil:

This can be achieved by using the following locally available technologies, as well as washing the salt out of the soil with water, like:

(a) Addition of organic matter to the soil by plowing-in green manure and organic fertilizers,

(b) Addition of soil amendments such as rice husk to improve structure of the soil to be more friable and allow more water to seep and leach the salts down to a deeper layer as well as to increase the soil fertility,

(c) Covering the soil with waste materials, such as rice straw, to preserve soil moisture all the time,

(d) Transplanting older rice seedlings than usual or planting a higher number of seedlings than normal, and

(e) Select salt-tolerant crops such as Acacias and Eucalyptus. At the same time one must be careful when performing some activities that may cause spreading of salt to other vicinities such as large salt mining, deforestation or construction of reservoirs in salt-accumulated areas.

3.4. Soil is alkaline:

This is common to clay soils in arid and semi-arid climates and it may suffice to amend these soils with addition of elemental sulfur or iron sulfate. When soil test results show high soil pH levels (pH >7), your crops will benefit from some balance. Apply elemental sulfur and iron sulfate at rates dependent on your soil type provided by your soil-testing agency. Elemental sulfur reacts slowly with the soil, so apply it the year before planting. Alkaline soils require continual buffering, so monitor your soil pH every one to two years and amend as needed. For perpetually alkaline soils, grow crops that tolerate high pH, including asparagus, beets, cabbage, lettuce, parsley and spinach.

3.4.1 Soil has excess salinity (salt content) or sodicity (sodium content): This commonly occurs to arid and semi-arid climates soils in low-lying areas near salt water. To amend the soil, add gypsum (calcium sulfate) or elemental sulfur to the soil. If you notice white salt crusts forming on your soil, excess soluble salts could be blamed. Test your soil with electrical conductivity meter provided by your cooperative extension or a soil-testing lab to confirm your salinity or sodicity suspicions.

The application rate for gypsum and/or elemental sulfur varies based on soil type, so follow your soil-testing agency's recommendations. Do not apply gypsum to sandy or acidic soils, as it can cause mineral deficiencies in plants or nutrient imbalance in soils. Elemental sulfur reacts slowly with the soil, so apply it the year before planting.

Poor drainage is often a factor in sodic and salinic soils. If this is the case in your garden, you can improve the soil by incorporating compost and sand. Pond fresh water on the area to leach sodium out of the soil and away from the plants' root zone.

3.5. **Soil lacks organic matter:**

This phenomenon occurs commonly to many soils, especially those that have been continually or intensively farmed using less-sustainable methods. Plausible remediation measure could be the addition of well decomposed organic matter or mature compost.

Lack of soil life, failing crops and poor water retention or drainage are issues facing many crop areas and often point to an overall lack of organic matter. To remedy this, spreading a 3-inch-deep layer of compost and incorporating it into the top 3 to 6 inches (4.5-9.0 cm) of soil is able to restore the soil health. Be sure to add fully decomposed compost to prevent the decomposition process from depriving your crops of necessary nutrients. You can provide additional benefits to soil microbes by using cover crops either intercropped or relayed in the inter rows, crop rotation, perennial crops and conservation-tillage practices. Avoid soil compaction by not working wet ground

4.0. Conclusion:

Problem soil' should be seen from the context of identified limitation of that soil/land for use in sustainable agricultural product. These soils always occur naturally, including saline soil, acid sulfate soil, sandy soil, organic soil, skeletal soil and shallow soil. The onus rests on the specialist to adduce appropriate management measure for suited landuse to deploy in such instance, but to ensure sustainable agricultural production and environmental health.

5.0. Summary:

In the instance of acid sulfate soil management for crop cultivation, it is important that acidity of the soil must be controlled to mitigate acidity increase. But salt-affected soil refers to a soil having too high amount of salt dissolved in soil solution that consequently affects the growth and productivity of plants. Conversely, organic soil is classified as a problem soil and not recommended to use for growing economic crops.

6.0. Tutor-Marked Assignment:

i). Discuss two ways of managing coastal saline soils

ii). How would a soil lacking organic matter best be managed?

7.0. References/Further Readings

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PROBLEM SOILS 2:

UNIT 2 CONTENTS

1.0 Introduction
2.0 Objectives
3.0 Main Content: Problem Soils 2 (sandy soil, shallow or skeletal soils, soils too dry or too wet)
3.1. Sandy soils
3.2. Shallow soils or skeletal soils
3.3. Slope complex
3.4. Soil is too dry
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1.0 INTRODUCTION:

Problem soil' in the context of this discussion implies 'soil that has agricultural problems due to the soil's unsuitable physical and chemical properties, or less suitable for cultivation, resulting in that crops are not able to grow and produce yields normally. These soils always occur naturally, including sandy soils, shallow soils or skeletal soils, slope complex and soil is too dry or too wet, and will be discussed in this unit. If these lands are used for agricultural purpose, then it may cause some severe effects on the ecology and environment.

2.0. **Objectives:**

Objectives of this unit include to:

i). identify sandy soils and their utilization
ii).identify shallow soils or skeletal soils and their management measures
iii). identify slope complexes
iv). Identify too dry or too wet soils

3.0 Main Content: Problem Soil: sandy soil, shallow or skeletal soils, soils too dry or too wet

3.1. Sandy Soils

Sandy soil means the soil that its upper part is sandy or sandy loam, with at least 50 cm thickness, but most sandy soils are thicker than 100 cm from the soil surface. The soil particles do not stick together. Drainage is too fast and makes the soil less able to hold water. Its ability to absorb plant nutrients is low, making fertility of the soil to be low. Plants are vulnerable to suffer water shortage during dry spells. Sand grains tend to become compacted under the plow layer, becoming prone to erosion. Soils at certain locations have compact organic layer, thus making seepage of water into the soil and penetration of plant roots even more difficult. Sandy soil is usually caused by the deposition of coarse sediments or sandy sediments on the coast; it can be found in both lowland and upland areas.

3.1.2 Sandy soil details are as follows:

Sandy soils in upland areas: These are found along beaches, coastal dunes, or on undulating terrains up to the foothill slope. Underlying rocks are coarse textured; soil texture is sand with great thickness and very quick drainage. The soils have very low water holding capacity and are prone to erosion, as soil particles do not bind together. They are used mostly for growing field crops such as cassava and pineapple.

Sandy soils in lowland basins: They are usually found between beach ridges or coastal dunes or on plains close to Sandstone Mountains. The drainage of these soils is poor or rather poor, making the area wet or submerged in short periods after heavy rain events. Some areas are used for growing rice and some for field crops such as sugarcane and jute; but certain places are abandoned or left as a natural grassland. Besides, in some areas such as old sandy beach or coastal dunes, we may find sandy soils with organic subsoil layers that have specific feature, i.e. the upper layer is white sand, but when going lower it becomes a reddish brown, compact, sandy layer caused by the coagulation of iron compounds and organic matter. During the dry season the compact layer is very dry and hard that the plant roots cannot penetrate. But in rainy season, the soil is wet and muddy. Most of these areas are left in forest, beach forests, or some areas are planted to coconut and cashew nut, etc.

3.1.3 The problem of sandy soil:

(1) Surface soil erodes easily because soil particles bind together rather loosely; it is a serious problem in upland and undulating areas. The problem becomes severe in mountainous areas that plants are grown without suitable soil and water conservation measures. It also causes many problems; such deterioration of the land by erosion to cause sedimentation in streams, rivers, storage dams and irrigation reservoirs, with repetitive drought-flood events.

(2) Low fertility soils: they are often due to low contents of organic matter, potassium and phosphorus, all being essential to the plant growth. The exchange capacity for plant nutrients of the soil is very low. Therefore, when fertilizers are put into the soil, they tend to be lost easily to leaching. The plant's response to fertilizer application is poor.

(3) In soils with very coarse sand component, soil pores are large. When it rains, the water will flow through the soil quickly while the land can absorb only a small amount of water. The crops are easily prone to water scarcity. But if the soil is fine sandy and is in a lowland area, it may result in soil compaction, with poor drainage and poor air movement; they are major obstacles to the penetration of plant roots.

3.1.4. Utilization guidelines

The soil should be improved to increase its fertility by adding organic matter to the soil in various forms such as plant residues, animal carcasses, compost, farmyard manure, organic fertilizers, to increase the aggregation of soil particles and eventually better soil structure and increase ability of the soil to absorb water and plant nutrients, reduce compaction of the soil under the plow layer, which will also reduce soil erosion. Then use chemical and organic fertilizers appropriately to enrich the soil with sufficient amounts of plant nutrients for the requirement of crops. Also, the organic matter application intervention will preserve water to use during dry spells and manage to have efficient soil and water conservation system.

3.2. Shallow soils or skeletal soils:

Shallow soil or skeletal soil implies soil with layers of dense laterite, gravel, rock debris, marl or the laterite layer can be found shallower than 50 cm from the soil surface, which impede penetration of plant roots and tillage operation. In addition, the shallow soil or skeletal soil has less amount of soil that plants can grow on; it has less ability to absorb water and adsorb plant nutrients. As a result, plants cannot grow as well as they should, and will give low yields.

3.2.1. The shallow soil can be divided into four categories:

(1) Shallow soils with poor drainage are those found in lowland. Drainage in these soils is rather poor, often waterlogged in rainy season. Most soils consist of a large amount of laterite gravels. There may be a soft laterite layer in the subsoil. Some areas are used as rice field while some are under scrub forest.

(2) Shallow soils with laterite or gravels with good water drainage. They are found along the undulating areas or on the hills. They often contain a large amount of laterite or conglomerate, starting from the soil surface down to deeper layers. In some areas, gravels or laterite boulders may scatter on the soil surface.

(3) The shallow soils mixed with stones with good drainage. They are normally found in undulating areas or on hills. There exist many big or large and small pieces of rock debris mixed in the soil. In certain places some weathered rock or hard rock can be found mixed with rubble or stones of various sizes scattering widely on the soil surface.

(4) The shallow soils mixed with marl. They are found in a flat to undulating areas or on the hills. At a depth of 20-50 cm, one may find white carbonate grains or clods that are the compounds of calcium or magnesium carbonate mixed in the soil. This type of soil is classified as a soil with high fertility but with one disadvantage that the soil is very alkaline in reaction, which is a limitation for the plants that do not like alkalinity, e.g. pineapple.

3.2.2 The problem of shallow soil

Shallow soils are unsuitable for cultivation because there is a layer that hinders growth of plants. The amount of 'soil' material is small because there are large amounts of coarse materials mixed in the soil. The soil aggregation is poor, being sensitive to erosion. The soils are not fertile; they contain fewer amounts of plant nutrients and can hold only small amount of water. The subsoil is very compact so the plant roots can penetrate with difficulty, making the spread of plant roots not uniform. Plants cannot grow normally, so there is a good chance that large trees will fall down easily.

3.2.3. Utilization guidelines:

Using these areas needs careful management. If one will farm shallow soil areas, the topsoil thickness should be thicker than 25 cm and should not contain too large amounts of pebbles or lateritic materials mixed in the soil and with slightly sloping terrain. The soil should be improved by plowing green manure crops under the soil as well as applying compost or farmyard manure. Drought-resistant plants with shallow root systems should be planted. If fruit trees are to be planted, planting holes should be wider and deeper than usual so that roots can grow well. Soil improvement can be done by putting topsoil without pebbles or gravels into the holes or simply carrying good soil material from elsewhere. After that, the compost or manure as well as chemical fertilizers are applied to meet requirements of the planted crops. After that the soil surface should be covered to preserve soil moisture and should be arranged to fit efficient irrigation system such as drip irrigation. For shallow soil with shallow bedrock, the area should be developed as pasture or leave it as a natural forest.

3.3. Slope complex:

Slope complex refers to mountainous areas with 35% slopes or greater. Most of them are improperly used and they lack good management, resulting in soil erosion and soil degradation quickly. The nature and properties of soils found on areas with steep slopes can be a lot different depending on different factors of soil formation. On such sloping area, one may find from shallow soils to deep soils. The soil texture can vary from sandy to clay. The soil reaction can vary from acidic to alkaline. The soil fertility can also vary from low to high. There may also be stones or rock fragments mixed in the soil or solid rocks protrude out of the soil surface to form Inselbergs (rock islands).

3.3.1. Utilization guidelines

If it is necessary to use these areas for cultivation, there must be adequate measures to prevent soil erosion. There are two major factors, i.e. reduction of the impact of falling raindrops to hit soil surface and to slow down speed of runoff through the soil surface. The soil should be tilled as little as possible, only to maintain soil lumps not to break apart and washed away easily. Soil and water conservation systems should be established, such as contour cultivation, field terraces and bench terraces. Planting vetiver grass across the slope to stabilize contour bunds and prevent soil erosion is also an efficient soil conservation measure.

3.4. **Soil is too dry**:

This is common to sandy soils and the possible mitigation measure is to amend the soil by adding well decomposed organic matter or compost.

If your crop beds drain and dry out too quickly, they can benefit from the addition of compost, which will add both nutrients and water-retention capacity. In this instance, incorporating a 3- to 6-inch layer of decomposed organic material to the soil that needs amended is a plausible solution. Be sure to use mature compost, as compost that hasn't fully decomposed can actually deprive your growing plants of nutrients as it continues to break down.

In addition to incorporating compost into the soil, mulch crop areas to reduce water evaporation from the soil, then turn the mulch into the soil at the end of the growing season.

3.5. **Soil is too wet:**

This is common to: clay soils, low-lying areas, areas with a high water table. Plausible measure is to amend the soil with addition of well decomposed organic matter or compost and sand. Soggy, compacted ground needs an amendment to add space between soil particles and allow better drainage. An effective way to combat this is to incorporate gravel or sand into the soil—not simply adding it as a drainage layer below the topsoil. Addition of these amendments will also require you to add organic materials to boost nutrients. Avoid adding sand to clay soils, as the mixture can set up like concrete. The amendment rate for non-clay soils will vary depending on soil type and the amendment you choose to use.

In addition to using amendments, build raised beds to encourage crop areas to drain faster. Plant crops in areas away from natural water pathways. Do not work soil, particularly dense clay soil, when it is wet, as this will only add to your soil compaction problems.

4.0. Conclusion:

Problem soil' should be seen from the context of identified limitation of that soil/land for use in sustainable agricultural product. These soils always occur naturally, including saline soil, acid sulfate soil, sandy soil, organic soil, skeletal soil and shallow soil. The onus rests on the specialist to adduce appropriate management measure for suited landuse to deploy in such instance, but to ensure sustainable agricultural production and environmental health.

3.0. Summary:

Problem soils always occur naturally, including sandy soils, shallow soils or skeletal soils, slope complex and soil is too dry or too wet, and was discussed in this unit. For sandy soils, the soil should be improved to increase its fertility by adding organic matter to the soil in various forms such as plant residues, animal carcasses, compost, farmyard manure, organic fertilizers, to increase the aggregation of soil particles and eventually better soil structure and increase ability of the soil to absorb water and plant nutrients, reduce compaction of the soil under the plow layer, which will also reduce soil erosion.

6.0 Tutor-Marked Assignment
a. In how many categories are there shallow soils?
b. discuss any two of the categories
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UNIT 3: POLLUTED SOILS:

UNIT 3 CONTENTS

1.0 **Introduction**:
Soil is the essential base of biosphere, limited and fragile resource of mankind, food and drinking water. Therefore, soil quality must be preserved. Although heavy metals are naturally present in the soil, geologic and anthropogenic activities increase the concentration of these elements to amounts that are harmful to both plants and animals. A few of these activities include mining and smelting of metals, burning of fossil fuels, use of fertilizers and pesticides in agriculture, production of batteries and other metal products in industries, sewage sludge as well as municipal waste disposal.

3.0. Objectives:
Objectives in this unit include to:
i). identify heavy metal polluted soils

ii). Identify heavy metals availability in soils
iii). identify the effect of heavy metal polluted soil on plant growth

3.0 Main Content: Polluted Soils

The nature of soils is often altered by mismanagement of industrial and mining activities, energy generation; increase of traffic, overuse of agrochemicals and waste disposal, causing worldwide concern, especially in relation to food chain and human health (Bech, 2018). Growth reduction as a result of changes in physiological and biochemical processes in plants growing on heavy metal polluted soils continue to decline in plant growth with reduced yield eventually leading to increased hunger and food insecurity.

3.1. **Heavy Metal Polluted Soils:**

Heavy metals are elements that exhibit metallic properties such as ductility, malleability, conductivity, cation stability and ligand specificity. They are characterized by relatively high density and high relative atomic weight and with atomic number greater than 20. Some heavy metals; such as Co, Cu, Fe, Mn, Mo, Ni, V, and Zn are required in minute quantities by organisms. However, excessive amounts of these elements can become harmful to organisms. Other heavy metals such as Pb, Cd, Hg, and As (a metalloid but generally referred to as a heavy metal) do not have any beneficial effect on organisms and are thus regarded as the “main threats” since they are very harmful to both plants and animals.

Metals exist either as separate entities or in combination with other soil components. These components may include exchangeable ions adsorbed on the surfaces of inorganic solids, non-exchangeable ions and insoluble inorganic metal compounds such as carbonates and phosphates, soluble metal compound or free metal ions in the soil solution, metal complex of organic materials, and metals attached to silicate minerals (Marques *et al*., 2009). Metals bound to silicate minerals represent the background soil metal concentration and they do not cause contamination/pollution problems compared with metals that exist as separate entities or those present in high concentration.

3.2. **Heavy metals Availability**:

Soil properties affect metal availability in diverse ways, for example, soil pH is the major factor affecting metal availability in soil, availability of Cd and Zn to the roots of Thlaspi caerulescens decreased with increases in soil pH (Wang *et al.*, 2006) and organic matter and hydrous ferric oxide decrease heavy metal availability through immobilization of these metals. Significant positive correlations exist between heavy metals and some soil physical properties; such as moisture content and water holding capacity. Other soil properties affecting metal availability include density and type of charge in soil colloids, degree of complexation with ligands and the soil’s relative surface area (Sharma and Raju, 2013; Norvell, 1984). The large interface and specific surface areas provided by soil colloids help in controlling the concentration of heavy metals in natural soils. In addition, soluble concentrations of metals in polluted soils may be reduced by soil particles with high specific surface area, though this may be metal specific (Marques *et al*., 2009). For example, addition of amendment consisting of hydroxides with high reactive surface area decreased the solubility of As, Cd, Cu, Mo, and Pb while solubility of Ni and Zn did not changed. Soil aeration, microbial activity and mineral composition also influence heavy metal availability in soils as heavy metals may modify soil properties; especially soil biological properties.

Monitoring changes in soil microbiological and biochemical properties after contamination can be used to evaluate intensity of soil pollution because this method is more sensitive and results can be obtained at a faster rate when compared with monitoring soil physical and chemical properties. Toxicity of heavy metals on microorganisms depends on a number of factors; such as soil temperature, pH, clay minerals, organic matter, inorganic anions and cations, and chemical forms of the metal (Baath 1998).

It is advisable to use a wide range of methods (such as microbial biomass, C and N mineralization, respiration and enzymatic activities) when studying effect of metals on soil biological properties rather than focusing on a single method since results obtained from use of different methods would be more comprehensive and conclusive. The presence of one heavy metal may affect the availability of another in the soil and hence plant. In other words, antagonistic and synergistic behaviours exist among heavy metals.

3.3. Effect of Heavy Metal Polluted Soil on Plant Growth:

The heavy metals that are available for plant uptake are those that are present as soluble components in the soil solution or those that are easily solubilized by root exudates (Blaylock and Huang, 2000). Although plants require certain heavy metals for their growth and upkeep, excessive amounts of these metals can become toxic to plants. The ability of plants to accumulate essential metals equally enables them to acquire other nonessential metals (Djingova and Kuleff, 2000). As metals cannot be broken down, when concentrations within the plant exceed optimal levels, they adversely affect the plant both directly and indirectly.

Some of the direct toxic effects caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress (Assche and Clijsters, 1990; Jadia and Fulekar, 2009). An example of indirect toxic effect is the replacement of essential nutrients at cation exchange sites of plants (Taiz and Zeiger, 2002). Further, the negative influence heavy metals have on the growth and activities of soil microorganisms may also indirectly affect the growth of plants. For instance, a reduction in the number of beneficial soil microorganisms due to high metal concentration may lead to decrease in organic matter decomposition leading to a decline in soil nutrients. Enzyme activities useful for plant metabolism may also be hampered due to heavy metal interference with activities of soil microorganisms. These toxic effects (both direct and indirect) lead to a decline in plant growth which could result in the death of plant.

The effect of heavy metal toxicity on the growth of plants varies according to the particular heavy metal involved in the process. Metals such as Pb, Cd, Hg, and As which do not play any beneficial role in plant growth, have adverse effects even at very low concentrations of these metals in the growth medium. Kibra (2008) recorded significant reduction in height of rice plants growing on a soil contaminated with 1 mgHg/kg. Reduced tiller and panicle formation also occurred at this concentration of Hg in the soil. For Cd, reduction in shoot and root growth in wheat plants occurred when Cd in the soil solution was as low as 5 mg/L (Ahmad *et al*., 2012). Most of the reduction in growth parameters of plants growing on polluted soils can be attributed to reduced photosynthetic activities, plant mineral nutrition, and reduced activity of some enzymes.

For other metals which are beneficial to plants, “small” concentrations of these metals in the soil could actually improve plant growth and development. However, at higher concentrations of these metals, reductions in plant growth have been recorded. For instance, Jayakumar *et al.,* 2013) reported that, at 50 mgCo/kg, there was an increase in nutrient content of tomato plants compared with the control. Conversely, at 100 mgCo/kg to 250 mgCo/kg, reductions in plant nutrient content were recorded. Similarly, increase in plant growth, nutrient content, biochemical content and antioxidant enzyme activities (catalase) was observed in radish and mung bean at 50 mgCo/kg soil concentration while reductions were recorded at 100 mgCo/kg to 250 mgCo/kg soil concentration (Jayakumar *et al*., 2007, 2008). Improvements in growth and physiology of cluster beans have also been reported at Zn concentration of 25 mg/L of the soil solution. On the other hand, growth reduction and adverse effect on the plant’s physiology started when the soil solution contained 50 mgZn/L

4.0 Conclusion:

Nature of soils is often altered by mismanagement of industrial and mining activities, energy generation; increase of traffic, inappropriate cultivation practices, overuse of agrochemicals and waste disposal, causing worldwide concern, especially in relation to food chain, human and environment health. Growth reduction as a result of changes in physiological and biochemical processes in plants growing on heavy metal polluted soils has resulted in continued decline in plant growth with reduced yield eventually leading to food insecurity. Hence, effects of heavy metal pollution in soils and environment as these border on sustainable crop production was addressed.

5.0 Summary:

Soil, the essential base of biosphere, is a limited and fragile resource of mankind, food and drinking water. Its quality must therefore be preserved to meet the needs of mankind and environment. Some heavy metals; such as Co, Cu, Fe, Mn, Mo, Ni, V, and Zn are required in minute quantities by organisms. However, excessive amounts of these elements can become harmful to organisms and man. Organic matter and hydrous ferric oxide can decrease heavy metal availability through immobilization of these metals.

6.0 Tutor-Marked Assignment

Which heavy metals have no beneficial effects on soil organisms?

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Unit 4: **RECLAMATION AND MANAGEMENT OF POLLUTED SOILS**

UNIT 4 CONTENTS

1.0 **INTRODUCTION**:

The nature of soil is often altered by mismanagement of industrial and mining activities, energy generation; the increase of traffic, inappropriate cultivation practices, overuse of agrochemicals, deforestation and inappropriate waste disposal systems; causing worldwide concern, especially in relation to food chain and human health. Therefore, it is imperative to engage in the identification, site investigation, assessment, eco-friendly and cost efficient remediation, monitoring and adequate management of contaminated areas to address sustainable management of polluted sites, ensure food security and human and livestock health.

2.0 Objectives:

Objectives of this unit include to:

i). identify microbial and enzymatic activities in soil
ii). identify soil plant interactions
iii). identify urban soils
iv). identify organic pollutants

3.0 Main Content: Reclamation and Management of Polluted Soils

Discussion in this unit will center on eight topics: (1) microbial and enzymatic activities, (2) mine soils, (3) soil plant interactions, (4) urban soils, (5) organic pollution, (6) sequential extraction, (7) radionuclides, and (8) pollution and soil properties.

3.1. **Microbial and enzymatic activities:**

Wang *et al*. (2017) investigated the combined bioremediation of soil co-contaminated with Cd and endosulfan by Pleurotus eryngii and Coprinus comatus and the effects on soil biochemical indicators and microbial counts of co-contaminated soils. The results indicated that the combined bioremediation exerted best remediation effect for co-contaminated soils. Also, Campos *et al*. (2017) examined effect that wood ashes may have on soil microbial activity on the basis of the dehydrogenase activity and soil oxygen consumption. Different wood ashes proportions and time dependence have shown that ashes coming from olive marc and vine shoots may affect positively soil fertility and organisms respiration, if they are applied in moderate amounts. Rico Hernandez *et al*. (2017) also analyzed survival of Escherichia coli, total coliforms and Salmonella spp. in a soil amended with urban sewage sludge due to its potential use in soil rehabilitation and the risk of microbial pollution. They found that long periods of time reduce the risk from presence of pathogens in soils and the persistence may be closely related to treatment of sewage sludge and initial amount of microorganisms in the sewage sludge

3.2. Mine Soils:

Opencast mining results in severe destruction of landscapes due to formation of overburden dumps and voids at mining sites, increased soil erosion, altered aesthetics and increased pollution load onto surroundings. Soils so formed are termed ‘Mine Soils’ or ‘Technosol’. Lebrun *et al*. (2017) evaluated the phytostabilization (use of plants to stabilize polluted soil) capacity of a plant (S. viminalis) to remediate highly contaminated (with As and Pb) mine technosol amended with biochar, assessed their particle size and dose application effects. The result was that fine biochar particles allowed S. viminalis growth on the contaminated soil, allowing this species to be used for technosol phytostabilization. Also, Lam *et al*. (2017) assessed the adaptive capacity of plant species ‘*Gazania rigens*’ and ‘*Pelargonium hortorum*’ in copper mine tailings. Findings from this investigation were that the bioconcentration factor demonstrated that both species act as excluders of Fe, Mn, Pb, Al, and Zn. Oxidation of pyrite releases As and heavy metals that can be sequestered by sulfate-arsenate or efflorescent sulfates. Iron oxy-hydroxides were more stable and they retained the contaminants at oxidant conditions. Cadmium, zinc and lead (Cd, Zn, and Pb) tend to be adsorbed at high pH and As was adsorbed by clays and iron-oxy-hydroxides

3.3**.** Bioremediation of Heavy Metal Polluted Soils:

Bioremediation is the use of organisms (microorganisms and/or plants) for the treatment of polluted soils. It is a widely accepted method of soil remediation because it is perceived to occur via natural processes. It is equally a cost effective method of soil remediation. Blaylock *et al*. (1997) reported 50% to 65% saving when bioremediation was used for the treatment of 1 acre of Pb polluted soil compared with the case when a conventional method (excavation and landfill) was used for the same purpose.

Although bioremediation is a non-disruptive method of soil remediation, it is usually time consuming and its use for the treatment of heavy metal polluted soils is sometimes affected by climatic and geological conditions of the site to be remediated. Heavy metals cannot be degraded during bioremediation but can only be transformed from one organic complex or oxidation state to another. Due to a change in their oxidation state, heavy metals can be transformed to become either less toxic, easily volatilized, more water soluble (and thus can be removed through leaching), less water soluble (which allows them to precipitate and become easily removed from the environment) or less bioavailable. Bioremediation of heavy metals can be achieved via the use of microorganisms, plants, or the combination of both organisms.

3.3.1**:** Using Microbes for Remediation of Heavy Metal Polluted Soils.

Several microorganisms especially bacteria (*Bacillus subtilis, Pseudomonas putida, and Enterobacter cloacae*) have been successfully used for the reduction of Cr (VI) to the less toxic Cr (III). *B. subtilis* has also been reported to reduce nonmetallic elements. For instance, *B. subtilis* could reduce selenite to the less toxic elemental Se. Further, *B.cereus* and *B. thuringiensis* have been shown to increase extraction of Cd and Zn from Cd rich soil and soil polluted with effluent from metal industry (Mohideena *et al*., 2010). It is assumed that the production of siderophore (Fe complexing molecules) by bacteria may have facilitated the extraction of these metals from the soil. This is because heavy metals simulate the production of siderophore and this consequently affects their bioavailability (van der Lelie *et al*., 1999). For instance, siderophore production by *Azotobacter vinelandii* was increased in the presence of Zn (II) (Huyer and Page, 1988).

Bioremediation can also occur indirectly via bioprecipitation by sulphate reducing bacteria (*Desulfovibrio desulfuricans*) which converts sulphate to hydrogen sulphate which subsequently reacts with heavy metals such as Cd and Zn to form insoluble forms of these metal sulphides (White et *al*., 1998). Most of the above microbe assisted remediation is carried out ex situ. However, a very important in situ microbe assisted remediation is the microbial reduction of soluble mercuric ions Hg (II) to volatile metallic mercury and Hg (0) carried out by mercury resistant bacteria (Hobman and Brown, 1997). The reduced Hg (0) can easily volatilize out of the environment and subsequently be diluted in the atmosphere (Lovley and Lloyd, 2000).

Making the soil favourable for soil microbes is one strategy employed in bioremediation of polluted soils. This process known as biostimulation involves the addition of nutrients in the form of manure or other organic amendments which serve as C source for microorganisms present in the soil. The added nutrients increase the growth and activities of microorganisms involved in the remediation process and thus increase the efficiency of bioremediation. Biostimulation can equally be used for the remediation of heavy metal polluted soils. Heavy metals cannot be biodegraded, biostimulation but can indirectly enhance remediation of heavy metal polluted soil through alteration of soil pH. The addition of organic materials reduces pH of the soil thus increasing the solubility and hence bioavailability of heavy metals which can then be easily extracted from the soil.

Biochar is one organic material that is currently being exploited for its potential in the management of heavy metal polluted soils. Addition of biochar would cause a reduction in the availability of heavy metals when the polluted soil was amended with biochar. This would reduce plant absorption of the metals. The potential of biochar to increase soil pH unlike most other organic amendments may have increased sorption of the metals, thus reducing their bioavailability for plant uptake. Characteristics of biochar however vary widely depending on its method of production and the feedstock used in its production. Therefore, the effect different biochar amendments will have on the availability of heavy metals in soil will also differ.

3.3.2: Using Plants for Remediation of Heavy Metal Polluted Soils:

Phytoremediation is an aspect of bioremediation that uses plants for the treatment of polluted soils. It could be applicable when the pollutants cover a wide area and when they are within the root zone of the plant. This process involves three mechanisms namely phytoextraction, phytostabilization, and phytovolatilization.

3.3.2.1. Phytoextraction. This is the most common approach to phytoremediation. It involves accumulation of heavy metals in the roots and shoots of phytoremediating plants. These plants are later harvested and burnt. Plants used for phytoextraction usually possess the following characteristics: rapid growth rate, high biomass, extensive root system and ability to tolerate high amounts of heavy metals. This ability to tolerate high concentration of heavy metals by these plants may lead to metal accumulation in the harvestable part and could lead to health hazards through contamination of the food chain. Two approaches are involved in phytoextraction: namely, the use of natural hyperaccumulators, that is, plants with very high metal-accumulating ability, and the second the use of high biomass plants whose ability to accumulate metals is induced by the use of chelates (that is, soil amendments with metal mobilizing capacity). The possibility of contaminating food chain through the use of hyperaccumulators is a major limitation in phytoextraction

3.3.2.2: Phytostabilization

This process involves use of plants to immobilize metals, thus reducing their bioavailability via erosion and leaching. It is readily employed phytoextraction is not desirable or even possible or perhaps the soil is not too heavily polluted. Phytostabilization of heavy metals occurs due to precipitation, sorption, metal valence reduction or complexation in the soil. Efficiency of phytostabilization depends on the plant and soil amendment used. Plants help in stabilizing the soil through their root systems; thus, thus preventing soil erosion. Plant root systems equally prevent leaching via reduction of water percolation through the soil. In addition, plants prevent man's direct contact with pollutants and they equally provide surfaces for metal precipitation and sorption.

For effective phytostabilization to occur, plants used for phytostabilization should have the following characteristics: dense rooting system, ability to tolerate soil conditions, ease of establishment and maintenance under field conditions, rapid growth to provide adequate ground coverage, and longevity and ability to self-propagate. Hence, soil amendments used in phytostabilization help to inactivate heavy metals to prevent plant metal uptake and reduce biological activity. Soil amendments to be employed are those that are easy to handle, safe to workers who apply them, easy to produce, inexpensive and are not toxic to plants. Often, organic amendments are used because of their low cost and the other benefits they provide such as provision of nutrients for plant growth and improvement of soil physical properties. Generally, phytostabilization is very useful when rapid immobilization of heavy metals is needed to prevent groundwater pollution. But, because the pollutants remain in soil, regular monitoring of the environment is required to forestall adverse conditions.

3.3.2.3. Phytovolatilization:

Phytovolatilization employs plants used to take up pollutants from the soil and transforms the pollutants to volatile forms transpired into the atmosphere. Phytovolatilization is commonly used to remediate soils polluted with Hg. The toxic form of Hg (mercuric ion) is transformed into the less toxic form (elemental Hg). The problem with this process is that the new product formed (elemental Hg) may be redeposited into lakes and rivers after being recycled by precipitation.

3.3.2.4: Combining Plants and Microbes for the Remediation of Heavy Metal Polluted Soils.

Combining use of both microorganisms and plants for the remediation of polluted soils would result in a faster and more efficient clean-up of polluted sites. Benefits derived from mycorrhizal associations; ranging from increased nutrient and water acquisition to the provision of a stable soil for plant growth and increase in plant resistance to disease incidents aid the survival of plants growing in polluted soils, thus helping to re-vegetate remediated soils. Other microorganisms apart from mycorrhizal fungi have also been used in conjunction with plants for the remediation of heavy metal polluted soils. Most of these microbes are the plant growth-promoting rhizobacteria (PGPR) that are usually found in the rhizosphere. These PGPR stimulate plant growth through such mechanisms as production of siderophores and some chelating agents, specific enzyme activity and N fixation and reduction in ethylene production which encourages root growth (Chibuike and Obiora, 2014).

4.0. Conclusion:

Plants growing on heavy metal polluted soils exhibit reduction in growth due to changes in their physiological and biochemical activities resulting from effects of absorbed metals. Bioremediation can be effectively used for the treatment of heavy metal polluted soil. It is most appropriate when the remediated site is used for crop production because it is a non-disruptive method of soil remediation.

5.0. Summary:

Different wood ashes proportions and time dependence have shown that ashes coming from olive marc and vine shoots may affect positively soil fertility and organisms' respiration, if they are applied in moderate amounts. Also, addition of biochar would cause a reduction in the availability of heavy metals when the polluted soil was amended with biochar. For effective phytostabilization to occur, plants used for phytostabilization should have the following characteristics: dense rooting system, ability to tolerate soil conditions, ease of establishment and maintenance under field conditions, rapid growth to provide adequate ground coverage, longevity and ability to self-propagate.

6.0. Tutor-Marked Assignment

i). Explain phytostabilization in pollution remediation

ii). How will biochar added to a polluted soil remediate the pollution?

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Module 4:

UNIT 1: BIOREMEDIATION OF POLLUTED SOIL SITES WITH CRUDE OIL HYDROCARBONS

UNIT 1 CONTENTS

1.0 INTRODUCTION:

Crude oil is the most important source of energy worldwide and routine operations of extraction drilling and management of this fossil energy resource cause serious environmental concerns. Crude oil contains a wide range of compounds that pose a significant risk for the environment, livestock and human health effects that could cause cytotoxic, mutagenic and carcinogenic outcomes. Reducing petroleum hydrocarbon compounds in a polluted environment presents significant challenges for oil environments. Companies operating petroleum industries are forced to conduct adequate and effective treatment of these pollutant emissions at very exorbitant costs. Thermal treatment, soil washing, soil vapor extraction, solidification and stabilization are physical and chemical techniques used to treat petroleum hydrocarbon-polluted soil (Latifa *et al*., 2018). Using the principle of complete mineralization or transformation of petroleum products and bi-products into less toxic forms by different groups of microorganisms, bioremediation appears the most effective, non-invasive, least expensive and ecologically-friendly technique so far, for sustainably managing hydrocarbon polluted environments.

2.0. Objectives:

Objective of this unit include to:

i). identify advantages of bioremediation of crude oil hydrocarbons
ii). identify process of bio-remediation of hydrocarbon polluted soils

3.0 Main Content: Bioremediation of Polluted Soil Sites with Crude Oil Hydrocarbons

Soils polluted with heavy metals have become common across the globe due to increase in geologic and anthropogenic activities. Plants growing on these soils show a reduction in growth,

performance and yield. Bioremediation is an effective method of treating heavy metal polluted soils and is a widely accepted method that is mostly carried out in situ; hence it is suitable for the establishment/reestablishment of crops on treated soils. Combining both microorganisms and plants is an approach to bioremediation that ensures a more efficient clean-up of heavy metal polluted soils. However, success of this approach largely depends on the species of organisms involved in the process.
Using the principle of complete mineralization or transformation of petroleum products and bi-products into less toxic forms by different groups of microorganisms, bioremediation appears the most effective, non-invasive, least expensive and ecologically-friendly technique so far, for sustainably managing hydrocarbon polluted environments.

3.1. Advantages of bioremediation of hydrocarbon polluted spoils:

Advantages of adopting bioremediation techniques in combating hydrocarbon pollution in soils include the conservation of soil texture and characteristics; physical and chemical properties of the soil, such as aeration, pH, water-holding capacity and ion exchange capacity would be improved after bioremediation.

3.2. Process of bio-remediation of Hydrocarbon polluted soils:

This process of bio-remediation does occur naturally, but can be accelerated by bio-stimulation; stimulation of the catabolic activity of indigenous microorganisms by the addition of nutrient-rich organic and inorganic materials, supplying oxygen or other electron acceptors and by maintaining suitable conditions of temperature, pH and moisture. In arid areas, soils are generally poor in organic and mineral nutrient matters, are usually subjected to extreme environmental conditions; such as high temperatures and irradiance. The rate of degradation of complex hydrocarbon compounds from crude oil polluted sites is therefore usually limited by bio-degrading micro organisms. Bio-stimulants that have shown promising results include carob kibbles, sugarcane bagasse, sugarcane molasses, wheat straw, banana skin, yam peel, saw dust, spent brewing grain, rice husk and coconut shell (Latifa *et al*., 2018). However, bioavailability is governed by the interactions between microorganisms and the environmental conditions (pH, temperature, etc.) as well as the physico-chemical interactions between polluting compounds and the soil matrix. Hence, bioavailability of polluting hydrocarbons to degrading bacteria can be related to soil mineral composition. Also, the biodegrading crude oil microbiota in crude oil polluted soils is positively related to the total petroleum hydrocarbon (TPH) degradation efficiency during bio-remediation.

4.0: Conclusion:

Crude oil contains a wide range of compounds that pose a significant risk for the environment, livestock and human health that could cause cytotoxic, mutagenic and carcinogenic concerns. Reducing petroleum hydrocarbon compounds in a polluted environment presents significant challenges for oil environments. The use of complete mineralization or transformation of petroleum products and bi-products into less toxic forms by different groups of microorganisms, bio-remediation appears the most effective, non-invasive, least expensive and ecologically-friendly technique so far, for sustainably managing hydrocarbon polluted environments; hence it is widely adopted

5.0. Summary

This process of bio-remediation does occur naturally, but can be accelerated by bio-stimulation; stimulation of the catabolic activity of indigenous microorganisms by the addition of nutrient-rich organic and inorganic materials, supplying oxygen or other electron acceptors and by maintaining suitable conditions of temperature, pH and moisture. Bio-stimulants that have shown promising results include carob kibbles, sugarcane bagasse, sugarcane molasses, wheat straw, banana skin, yam peel, saw dust, spent brewing grain, rice husk and coconut shell.

6.0 Tutor-Marked Assignment

i). What advantages do you have employing bioremediation to remedy crude oil hydrocarbon pollution?

ii) Name promising bio-stimulants that can be employed for bio-remediation in crude oil hydrocarbon polluted area.

7.0 References/Further Readings

Latifa Hamoudi-Belarbi, Safia Hamoudi, Khaled Belkacemi, Hadi Nouri , Leila Bendifallah and Mohamed Khodja (2018). Bioremediation of Polluted Soil Sites with Crude Oil Hydrocarbons Using Carrot, Peel, Waste. Environment Journal.5: 124. Doi:10.3390/environment 5110124

UNIT 2: SOIL NUTRIENT DYNAMICS:

UNIT 2 CONTENTS

1.0 INTRODUCTION:

Intensive cultivation of land with fertilizer inputs has enhanced production of agricultural crops, it has put immense pressure on scarce natural resources like soil; posing threat to future sustainable agricultural production systems. Over recent decades, soil quality/health has continued to decline at faster rate with higher rates of erosion, declining nutrient use efficiency, loss of soil biota and degradation of land due to environmental pollution. Under scenarios as this, improvement in nutrient use efficiency of crops is essentially required to sustain crop productivity in the country. Mineral nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, and other micronutrients are essential for plant growth and food production. They ultimately contribute towards adequate nutrition for human beings. Presently, the world population is facing a glaring contrast of insufficient use of nutrients on one hand and excessive use on another. Humans have been altering the world's biogeochemical cycles for many millennia to ensure food and energy security. Many of these anthropogenic activities have modified nutrient cycles of major and micro nutrients of the world. The scale of these changes has massively accelerated since the industrial revolution, throwing the equilibrium into disarray. The rates of anthropogenic carbon dioxide and other green-house gas emissions have increased substantially since 1750 (IPCC, 2007) and the greenhouse gases include both methane; especially from fossil fuel sources and livestock, carbon dioxide and nitrous oxide, which is also emitted from agricultural and forestry soils.

2.0 Objectives:

Objectives of this unit include to:

i) explain spatial patterns of nutrients in soil
ii) explain nutrients cycle (C, N, H, O) in soils

3.0 Main Content: Soil Nutrient Dynamics

Whereas recent trends in nutrient consumption appear relatively stable in developed countries, growing human population and rising per capita protein based food consumption as a result of increasing incomes are together causing a rapid increase in nutrient consumption in transitional and developing countries, including Nigeria. Indiscriminate and imbalanced use of nutrients has created a web of pollution at the global level as oversupply of nutrients or imbalance between nutrients also reduces the efficiency of nutrient use and insufficient uses of nutrients lead to land degradation. The inability to match crop harvests with sufficient nutrient return leads to depletion of nutrients and organic matter, reducing soil quality and increasing the risk of land degradation through nutrient mining by plants, erosion and compelling agricultural incursion into erstwhile virgin ecosystems.

3.1. Spatial patterns of Nutrients in Soil:

On well-drained sites, soil organic matter and constituent organic carbon, nitrogen, phosphorus, sulphur, and potassium concentrates near the soil surface. Salts and carbonates leach through the profile to accumulate at relatively shallow depths compared to more humid regions. On soils with high water table however, salts move upward mainly by capillary action to cause salinization that has destroyed the productivity of most soils put under irrigated agricultural production. Proper soil management to ensure balanced nutrient availability and uptake by plant roots is advocated.

Scale and geographical context to ecological processes has relevance to nutrient cycles in drier regions, as erosion could upset/tilt nutrient balance over a toposequence position and time scale. Also, age of landform can have profound influence on the standing crops and labile amounts of nutrients.

Low herbage quality could lead to slower decomposition of biomass. High ratio of C to other nutrients in the litter could produce nutrient-poor soils, leading to protracted immobilization of nutrients in microbial biomass and its by-products; hence, slow nutrient release. However, roots of desert shrubs can pump and exude water from wet soils at depths to dry soils within the upper soil layers during nights of dry spells or droughts. This could account for shrubs and nearby herbaceous species growing during extreme soil moisture deficit periods.

3.2. Nutrients cycle; C, N, H, O

3.2.1. Carbon (C):

This is the fundamental building block of life in soil (earth). Various biota have fixed C into soil organic matter (SOM), with comparatively less storage in arid and semi-arid regions. Also, huge amounts of inorganic carbonates have accumulated in soils of arid and semi-arid regions. The worldwide buildup of atmospheric carbon dioxide (CO_2) concentrations from industrial and transportation activities, agricultural land cultivation, drainage and dredging has continued for over 150 years. Whether any increases in C fixation that results from CO_2 enrichment will result in increased or decreased decomposition is a very crucial question. However, where other nutrients; especially nitrogen, are limiting to growth, plants produce tissues with high C/N ratios when CO_2 levels are elevated. Altered tissue chemistry could change herbivore consumption and litter decomposition rates with consequence on nutrient release.

3.2.2. Hydrogen:

Hydrogen (H) inputs to grassland and desert ecosystems come largely through water. Plants subsequently recombine H, splits in the major assimilatory process of photosynthesis, into a wide variety of organic compounds. Animals rearrange more complex organic molecules containing hydrogen to confirm that water is limiting to both higher plants and animal activities. In this context, critical nutrients accumulate in the soil after rainfall and decomposition of organic matter.

3.2.3. Oxygen:

Oxygen is required for all respiratory activity and is inhibitory to some processes, like fixation, de-nitrification and heterotrophic nitrification.

3.2.4: Nitrogen:

If carbon, hydrogen and oxygen are not limiting, then nitrogen (N) automatically becomes next most important element for green plants. Nitrogen is rated therefore next in limiting and importance for plants' regulatory of primary and all other production in semi-arid to desert ecosystems after water. The most abundant form of nitrogen; N_2, is very stable and requires energy for necessary processes to make it available in forms conducive to life (fixation). Some of these energy requiring processes include natural electrical discharge, fire, photo-chemical reactions and industrial processes.

The major way that atmospheric N is fixed is biologically, through Mo-mediated enzyme nitrogenase in prokaryotic microorganisms. The energy required comes from photosynthesis. Much nitrogen fixation in drier areas is done during short interludes of moisture availability by cyanobacteria and bacteria in soils and in special moist, anaerobic, high C/N microenvironments within animals.

The greatest N fixation in most terrestrial ecosystems takes place in nodules of legumes. However, a number of drought tolerant legumes (e.g., *Cercidium*) cannot nodulate, whereas *Acacia, psorothamus and Prosopsis* are able to nodulate, though appearing not to do so in drier regions. Free-fixing bacteria like *Streptomyces* and *Spirilla*, occur in rhizosphere of many non-leguminous shrubs and grasses found in drier ecologies.

Whereas vascular plants take up nitrogen mostly as NO_3^- or NH_4^+ through roots, gaseous NH_3 can also be taken up through above ground tissues. The NH_4^+ can be fixed to the cation-exchange complex in soil clays or organic matter, but NO_3^- is soluble. Lowered soil pH would affect availability and uptake of nutrients since rhizosphere acidification is associated with ammonium nutrition in the presence or absence of NO_3^- or NH_4^+ in soil.

Plants incorporate NO_3^- or NH_4^+ mostly into proteins and animals assimilate the proteins. As both plants and animals die to allow mineralization to occur and deposit carbon (C). The lack of appropriate measures to move livestock feces, feed remains and urine belowground is responsible for the substantial losses of NH_3 from free-range and open grazing of livestock through volatilization. It is therefore advised to restrict livestock industries to ranched enclosures in order to harvest livestock feces, feed remains and urine for the purpose of improving soil quality on a sustainable manner.

A major loss of fixed N from native grasslands is witnessed through volatilization of NH3 from unregulated excreta and plant and animal residues. Gaseous N may also be produced by abiotic reactions of NO_2^- with organic constituents of soil. Both nitrifying and de-nitrifying bacteria survive in very dry soils associated with annual grasslands and are able active producers of N_2O within short times after wetting. Hence, high levels of nitrite can be found in alkaline soils of deserts.

4.0. Conclusion:

Before now, the impression that was popular was that water availability was the major controlling factor of productivity and decomposition in ecosystems of arid and semi-arid regions. Now research has shown that age of landforms, history of landuse and interaction between portions of a landscape in producing dynamic patterns of change on numerous temporal and partial scales are as important as water availability in understanding nutrient cycling; in particular, in the arid and semi-arid regions.

5.0 Summary

Mineral nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, and other micronutrients are essential for plant growth and food production. Anthropogenic activities have modified nutrient cycles of major and micro nutrients of the world which has resulted in inability to match crop harvests with sufficient nutrient return leading to depletion of nutrients and organic matter, reduced soil quality and increased risk of land degradation through nutrient mining by plants, erosion and compelling agricultural incursion into erstwhile virgin ecosystems.

6.0 Tutor-Marked Assignment

i).Which enzyme is responsible for the major way atmospheric N is biologically fixed in soil ?

ii). In what functions in soils is oxygen required?

7.0 References/Further Readings

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UNIT 3: **NUTRIENTS CYCLE IN SOILS**: (P, S, Ca, K & minor elements)

UNIT 3. CONTENTS

1.0. INTRODUCTION:

Mineral nutrients like phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg)), sulphur (S), and other micronutrients (Fe, Zn, Cu, & B) are essential for plant growth and food production. They ultimately contribute towards adequate nutrition for human beings. Limitations of nutrients have traditionally been shown by addition and elimination of nutrients' experiments. This study unit will therefore focus on phosphorus, sulphur, calcium and minor nutrients' (Fe, Zn, Cu, & Boron) roles in nutrients cycle in soils.

2.0 Objectives:

Objectives of this unit include to:

i). identify the roles of phosphorus in soil

ii). identify the roles of Sulfur in soil

iii). identify the roles of Calcium

iv). identify the role of Magnesium in soil

v). identify the roles of minor elements in soil

3.0 Main Content: Nutrients Cycle in Soils: (P, S, Ca, K & Minor Elements):

Intensive cultivation of land with fertilizer inputs has enhanced production of agricultural crops; it has also put immense pressure on scarce natural resources like soil, posing threat to future sustainable agricultural production systems. Recently, soil health/quality has declined at faster rate, with higher rates of erosion, declining nutrient use efficiency, loss of soil biota and degradation of land due to mismanagement of soil and environmental pollution. Under such scenario, improvement in nutrient use efficiency of crops is essentially required to sustain crop productivity in the country.

3.1. Phosphorus:

Phosphorus is known to positively influence N absorption and fixation in semi-arid grassland. It is also needed for maximum N mineralization and nitrification, as well as is more limiting than N in most terrestrial ecosystems. The alkaline, calcic and gysic soils common in desert ecosystems could tie up phosphorus in insoluble forms; such that though P may be abundant, it would not be readily available for plants uptake. Also, oxalates are abundant in the rhzosphere of *Agropyron smithii*, a widespread xeric grass and increased oxalates are correlated with increased concentration of soluble plant available phosphorus. These suggest that increase of oxalates in rhizosphere of plants could input soil available P for roots uptake.

3.2. Sulphur (S):

Sulphur is a requirement for some amino acids. MvGill and Cole (1981), Mitechell and Fuller (1988) showed that Sulfur cycling should follow pathways more similar to N than P. Also, where anthropogenic sources are abundant, additional S entering such soil from pollutants may make positive impacts in deserts through reducing soil pH by rainfall to make P and other nutrients available for roots uptake.

3.3. Calcium (Ca^{2+}):

Often, calcium is assumed available in arid and semi-arid environments because of its accumulation in poorly leached soils. Naturally adapted plants to calcium rich soils exist in such environments but exotic plant react with lime- induced chlorosis under calcium-rich soil conditions. Abundance of filamentous cynobacteria in soils of drier ecological zones may be related with their high requirements for calcium and abundance of microphytic soil crusts is related to gypsum rich parent materials. Hence, the acid low-calcium and seasonally dry soils on lateritic ecological zone will support select plants and microbes with low calcium requirements and/or tolerance. Calcite aerosols from desert soils may also act to neutralize acid rains where deposited (Skujins, 1991).

3.4: Potassium (K^+) & Magnesium (Mg^{2+}):

Griffiths (1978) observed K^+ to be synergistic in N fixation, though a few have shown no losses of potassium over a chronosequence in arid or semi-arid areas. However, K/Mg ratios of soil were negatively correlated to grass production but positively correlated to shrubs production. Perhaps, shrubs have significantly higher root cation exchange capacity values than grass to absorb Mg from soil solution more readily. Conversely, the rate shrubs absorb K would be less than that for shrubs grasses. This is perhaps related to cation-exchange capacity (CEC) of roots of the two types of plants, because shrubs have significantly higher roots' CEC values than grasses. It would thus be expected that shrubs would absorb Mg from the soil solution more readily than grasses.

3.5: Minor elements (Fe, Zn, Cu, B):

Rarely do other potential nutrients get studied; except for irrigated soils in arid and semi-arid ecologies (Skujins, 1991). Some studies have also shown Fe-efficiencies with some native grasses in semi-arid and arid zones, but Hunter *et al*. (1980) described *L. tridentate* as Fe-efficient species. However, Zinc and copper (Zn & Cu) may limit primary productivity of some desert ecosystem crops; though Zn deficiency has been shown to limit N resorption by octotillo (*Flouquieria splendens*). Excess of elements like boron, selenium and arsenic in drier regions continue to cause problems when humans develop irrigated crop production in soils rich in these nutrients.

4.0 Conclusion:

The concentration of vital elements and attendant biological activity near the surface layers of grassland soils reinforces the need to conserve; in particular, the plow layer of arable lands against all forms of degradation if sustainable agriculture with environment health will be achieved. It is important therefore to further research on vital nutrient elements and other soil biota effects in nutrient cycling, to ascertain their role in promoting sustainable agricultural production.

5.0. Summary:

In recent decades, soil health/quality has declined at faster rate, with higher rates of erosion, declining nutrient use efficiency, loss of soil biota and degradation of land due to mismanagement of soil and environmental pollution, thus necessitating soil nutrient balancing to ensure sustainable crop and livestock feeds production. Therefore this study on vital nutrient elements and other soil biota effects in nutrient cycling, to ascertain their role in promoting sustainable agricultural production was conducted.

6.0 Tutor-Marked Assignment

i). what are the importance of phosphorus in arid zone soils?

ii). what informs the abundance of filamentous cynobacteria in soils of drier ecological zones?

7.0 References/Further Readings:

McGill, W. G.., and Cole, C. V, (1981). Comparative aspects of cycling of organic C, N, S and P through soil organic matter. Geoderma 26:267-286.

Mitchell, M. J., and Fuller, R. D. (1988). Models of sulfur dynamics in forest and grassland ecosystems with emphasis on soil processes. Biogeochemistry 5: 133-163.

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Hunter, R. B., Wallace, A, and Romney, E. M. (1980). Field studies of mineral nutrition of Larrea tridentate: Importance of N, pH and Fe. Great Basin Naturalist Memoirs. 4: 162-167

UNIT 4: ROLES OF ANIMALS IN NUTRIENT CYCLING IN SOILS:

UNIT 4. CONTENTS

1.0. INTRODUCTION:

Increasing attention is being beamed recently on the roles of animals in nutrient cycling in semi-arid and arid environments. Generally, animals greatly increase the rate of nutrients cycling through consumption of feeds (forage and supplements), contribution of wastes (feed remains, feces and urine) for incorporation at decomposition to recycle nutrients in soil.

2.0. Objectives:

Objectives of this unit include to:

i). identify processes involved

ii). identify practical implications of the role

3.0 Main Content: Roles of Animals in Nutrient Cycling in Soils

Animals generally greatly increase the rates of nutrient cycling; under dry and cold conditions activities of microorganisms responsible for decomposition is limited, but higher tropic level consumers would play greater role in reduction of organic matter in tropical environments. The net effect however is rapid decomposition of organic matter after each rainfall event. Herbivores, because they require large amounts of energy to support respiration to maintain body temperature, excrete feces and urine with high concentration of nutrients available to plants, animals and microbes in the soil. Also, available organic matter in soil impact on soil aggregate development and quality improvement.

3.1. Processes involved:

Under dry and cold conditions, activity of microorganisms responsible for decomposition is limited in response to reduced soil temperature and moisture deficit. Higher tropic level consumers would however play greater role in rapidly decomposing organic matter in such ecologies after each rainfall events. Herbivores would require large amounts of energy to support catabolic activities maintain body temperature and would thus excrete feces and urine with high concentrations of nutrients available in plants, animals and microbes in soil. However, invertebrates play enormous role in breaking down plant litter and moving it belowground for mineralization in deserts and grasslands. The dietary complexity and opportunism of many desert herbivores and predators also contribute to the quality stability of soils in desert ecosystems.

Termites play a crucial role in moving organic detritus of all kinds into the soil. Removal of termites can lead to increase in soil nitrogen and improved growth of ephemeral plants, as termites can consume almost all available aboveground phytomass and relocate the nutrient in their mounds over a period. Such localized deposits of nutrients of broken termite mounds have been used as fertilizer in parts of Africa. Foliar herbivores like cattle could modify N distribution such that there occur higher concentrations in plant roots. This would subsequently encourage root herbivores like nematodes to further decompose the organic matter to humus levels.

3.2. Practical Implications:

Nutrients do not influence ecosystem structure and function singly or simply, but interactions between elements and other processes are most important and intriguing. For example, in arid and semi arid regions availability of water is usually regarded as most important in determining productivity, but there is a multiple indices combining effects of N, P, K, B and Na on productivity of crops like agave and cacti. McNaughton *et al*. (1988) pointed out that the precipitation-production correlation may be a at least partially a mineralization-production cause and effect rather than purely a direct limitation of yield by water. Also, small rainfall may contribute more to mineralization than vascular plant growth.

Decomposition of plant litter in deserts is more related to invertebrate activity, number and distribution of rainfall events than total precipitation.In tropical and subtropical zones, where temperature is not usually limiting, plants, invertebrates and microbial growth takes place anytime there is adequate soil moisture. More nitrogen may be available in a grassland soil the year after drought because of fewer uptakes by plants during drought years, but continued microbial activity at lower soil moisture.

In temperate zone deserts and semi-deserts; especially at higher elevations, annual cold seasons restrain animal and invertebrates activity. Also, in this zone soils are usually young and strongly altered by ice age events, while tropical soils in drier areas are old, well leached and some being lateritic. Much of the tropical soils have lost their vital nutrients long ago and the clays and silicates presents special concerns like surface capping and high fixation capacity for applied nutrients. Extensive low-level nutrient transfers; as done by nomads in subsistence economies, may not permanently degrade the ecology in the short run, but will in the long run degrade the environment and should therefore be discouraged. Livestock herding should be confined in ranches in order to obtain maximum benefit of livestock industry and ensure healthy environment.

Desertification is a complex phenomenon involving climate change, social change and feedbacks. The component of soil change includes reduction in soil organic matter (SOM), moisture retention capacity and loss of soil aggregate stability, such that infiltration/percolation is altered. Also, 'xerification' process will ensue to result in less plant growth and population, as well as reduced microbial population and activity. Consequently, decline in primary production leads to increased rates of forage utilization as pastoralists seek to maintain herds. The net transport of nutrients in animal products and increased soil erosion eventually leads to lowered soil quality and fertility. If erosion has left only clay scalds , sand, and/or rocks, the change can be essentially permanent and reversal , restoration, rehabilitation of this process is not simple, ease or cheap. Mismanagement of livestock is a major factor in the degradation of semi-arid regions. Most nutrient values of forages are lost through abiotic means; such as volatilization, leaching and erosion (by wind and water), therefore, concentrate livestock on relatively small piece of ground/land (ranches) to maximize gains of the industry and minimize damages therefrom.

Until recently, influence of fire on nutrient cycling in semi arid ecologies was largely ignored. The view then was that fire had more stimulatory than degrading effect on grassland, because very little of the pools of most nutrients is found in the aboveground parts of the plants or their litter. Recent evidence shows that fire can be more disruptive to nutrient cycles than livestock grazing. For instance, essentially all the aboveground and surface N in plants and litter of mid-Sahel can be lost through burning. Also, wildfire in a savanna can lead to losses of >90% of the N and S in aboveground phytomass and subsequent pasture growth may be reduced by about 50% until N fixers can succeed to replace these losses. Fortunately, filamentous N-fixing cyanobacteria are stimulated by the P released by burning and some areas can rapidly recover N pools in the soil.

4.0 Conclusion.

The role of animals in spatially concentrating nutrients, accelerating decomposition and controlling nutrient availability, soil and vegetation development through enhanced nutrient cycling has become topical recently. Further search to optimize knowledge and benefits of livestock role in nutrient cycling and environment management is here being advocated.

5.0 Summary

Herbivores would require large amounts of energy to support catabolic activities maintain body temperature and would thus excrete feces and urine with high concentrations of nutrients available in plants, animals and microbes in soil. However, invertebrates play enormous role in breaking down plant litter and moving it belowground for mineralization in deserts and grasslands, improvement of soil aggregate development and to improve soil quality/health and fertility.

6.0 Tutor-Marked Assignment

i). In tropical and subtropical zones, where temperature is not usually limiting, how would plants, invertebrates and microbial growth interact anytime there is adequate soil moisture?

ii). Explain that mismanagement of livestock is a major factor in the degradation of semi-arid regions.

7.0 References/Further Readings:

McNaughton, S. J., Ruess, R. W., and Seagle, S.W. (1988). Large mammals and process dynamics in African ecosystems. Bioscience 38: 794-8000.

Skujins, J. (1991). Semiarid lands and deserts: Soil resource and reclamation. Marcel Dekker, Inc. New York Pp 659

MODULE 5:

UNIT 1: WETLAND SOILS:

UNIT 1. CONTENTS

1.0 Introduction
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3.1. Use of wetland ecologies
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3.4. Prospects for Food Production
4.0. Conclusion
5.0 Summary
6.0 Tutor-Marked Assignment
7.0 References/Further Readings

1.1. INTRODUCTION:

Wetland soils are extensive throughout the world, except in major deserts. In temperate zones, large areas of wetlands suitable for food production have already been developed. In South America and Africa, large areas with potential for food production remain undeveloped; the tropical climate and increasing demand for food, including rice, make wetland soils on these continents especially attractive for agricultural development. Some wetland soils have special problems such as salinity, high Na content, low pH, or poor physical properties following drainage (Guthrie, 1985).

2.0. Objectives:

This unit's objectives are to:
i). identify tropical wetland soils
ii). identify potentials and limitations of wetland soils
iii). identify prospects for their use in food Production

3.0 Main Content: Wetland Soils:

Wetland soils have distinct advantages and disadvantages for food production. In addition to their ample water supply, they are usually level and often occur in large land units, making large-scale farming feasible. Other advantages include low erosion hazard and moderate to high inherent fertility. Major disadvantages include cost of development and difficulty of management.

3.1. Use of wetland ecologies:

Wetlands are essential breeding, rearing and feeding grounds for many species of fish and wildlife. They are also important for producing food for humans and domestic animals.

International recognition of these sometimes conflicting values has led to an ever increasing need to classify and characterize wetland soils in relation to food production. Some of the issues that must be dealt with include the potential of wetland soils to produce food, development costs, and conflicts between agricultural development and other land uses

Wetlands may be seen as those lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities. This definition focuses on soil as an integral component of wetland systems and allows soil classification and soil surveys to be used as tools for identification. The concept of saturation with water as a dominant factor in determining the nature of soil development is the basis for the definition of aquic moisture regime used in Soil taxonomy of (USDA, 1975).

Food production on wetland soils must focus on rice, although many other crops can be grown quite productively on these soils with adequate water management. Rice could be grown throughout the world and is the world's most important single food crop (Brady, 1979). It is the primary food in Asia and is rapidly gaining acceptance in Latin America and Africa, where the potential for increased production from expanding the area of cultivable land is enormous. Substantial increases in production have resulted, but as rice became an important food throughout the world, emphasis shifted to expansion of production into new areas. Soil scientists began to play a strong role, both in making soil resource inventories and in production research.

3.2. Tropical Wetland Soils:

Wetland soils are fairly extensive throughout the humid tropics. South and Southeast Asia have the highest percentage, although large areas exist in South America. Africa has a few large areas, but they constitute only a small percentage of the land mass. Osborn (1953) pointed out that Africa, which represents one-fifth of the world's land, is about one-third desert and that all of its irrigated land makes up only 0.1% of the continent. Wetland soils occupy a larger area than irrigated land, but compared to the total area is still quite small. There are, however, several large areas, principally in central Africa, where wetland soils are common. These soils vary in texture and chemical properties and have limited suitability or conversion to productive use. The proportion of wetland soils to total land area is probably higher in South and Southeast Asia than in any other major tropical region of the world.

3.3. Potentials and Limitations:

Characterizing wetland soils in relation to food production must take into account their advantages and disadvantages. Regardless of their geographic location, these soils share many common properties. Other factors that influence the potential productivity of wetland soils are their level topography, minimal soil erosion, natural fertility and location in climatic regions of adequate rainfall for most crops.

3.3.1. Level topography:

Most wetland soils are on level to gently sloping terrain and have poor natural drainage. Many areas are on coastal plains, deltas and broad floodplains. When drained, these large tracts allow efficient mechanized farming operations.

3.3.2. Minimal soil erosion:

Gentle slopes and the possibility of water table control in wetland soils make it possible to maintain low levels of soil loss due to erosion. Wetlands offer a unique opportunity to expand the land base for food production without increasing the risk of soil degradation. However, many of these soils have not been previously placed in production because of physical and chemical limitations, which must be overcome before they are made productive.

3.3.3. Fertility

Fertility levels have a direct bearing on the potential for development of wetland soils; especially, in developing countries where fertilizer and lime are often scarce. Wetland soils however, could be acid and low in fertility. Crop production in such area would require fertilizer and/or lime application. Many of the wetland soils that have potential for agricultural development are forming in young alluvium or coastal marine sediments. As a result, most are nonacid and have at least a moderate level of fertility. After drainage, these soils can be farmed successfully with a minimum of inputs.

3.3.4. Rainfall:

With the exception of Nile Delta areas, most wetland soils are in climatic regions typified by abundant rainfall. The climatic factor that makes the soils wet becomes an asset after they are drained. Water management makes supplemental irrigation possible and also provides water for flooding rice fields. Dryland crops can be grown successfully during the dry season without the expensive irrigation that would be necessary in drier areas.

3.4. Prospects for Food Production:

Wetland soils have many advantages for food production, but they also have disadvantages some of which include:

1. Cost of development and maintenance.

Often forests must be cleared before drainage work; which requires large expenditures for construction and maintenance can begin.

2. Intensive water management is usually required and often calls for sophisticated construction work as well as well-trained management personnel.
3. Wetland soils in some areas have special problems like acid sulfates common in many estuarine areas. Upon drainage, these soils become so low in pH that crops cannot be produced.
4. Other wetland soils dry irreversibly after drainage and are unsuitable for cultivation.

5. Certain soils, especially those in coastal areas, are saline, and only salt-tolerant crops can be grown.

6. As many soils formed in sediments are clayey and poorly aggregated, tillage is often a problem, and successful seeding, cultivation, and weed control require careful management.

7. Nevertheless, as populations increase in developing countries and the pressure for increased food production grows, efforts must be made to expand the area of arable soils.

According to Crosson and Frederick (1977), the total of current and potential agricultural land in developing countries is 1.6 million ha, but only 32% of that land is now used. Much of this land is in upland areas, but a significant portion of it is in wetlands where 14 million ha of wetland soils are available compared to 118 million ha now planted to crops (Bartelli, 1974). With drainage and proper water management, these soils offer gentle slopes, good fertility, low erosion and abundant rainfall. Conditions for growing rice as well as many other food crops are better on these soils than on most upland soils as long as water can be controlled and utilized. Indeed, the greatest potential for expansion of food-producing lands may be in wetland soils.

4.0. Conclusion:

Wetlands are essential breeding, rearing and feeding grounds for many species of fish and wildlife. They are also important for producing food for humans and domestic animals. Care must however be taken to ensure appropriate management of wetland soils to ensure sustainability and environmental health.

5.0 Summary

Current and potential agricultural land in developing countries is 1.6 million ha, but only 32% of that land is now used. Much of this land is in upland areas, but a significant portion of it is in wetlands where 14 million ha of wetland soils are available compared to 118 million ha now planted to crops. Conditions for growing rice as well as many other food crops are better on these soils than on most upland soils as long as water can be controlled and utilized and appropriate conservation measures are adopted to mitigate soil and environmental degradation.

6.0 Tutor-Marked Assignment:

i). what issues will need to be addressed to use wetlands for food production in arid and semi-arid ecologies?

ii). What are the potentials and limitations of wetland soils?

7.0 References/Further Readings

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