COURSE GUIDE

SLM303
INTRODUCTION TO PEDOLOGY AND SOIL CLASSIFICATION

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INTRODUCTION

Soils play a vital role in the quality of our environment. For example, soil impacts the quality and quantity of our food, and serves as foundation of our structures, as well as interact with the hydrosphere and atmosphere. Soil can be a source, a sink, or an interacting medium for many nutrients, as well as contaminants that impact humans, plants, wildlife, and other organisms. An understanding of soil properties and processes is therefore critical to the evaluation of the criteria to be adopted for the soil management. The objective of the course is to be aware of chemical and biological reactions that may influence the behaviour of contaminants according to the different soil types and properties. Because soil is important for cultivation and agricultural production, soil fertility and productivity are important issues to address. Detailed pedological knowledge is useful for land evaluation purposes, i.e. the classification in fertile productive soils and less valuable soils. Soils are an integral part of landscapes and the knowledge of the distribution of different soils helps to preserve a high standard in environmental quality. For example, site specific management cannot be developed without detailed knowledge of soils. Critical sites, e.g. shallow hill slope soils prone to erosion and leaching of nutrients, can be identified using pedology. Soil surveys furnish basic inputs to soil conservation planning and provide information used in equations for predicting soil loss and water pollution under various management practices on different soils.

Prerequisites

The background knowledge from biology, chemistry, biochemistry and geology is required.

WHAT YOU WILL LEARN IN THIS COURSE

The course consists of modules in units and a course guide. This course guide tells you briefly what the course is about, what course materials you will be using and how you can work with these materials. In addition, it advocates some general guidelines for the amount of time you are likely to spend on each unit of the course in order to complete it successfully.

It gives you guidance in respect of your Tutor-Marked Assignment which will be made available in the assignment file. There will be regular tutorial classes that are related to the course. It is advisable for you to attend these tutorial sessions. The course will prepare you for the challenges you will meet in the field of soil pedology and classification.

COURSE AIMS

The aim of the course is not complex. The course aims to provide you with an understanding of soil pedology and classification; it also aims to provide you with solutions to problems with soil classification in the field.

COURSE OBJECTIVES

To achieve the aims set out, the course has a set of objectives. Each unit has specific objectives which are included at the beginning of the unit. You should read these objectives before you study the unit. You may wish to refer to them during your study to check on your progress. You should always look at the unit objectives after completion of each unit. By doing so, you would have followed the instructions in the unit.

Below are the comprehensive objectives of the course as a whole. By meeting these objectives, you should have achieved the aims of the course as a whole. In addition to the aims above, this course sets to achieve some objectives. Thus, after going through the course, you should be able to:

- explain the concept of soil its origin and formation
- study the morphological characteristics of soil
- identify the basic soil components
- explain the concept of soil forming rocks and minerals
- explain the concept of weathering of rocks and minerals
- description of soil profile
- facts about soil survey
- steps in soil mapping
- steps in soil classification
- to study the properties and management of Nigerian soils.

WORKING THROUGH THE COURSE

To complete this course you are required to read each study units, read the textbook and other materials which may be provided by the National Open University of Nigeria. Each unit contains self-assessment exercises and at certain points in the course you would be required to submit assignment for assessment purpose. At the end of the course there is a final examination. The course should take you a total of 17 weeks to complete. Below you will find listed all the components of the course, what you have to do and how should allocate your time to each unit in order to complete the course on time and successfully.

The details that you spend a lot of time to read. I would advise that you avail yourself the opportunity of attending the tutorial sessions where you have the opportunity of comparing your knowledge with that of other people.

THE COURSE MATERIALS

The main components of the course are:

1. The Course Guide
2. Study Units
3. References/Further Reading
4. Assignments
5. Presentation Schedule

STUDY UNITS

The study units in this course are as follows:

Module 1 Soil Origin, Formation, Morphological Characteristics and Components

Unit 1 Origin of Soil
Unit 2 Soil Formation
Unit 3 Soil Morphology
Unit 4 Soil Characteristics
Unit 5 Soil Components

Module 2 Soil- Forming Rocks and Minerals and Weathering of Rocks and Minerals

Unit 1 Soil- Forming Rocks
Unit 2 Weathering of Rocks and Minerals
Unit 3 Profile Description and Soil Survey
Unit 4 Soil Mapping
Unit 5 Soil Classification

Module 3 Properties and Management of Nigerian Soils

Unit 1 Nigerian Soils
Unit 2 Properties of Nigerian Soils

Unit 3 Profile Description of Nigerian Soils
Unit 4 Classification of Nigerian Soils
Unit 5 Management of Nigerian Soils

Your course materials have important dates for the early and timely completion and submission of your TMAs and attending tutorials. You should remember that you are required to submit all your assignments by the stipulated time and date. You should guard against falling behind in your work.

ASSESSMENT

There are three aspects to the assessment of the course. First is made up of self-assessment exercise, second consist of the tutor-marked assignments and third is the written examination/end of course examination. You are advised to do the exercises. In tackling the assignments, you are expected to apply information, knowledge and techniques you gathered during the course. The assignments must be submitted to your facilitator for formal assessment in accordance with the deadlines started in the presentation of schedule and the assignment file. The work you submit to your tutor for assessment will count for 30 % of your total course work. At the end of the course you will need to sit for a final or end of course examination of about three hour duration. This examination will count for 70 % of your total course mark.

TUTOR-MARKED ASSIGNMENT (TMA)

The TMA is a continuous assessment component of your course. It accounts for 30 % of the total score. You will be given four (4) TMAs to answer. Three of these must be answered before you are allowed to sit for end of course examination. The TMAs would be given to you by your facilitator and return after you have done the assignment. Assignment questions for the units in this course are contained in the assignment file. You will be able to complete your assignment from the information and material contained in your reading, references and study units. However, it is desirable in all degree level of education to demonstrate that you have read and researched more into your references, which will give you a wider view point and may provide you with a deeper understanding of the subject.

Make sure that each assignment reaches your facilitator on or before the deadline given in the presentation schedule and assignment file. If for any reason you cannot complete your work on time, contact your facilitator before the assignment is due to discuss the possibility of an extension. Extension will not be granted after the due date unless there are exceptional circumstances.

FINAL EXAMINATION AND GRADING

The end of course examination for introduction to Soil Pedology and Classification will be for about 3 hours and it has a value of 70 % of the total course work. The examination will consist of questions, which will reflect the type of self-testing, practice exercise and tutormarked assignment problems you have previously encountered. All areas of the course will be assessed.

Use the time between finishing the last unit and siting for the examination to revise the whole course. You might find it useful to review your self-assessment exercises, TMAs and comments on them before the examination. The end of course examination covers information from all parts of the course.

COURSE MARKING SCHEME

Assignment	**Marks**
Assignment 1-4	Four assignments, best three marks of the four count at 10 % each -30 % of course marks
End of course examination	70 % of overall course marks
Total	100 % of course materials

FACILITATORS/TUTORS AND TUTORIALS

There are 16 hours of tutorials provided in support of course. Your will be notified of the dates, times and location of these tutorials as well as the name and phone number of your facilitator, as soon as you are allocated a tutorial group.

Your facilitator will mark and comment on your assignment, keep a close watch on your progress and any difficulties you might face and provide assistance to you during the course. You are expected to mail your Tutor Marked Assignment to your facilitator before the schedule date (at least two working days are required). They will be marked by your tutor and returned to you as soon as possible. Do not delay to contact your facilitator by telephone or e-mail if you need assistance.

The following might be circumstances in which you would find assistance necessary, hence you would have to contact your facilitator if:

- you do not understand any part of the study or the assigned reading.
- you have difficulty with the self-tests
- you have a question or problem with an assignment or with grading of an assignment.

You should endeavour to attend the tutorials. This is the only chance to have face to face contact with your course facilitator and to ask questions which are answered instantly. You can raise any problem encountered in the course of your study.

To gain much benefit from course tutorials prepare a question list before attending them. You will learn a lot from participating actively in discussions.

SUMMARY

Introduction to Soil Pedology and Classification is a course that intends to provide concept of the discipline and concerned with knowledge of soil origin and formation, types, properties, fertility and management for sustainable agriculture and land management. In addition you will be able to answer the following type of questions:

- How did soil evolve and its formation?
- State the morphological characteristics of soil.
- Identify the basic soil components.
- Explain the concept of soil- forming rocks and minerals.
- Explain the concept of weathering of rocks and minerals.
- Describe the concepts in soil survey, mapping and classifications.
- Discuss the properties and management of Nigerian soils.

Of course, the list of questions that you can answer is not limited to the above list. To gain the most from this course you should Endeavour to apply the principles you have learnt to your understanding of Soil Pedology and classification.

I wish you success in the course and hope that you will find it both interesting and useful.

MAIN COURSE

CONTENTS **PAGE**

MODULE 1 SOIL ORIGIN, FORMATION, MORPHOLOGICAL CHARACTERISTICS AND COMPONENTS

UNIT 1 ORIGIN OF SOIL

CONTENTS

1.0 INTRODUCTION

The soil is at the interface between the atmosphere and lithosphere (the mantle of rocks making up the Earth's crust). It also has an interface with the hydrosphere, i.e. the sphere describing surface water, ground water and oceans. The soil sustains the growth of many plants and animals, and so forms part of the biosphere. A combination of physical, chemical and biotic forces act on organic and weathered rock fragments to produce soils with a porous fabric that contains water and air (pedosphere). We consider soil as a natural body of mineral and organic material that is formed in response to many environmental factors and processes acting on and changing soil permanently. Soils have been cultivated intensively for at least 5500 years. About 2000 years ago some crude soil fertility relationships were proposed for crops. The need for water was clear. Most of our scientific knowledge has been accumulated in the last 70 to 90 years.

2.0 OBJECTIVES

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

- give details of soil quality
- list the combination of the soil.

3.0 MAIN CONTENT

3.1 Important Facts to Know

1. The concept of "soil" and its many variations in composition, qualities and origins.
2. The ionic forms of the plant macronutrients and the importance of aluminium, sodium and iron in soil solutions.
3. The difference between minerals and rocks and some common minerals and rocks from which soils form.
4. The origin of "organic soils"
5. The origin and nature of certain landforms, particularly moraines, alluvial deposits, loess peats and mucks.
6. The meaning of "soil formation" and "soil development" and the processes active in soil changes.
7. The meaning of these special letters which designate soil horizons: **O, A, E, B, C, R, k, g, s, m, p, t and x**
8. The dominant influence of parent material and climate on the properties of developed soils.
9. The many conditions that retard soil development, particularly cold, dryness, high quartz sand content, low-permeability material, slow erosion or deposition action at the surface and profile mixing.

The general climatic-time weathering relationships among the soil orders of Entisols, Inceptisols, Andisols, Aridisols, Mollisols, Alfisols, Spodosols, Ultisols, Oxisols and Histosols

Because soil is important for cultivation and agricultural production, soil fertility and productivity are important issues to address. Detailed pedological knowledge is useful for land evaluation purposes, i.e. the classification in fertile productive soils and less valuable soils. Soils are an integral part of landscapes and the knowledge of the distribution of different soils helps to preserve a high standard in environmental quality. For example, site specific management cannot be developed without detailed knowledge of soils. Critical sites, e.g. shallow hillslope soils prone to erosion and leaching of nutrients, can be identified using pedology. Soil surveys furnish basic inputs to soil conservation planning and provide information used in equations for predicting soil loss and water pollution under various management practices on different soils.

3.2 Soil: Its Origin and Formation

Soils are a mixture of different things; rocks, minerals, and dead, decaying plants and animals. Soil can be very different from one location to another, but generally consists of organic and inorganic materials, water and air. The inorganic materials are the rocks that have been broken down into smaller pieces. The size of the pieces varies. It may appear as pebbles, gravel, or as small as particles of sand or clay. The organic material is decaying living matter. This could be plants or animals that have died and decay until they become part of the soil. The amount of water in the soil is closely linked with the climate and other characteristics of the region. The amount of water in the soil is one thing that can affect the amount of air. Very wet soil each are found in a wetland probably has very little air. The composition of the soil affects the plants and therefore the animals that can live there.

3.3 Origin of Soil

Physical and biological agents, such as wind, running water, temperature changes, and living organisms, perpetually modify the Earth's crust, changing its upper surface into products that are more closely in equilibrium with the atmosphere, the hydrosphere, and the biosphere. Earth scientists sum up all processes through which these alterations take place under the collective term *weathering*. One speaks of mechanical weathering in the case that the dominant forces are mainly mechanical, such as the eroding action of running water, the abrading action of stream load or the physical action of wind and severe temperature fluctuations. Similarly, one speaks of biological weathering when the forces producing changes are directly or indirectly related to living organisms. Of these, we can mention several examples, such as the action of burrowing animals, the penetrating forces of plant roots, and the destructive action of algae, bacteria, and their acid-producing symbiotic community of the lichens, or simply the destructive action of man, who continuously disturbs the Earth's crust through various activities. Processes of disintegration, during which mantle rocks are broken down to form particles of smaller size, without considerable change in chemical or mineralogical composition are known as *physical weathering processes*. Changes of this type prevail under extreme climatic conditions as in deserts or arctic regions. They are also prevailing in areas of mountainous relief. The most prominent agents of physical weathering are: _ differential stress caused by unloading of deep-seated rocks on emerging to the surface; _ differential thermal expansion under extreme climatic conditions; _ expansion of interstitial water volume by freezing that leads to rupturing along crystal boundaries. Other mechanical agents enhance the effect of mechanical weathering. These may include processes such as gravity, abrasion by glacial ice or wind-blown particles.

The word 'soil' occurs many times in this course. In agriculture this word is used to describe the thin layer of surface earth that, like some great blanket, is tucked around the wrinkled and age-beaten form of our globe. The harder and colder earth under this surface layer is called the _subsoil_. It should be noted, however, that in waterless and sun-dried regions there seems little difference between the soil and the subsoil. Plants, insects, birds, beasts, men,--all alike are fed on what grows in this thin layer of soil. If some wild flood in sudden wrath could sweep into the ocean this earth-wrapping soil, food would soon become as scarce as it was in Samaria when mothers ate their sons. The face of the earth as we now see it, daintily robed in grass, or uplifting waving acres of corn, or even naked, water-scarred, and disfigured by man's neglect, is very different from what it was in its earliest days. How was it then? How was the soil formed? Scientists think that at first the surface of the earth was solid rock. How was this rock changed into workable soil? Occasionally a curious boy picks up a rotten stone, squeezes it, and finds his hands filled with dirt, or soil. Now, just as the boy crumbled with his fingers this single stone, the great forces of nature with boundless patience crumbled, or, as it is called, disintegrated, the early rock mass. The simple but giant-strong agents that beat the rocks into powder with a club like force a million fold more powerful than the club force of Hercules were chiefly (1) heat and cold; (2) water, frost, and ice; (3) a very low form of vegetable life; and (4) tiny animals--if such minute bodies can be called animals. In some cases these forces acted singly; in others, all acted together to rend and crumble the unbroken stretch of rock.

4.0 CONCLUSION

Soil originated from the decay of rocks and minerals by combining with organic matter. It takes some hundred million years to form soil.

5.0 SUMMARY

Soil formation hypothesis states that soil is formed as a result of the interaction of many variables the most important of which are:

- parent material
- climate
- organisms
- relief and

- time, these variable soil forming factors.

(Source: Pilot Phase II - Biology Hand Book for Student Grade 4-6. 2001)

6.0 TUTOR-MARKED ASSIGNMENT

i. Briefly describe the origin of soil.
ii. What are the factors of soil formation?
iii. Explain how soil formation factors influence the kind of soil that is finally formed.

7.0 REFERENCES/FURTHER READING

Albrecht, W.A. (1975). *The Albrecht Papers*. Charles Walters (Ed.). Acres USA.: Raytown. Missouri.

Young, G.A. (1999). A Training Manual for Soil Analysis Interpretation in Northern California. M.A. Thesis, Sonoma State University. Rohnert Park, Ca: California State University, Sonoma.

UNIT 2 SOIL FORMATION

CONTENTS

1.0 INTRODUCTION

Soils are that portion of the earth's crust in land plants can grow, if water and temperature are adequate, at least the minimum nutrients are available, and toxic substances are in low concentration. Some soils are very shallow (few centimeters deep) and some are few meters deep. All soils developed from weathered rock, volcanic ash deposits, or accumulated plant residues. Most soils are formed weathered rocks and minerals. These minerals include quartz, feldspars, micas, homblende, calcite, and gypsum. Combinations of minerals into solid masses are called rocks.

2.0 OBJECTIVES

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

- explain the origin of "organic soils"
- classify the origin and nature of certain landforms, particularly moraines, alluvial deposits, loess and peats and mucks
- define the meaning of "soil formation" and "soil development" and the processes active in the soil changes
- evaluate soil-forming factors.

3.0 MAIN CONTENT

3.1 Soil formation

Let us glance at some of the methods used by these skilled soil-makers. Heat and cold are working partners. You already know that most hot bodies shrink, or contract, on cooling. The early rocks were hot. As the outside shell of rock cooled from exposure to air and moisture it contracted. This shrinkage of the rigid rim of course broke many of the rocks, and here and there left cracks, or fissures. In these fissures water collected and froze. As freezing water expands with irresistible power, the expansion still further broke the rocks to pieces. The smaller pieces again, in the same way, were acted on by frost and ice and again crumbled. This process is still a means of soil-formation. Running water was another giant soil-former. If you would understand its action, observe some usually sparkling stream just after a washing rain. The clear waters are discoloured by mud washed in from the surrounding hills. As though disliking their muddy burden, the waters strive to throw it off. Here, as low banks offer chance, they run out into shallows and drop some of it. Here, as they pass a quiet pool, they deposit more. At last they reach the still water at the mouth of the stream, and there they leave behind the last of their mud load, and often form of it little three-sided islands called deltas.

In the same way mighty rivers like the Amazon, the Mississippi, and the Hudson, when they are swollen by rain, bear great quantities of soil in their sweep to the seas. Some of the soil they scatter over the lowlands as they whirl seaward; the rest they deposit in deltas at their mouths. It is estimated that the Mississippi carries to the ocean each year enough soil to cover a square mile of surface to a depth of two hundred and sixty-eight feet.

The early brooks and rivers, instead of bearing mud, ran ocean ward either bearing ground stone that they themselves had worn from the rocks by ceaseless fretting, or bearing stones that other forces had already dislodged. The large pieces were whirled from side to side and beaten against one another or against bedrock until they were ground into smaller and smaller pieces. The rivers distributed this rock soil just as the later rivers distribute muddy soil. For ages the moving waters ground against the rocks. Vast were the waters; vast the number of years; vast the results.

Glaciers were another soil-producing agent. Glaciers are streams "frozen and moving slowly but irresistibly onwards, down well-defined valleys, grinding and pulverising the rock masses detached by the force and weight of their attack.

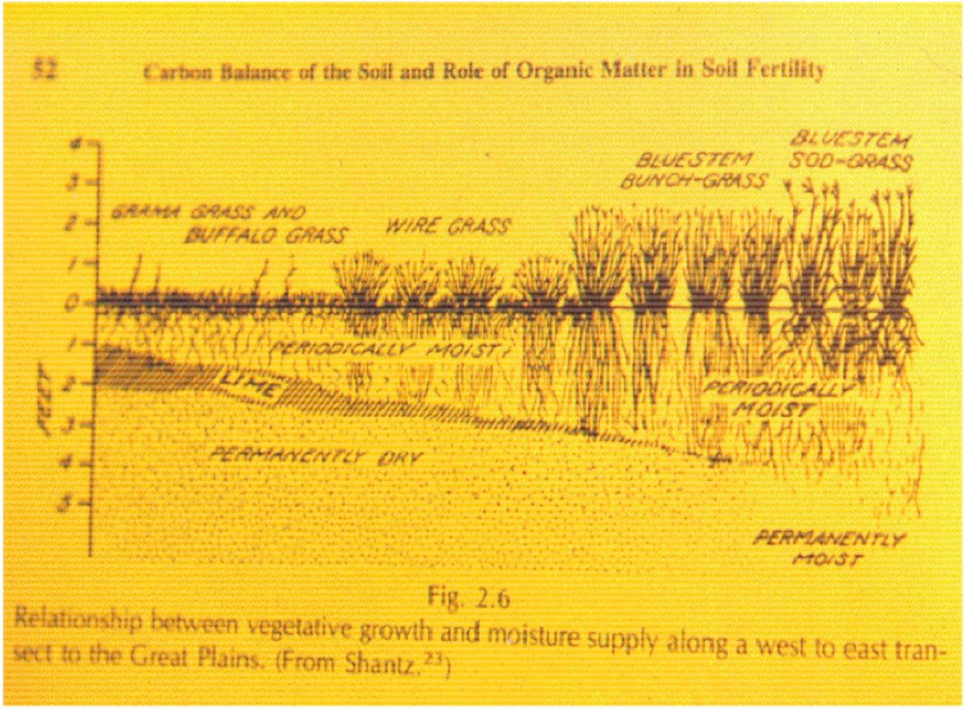

Fig. 2.6
Relationship between vegetative growth and moisture supply along a west to east transect to the Great Plains. (From Shantz.[23])

3.2 Types of Soil

Sand, silt, and clay are the basic types of soil. Most soils are made up of a combination of the three. The texture of the soil, how it looks and feels, depends upon the amount of each one in that particular soil. The type of soil varies from place to place on our planet and can even vary from one place to another in your own backyard.

3.3 The Soil-Forming Factors

Even if all soils were formed through the same weathering processes, they could still differ because of other influences. Five items, called soil-forming factors, are primarily responsible for the developed soil:

- Parent material
- Climate (temperature and precipitation mostly)
- Biota (living organisms and organic residues)
- Topography (slope, aspect and elevation)
- Time

3.4 Parent Materials and Soil Formation

Parent materials influence soil formation by their different rates of weathering, the nutrients they contain for plant use, and the particle sizes they contain (sandstones = sandy; conglomerates = rocky; shale's = clayey). The less developed a soil is, the greater will be the effect of parent material on the properties of the soil. However, even the properties of well developed soils will be greatly influenced by the parent material. Clay formation is favoured by a high percentage of decomposable dark minerals and by less quartz. The results of leaching and many translocations and transformations affected by water movement in soil will be evident even when the soil is well developed. All soils at the lowest category of soil classification (series) are placed into separates series if parent materials are different.

3.5 Climate and Soil Formation

Climate is an increasingly dominant factor in soil formation with increased time, mainly because of the effects of precipitation and temperature. Some direct effects of climate on soil formation include the following:

a shallow accumulation or retention of lime (carbonates) in areas having low rainfall occurs because calcium bicarbonates (from dissolving carbon dioxide, minerals and lime) are not leached if sufficient water is not present. Such soils are usually alkaline

- acidic soils form in humid areas due to intense weathering and leaching out of basic cations (calcium, sodium, magnesium, potassium)
- erosion of soils on sloping lands constantly removes developing soil layers
- deposition of soil materials downslope covers developing soils
- weathering, leaching and erosion are more intense and of longer duration in warm and humid regions, as in Hawaii, where the soil does not freeze. The reverse is true in cold climates, as in Alaska.

3.6 Biota and Soil Formation

The activity of living plants and animals and the decomposition of their organic wastes and residues (the living environment, the biota) have marked influences on soil development. Differences in soils that have resulted primarily from differences in vegetation are especially noticeable in the transition where trees and grasses meet. In Nigeria for example, the differences soils follows closely the difference in vegetation types: there are more work from earth, the vegetation get sparser and as its get shallower and fewer in organic matter.

Some soils beneath humid forest vegetation may develop many horizons, are leached (washed, eluviated) in the surface layers, and have slowly decomposing organic matter layers on the surface. In contrast, some grassland soils near the transition zone of forests are rich in well-decomposed organic matter, frequently to depths of 30cm or more (1ft or more) into the mineral soil.

Burrowing animals, such as rats, earthworms, ants and termites are highly important in soil formation when they exist in large numbers. Soils that harbour many burrowing animals have fewer but deeper horizons because of the constant mixing within the profile, which nullifies the organic colloid and clay movements downward.

Microorganisms help soil development by slowly decomposing organic matter and forming weak acids that dissolve minerals faster than pure water. Some of the first plants to grow on weathering rocks are crust-like lichens, which are beneficial (symbiotic) combination of algae and fungi. Man also plays a role in soil formation by modifying, soils; this is done through many various activities such as tillage, bush burning, construction, etc.

3.7 Topography and Soil Formation

The earth's surface contour is called its **topography** (sometimes called relief). Topography influences soil formation primarily through its associated water and temperature relations. Soils within the same general climatic area developing from similar parent material and on steep hillsides typically have thin A and B horizons because less water moves down through the profile as a result of rapid surface runoff and because the surface erodes quite rapidly. Similar materials on gently sloping hillsides have more water passing vertically through them than do materials on steeper slopes. The profile on gentle slopes generally is deeper, the vegetation more luxuriant, and the organic matter level higher than in similar materials on steep topography.

4.0 CONCLUSION

Soil is the combination of rock, mineral fragments (pieces) made by weathering (wind, rain, sun, snow, etc.), and organic matter (living things), water, and air.

5.0 SUMMARY

Soil is a 3-dimensional body with properties that reflect the impact of (1) climate, (2) vegetation, fauna, Man and (3) topography on the soil's (4) parent material over a variable (5) time span. The nature and relative importance of each of these five `soil forming factors' vary in time and in space. With few exceptions, soils are still in a process of change; they show in their `soil profile' signs of differentiation or alteration of the soil material incurred in a process of soil formation or `pedogenesis'.

6.0 TUTOR-MARKED ASSIGNMENT

i. What are the factors of soil formation? Explain how these factors influence the kind of soil that is finally formed.

ii. Write short notes on any 3 of the following:

a. Topography and Soil Formation

b. Biota and Soil Formation

c. Climate and Soil Formation

d. Types of Soil.

7.0 REFERENCE/FURTHER READING

Eswaran, H. *et al*. (Eds.). (2002). *Soil Classification: A Global Desk Reference*. Boca Raton, Fla.: CRC Press.

UNIT 3 SOIL MORPHOLOGY

CONTENTS

1.0 INTRODUCTION

Soil morphology is the field observable attributes of the soil within the various soil horizons and the description of the kind and arrangement of the horizons. C.F. Marbut (2003) championed reliance on soil morphology instead of on theories of pedogenesis for soil classification because theories of soil genesis are both ephemeral and dynamic.

The observable attributes ordinarily described in the field include the composition, form, soil structure and organisation of the soil, colour of the base soil and features such as mottling, distribution of roots and pores, evidence of translocated materials such as carbonates, iron, manganese, carbon and clay, and the consistence of the soil.

The observations are typically performed on a soil profile. A profile is a vertical cut, two dimensional, in the soil and bounds one side of a pedon. The pedon is the smallest three dimensional units, but not less than 1 meter square on top, that captures the lateral range of variability.

2.0 OBJECTIVES

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

- identify the micromorphology, porosity and soil texture.

3.0 MAIN CONTENT

3.1 Micromorphology

While soil micromorphology begins in the field with the routine and careful use of a 10x hand lens, much more can be described by careful description of thin sections made of the soil with the aid of a petrographic polarising light microscope. The soil can be impregnated with an epoxy resin, but more commonly with a polyester resin (crystic 17449) and sliced and ground to 0.03 millimeter thickness and examined by passing light through the thin soil plasma.

3.2 Porosity

Porosity of topsoil typically decreases as grain size increases. This is due to soil aggregate formation in finer textured surface soils when subject to soil biological processes. Aggregation involves particulate adhesion and higher resistance to compaction. Typical bulk density of sandy soil is between 1.5 and 1.7 g/cm^3. This calculates to porosity between 0.43 and 0.36. Typical bulk density of clay soil is between 1.1 and 1.3 g/cm^3. This calculates to porosity between 0.58 and 0.51. This seems counterintuitive because clay soils are termed heavy, implying lower porosity. Heavy apparently refers to a gravitational moisture content effect in combination with terminology that harkens back to the relative force required to pull a tillage implement through the clayey soil at field moisture content as compared to sand.

Porosity of subsurface soil is lower than in surface soil due to compaction by gravity. Porosity of 0.20 is considered normal for unsorted gravel size material at depths below the biomantle. Porosity in finer material below the aggregating influence of pedogenesis can be expected to approximate this value.

Soil porosity is complex. Traditional models regard porosity as continuous. This fails to account for anomalous features and produces only approximate results. Furthermore it cannot help model the influence of environmental factors which affect pore geometry. A number of more complex models have been proposed, including fractals, bubble theory, cracking theory, Boolean grain process, packed sphere, and numerous other models.

3.3 Soil Texture

An experienced soil scientist can determine soil texture in the field with decent accuracy, but not all soils lend themselves to accurate field determinations of soil texture. The mineral texture can be obfuscated by high soil organic matter, iron oxides, amorphous or short-range-order aluminosilicates, and carbonates. Soil texture is the relative relations of the components sand, silt and clay most often reported as percentages on a mass basis. Laboratory methods employ chemical pretreatments to mediate the effects of organic matter, iron oxides, amorphous or shortrange-order aluminosilicates, and carbonates

Cultivation disturbs the soil, causing fragmentation, compaction and displacement (Roger-Estrade *et al*., 2000). Consequently, two types of earth may appear within the soil profile: fine and compacted zones (most often defined as clods). The presence of a large portion of high penetration-resistant clods is one of the most serious factors limiting soil exploration by plant roots (Hoad *et al.,* 1992). Since water content fluctuates during the growing season and clod penetration resistance is strongly linked to moisture, impedance of clods to root growth changes considerably. An additional factor closely linked to these interactions is the intensity of soil compaction, which can be readily interpreted as an increase of bulk density of a specific soil type (Goldsmith *et al*., 2001).

If soil becomes compacted to the level that plant growth is impaired, the compaction must be alleviated through several measures intended to returning satisfactory growth conditions. Especially, loosening and sub-soiling aim at eliminating soil compaction and preventing reduced soil-rooting depth (Carter, 1988). However, it is safe to assume that even optimal techniques and excellent timings of agronomic operations cannot fully eliminate soil compaction. Thus, soil impedance remains one of the most important factors influencing crop yield (Atwell, 1988, Stenitzer and Murer, 2003). Some previous studies showed that soil compaction decreased root development and delayed root colonisation of deeper soil layers (e.g. Ehlersb *et al.* 1982). Frequently, the relation between the relative root elongation rate and soil penetration resistance was used to demonstrate the importance of soil compaction for root growth (Bennie, 1991). However, it appears that there is a lack of studies on alterations of other morphological properties of roots due to soil compaction, and hence on plant physiological processes and crop production (Bengough, 2003). The relationship between soil compaction and root growth was usually studied using a homogeneous substrate (see for instance Unger and Kaspar 1994), structured soil conditions were considered very rarely (Amato and Ritchie, 2002).

4.0 CONCLUSION

Soil morphology is composed of composition, form, soil structure and organisation of the soil, colour of the base soil and features such as mottling, distribution of roots and pores, evidence of translocated materials such as carbonates, iron, manganese, carbon and clay, and the consistence of the soil.

5.0 SUMMARY

Soil morphology, classification and survey are three intimately related sub-disciplines that made soil morphology. They are used one after the other.

6.0 TUTOR-MARKED ASSIGNMENT

i. Discuss the morphological characteristics of soil
ii. Write short notes on the following:
   a. Micromorphology
   b. Soil porosity
   c. Soil texture.

7.0 REFERENCES/FURTHER READING

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UNIT 4 SOIL CHARACTERISTICS

CONTENTS

1.0 INTRODUCTION

Soil scientists study many different aspects of the soil. Below are the soil characteristics which are the most important aspects of soil science.

2.0 OBJECTIVES

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

- explain the various characteristics of soil.

3.0 MAIN CONTENT

3.1 Soil Characteristics

- a layer of natural materials on the earth's surface containing both organic and inorganic materials and capable of supporting plant life
- the material covers the earth's surface in a thin layer
- it may be covered by water, or it may be exposed to the atmosphere.
- soil contains four main components: inorganic material, organic matter, water, and air
- ideal soil should contain about 50% solid material and 50% pore space
- about half of the pore space should contain water and half of the space should contain air
- inorganic material consists of rock slowly broken down into small particles
- the organic material is made up of dead plants and animals varying in stages of decay.

- the percentages of the four main soil components varies depending on the kind of vegetation, amount of mechanical compaction, and the amount of soil water present.
- soil is formed very slowly
- it results from natural forces acting on the mineral and rock portions of the earth's surface
- the rock is slowly broken down to small particles resulting in soil
- soil parent materials are those materials underlying the soil and from which the soil was formed
- there are five major categories of parent material: minerals and rocks, glacial deposits, loess deposits, alluvial and marine deposits and organic deposits
- minerals are solid, inorganic, chemically uniform substance occurring naturally in the earth
- some common minerals for soil formation are feldspar, micas, silica, iron oxides, and calcium carbonates
- rocks are different from minerals because they are not uniform
- there are three types of rocks, igneous, sedimentary, and metamorphic
- igneous rocks are those formed by the cooling of molten rock
- sedimentary rocks are those formed by the solidification of sediment.
- metamorphic rocks are simply igneous or sedimentary rocks which have been reformed because of great heat or pressure
- during the ice age, glaciers moved across areas of the northern hemisphere
- they ground, pushed, piled, gouged, and eventually deposited great amounts of rocks, parent material, and already formed soil material
- loess deposits are generally thought of as windblown silt.
- alluvial and marine deposits are water borne sediments
- alluvial deposits are left by moving fresh water
- marine deposits are formed on ancient ocean floors
- organic deposits are partially decayed plants that live plants are able to root and grow in
- these are found in swamps and marshes
- when minerals are exposed to weather, they begin to break down into smaller pieces.
- this is mostly done by heating and cooling of the minerals and rock
- some minerals are water soluble which means they dissolve when exposed to water.
- some rocks may contain some minerals that are water soluble and only that part of the rock will dissolve. Ex: some caves

- when a tree or other types of plants begin growing in the cracks of rocks, this may speed up the breakdown of the rock because of the pressure the roots may exert
- ice can also speed up the weathering process on rocks
- if a rock has a crack that can fill up with water, when the water freezes, it can literally crumble the rock into small pieces
- rocks can also be broken down by mechanical grinding such as wind blowing sand at high speeds or glaciers causing rocks to grind each other.

4.0 CONCLUSION

New soil is continually being made, but it takes a long time to create new soil and if it isn't managed properly, soil can be eroded away quicker than it can be made.

5.0 SUMMARY

Soil characteristics property used to describe the relative proportion of different grain sizes of mineral particles in a soil. Particles are grouped according to their size into what are called soil separates. These separates are typically named clay, silt, and sand. Soil texture classification is based on the fractions of soil separates present in a soil. The soil texture triangle is a diagram often used to figure out soil textures.

6.0 TUTOR-MARKED ASSIGNMENT

i. What are the general characteristics of soil
ii. Write short notes on the following:
   a. Major Soil types
   b. Soil Profile
   c. Soil microorganisms.

7.0 REFERENCES/FURTHER READING

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UNIT 5 SOIL COMPONENTS

CONTENTS

1.0 INTRODUCTION

Soils are a mixture of different things; rocks, minerals, and dead, decaying plants and animals. Soil can be very different from one location to another, but generally consists of organic and inorganic materials, water and air. The inorganic materials are the rocks that have been broken down into smaller pieces. The size of the pieces varies. It may appear as pebbles, gravel, or as small as particles of sand or clay. The organic material is decaying living matter. This could be plants or animals that have died and decay until they become part of the soil. The amount of water in the soil is closely linked with the climate and other characteristics of the region. The amount of water in the soil is one thing that can affect the amount of air. Very wet soil like you would find in a wetland probably has very little air. The composition of the soil affects the plants and therefore the animals that can live there.

2.0 OBJECTIVES

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

- identify the component of soil
- state the importance of soil component to a farmer who wants to undertake large-scale crop production.

3.0 MAIN CONTENT

3.1 Soil Components

Soils consist of four major components:
(1) mineral (or inorganic), (2) organic, (3) water, and (4) air.
The relative proportions of these four soil components vary with soil type and climatic conditions. Review the approximate proportions (by volume) of the four soil components in a mineral soil under optimum conditions for plant growth.

3.2 Mineral Components

Mineral particles are inorganic materials derived from rocks and minerals. They are extremely variable in size and composition.

3.2.1 Types of Primary and Secondary Minerals

a. **Primary minerals** are formed at high temperature and pressure, under reducing conditions without free oxygen**.** These minerals are mainly present in soils as sand and silt particles. They are not crystallised and deposed from molten lava.

b. **Secondary minerals** are formed at low temperature and pressure through oxidation. They are the weathering product of primary minerals, either through alteration of their structure or through re-precipitation. Secondary minerals are usually present in soil as clay particles.

3.2.2 Size of Soil Particles

The mineral particles present in soils vary enormously in size from boulders and stones down to sand grains and minute clay particles that cannot be seen by an optical microscope. An arbitrary division is made by size-grading soil into material:

a) that passes trough a sieve with 2-mm diameter holes - the **fine earth** (consisting of sand, silt, and clay particles),

b) that is retained on the sieve (> 2 mm) - the **coarse fragments** (gravel, cobbles, and stones).

Coarse fragments (diameter > 2 mm) are defined as rock fragments and do not include fragments of pads or concretions.

3.3 Soil Texture

Soil texture refers to the relative proportions of sand, silt, and clay in a soil. It is often the first and most important property to be determined when describing a soil, since many conclusions can be drawn from this information (water intake or infiltration, water storage in the soil, soil aeration, soil fertility, trafficability, etc.).

3.4. Weathering

Weathering refers to the breakdown and changes in rocks and sediments at or near the Earth's surface brought about by biological, chemical, and physical agents or combinations thereof. Weathering also involves the synthesis of new (secondary) minerals that are of great importance in soil (e.g. clay minerals).

Examples of **physical weathering** include processes such as crystal growth, thermal expansion, moisture swelling, abrasion, etc.

Chemical weathering consists of the following processes:

1) **Hydration** - intact water molecules bind to a mineral transforming hematite into ferrihydrate:

$$5Fe_2O_3 + 9H_2O \xrightarrow{hydration} Fe_{10}O_{15} \cdot 9H_2O$$

2) **Hydrolysis** - water molecules split into their hydrogen and hydroxyl components and hydrogen replaces a cation from the mineral structure (e.g. transformation of feldspar to kaolinite):

$$KAlSi_3O_8 + H_2O \xrightarrow{hydrolysis} HAlSi_3O_8 + K^+ + OH^-$$

3) **Dissolution (or solution)** - water is capable of dissolving many minerals by hydrating the cat ions and anions until they become dissociated from each other and surrounded by water molecules. (e.g. dissolution of gypsum):

$$CaSO_4 \cdot 2H_2O + 2H_2O \xrightarrow{dissolution} Ca^{2+} + SO_4^{2-} + 4H_2O$$

4) **Carbonation** - weathering is accelerated by the presence of acids that increase the activity of hydrogen ions in water. For example, when carbon dioxide dissolves in water (a process enhanced by microbial and root respiration) the carbonic acid (H2CO3) produced hastens the chemical dissolution of calcite into limestone (or marble):

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

$$H_2CO_3 + CaCO_3 \xrightarrow{carbonation} Ca^{2+} + 2HCO_3^-$$

5) **Oxidation-reduction** - minerals that contain Fe, Mn, or S are especially susceptible to oxidation-reduction reactions. When for example, iron is oxidized from divalent to trivalent form, the

change in valence and ionic radius causes destabilising adjustments in the crystal structure of the mineral.

Biological weathering effects include:

- the breakup of rock particles by roots
- the transfer and mixing of materials by burrowing animals and
- the formation of organo-mineral complexes (soil biological processes produce organic acids that can solubilise Al and Si ions, which are removed from a mineral by this process).

Biological Weathering

An example of biological weathering of a rock under the influence of clams
Image Source: Maja Krzic

3.5 Most Common Elements in Soils

The median and range of various elements present in soils from around the world are given in Table 1. The elements that are found in soils in the highest quantities are O, Si, Al, Fe, C, Ca, K, Na, and Mg. These are also major elements found in the Earth's crust and in sediments. Oxygen is the most prevalent element in the Earth's crust and in soils. It comprises about 47% of the Earth's crust by weight and more than 90% by volume.

Table 1: Contents of some Elements in Soils, the Earth's Crust and Sediments (extracted from Sparks, 2003)

Element	Soils (mg/kg)		Earth's crust (mean)	Sediments (mean)
	Median	Range		
O	490,000	-	474,000	486,000
Si	330,000	250,000-410,000	277,000	245,000
Al	71,000	10,000-300,000	82,000	72,000
Fe	40,000	2,000-550,000	41,000	41,000
C (total)	20,000	7,000-500,000	480	29,400
Ca	15,000	700-500,000	41,000	66,000
Mg	5,000	400-9,000	23,000	14,000
K	14,000	80-37,000	21,000	20,000
Na	5,000	150-25,000	23,000	5,700
Mn	1,000	20-10,000	950	770
Zn	90	1-900	75	95
Mo	1.2	0.1-40	1.5	2
Ni	50	2-750	80	52
Cu	30	2-250	50	33
N	2,000	200-5,000	25	470
P	800	35-5,300	1,000	670
S (total)	700	30-1,600	260	2,200

3.6 Particle and Bulk Density

Particle density (ρ_σ) is mass of solids (M_s) per volume of solids (V_s).

$\rho_\sigma = M_s/V_s$

In most mineral soils the mean density of the particles is about 2.6-2.7 gm/cm^3 (or 2600 - 2700 kg/m^3). Soils with a high content of iron oxides and various heavy minerals have a particle density of 5.2-5.3 gm/cm^3, while soils with high organic matter content can have a particle density as low as 1.3 gm/cm^3.

Bulk density (ρ_b) is the mass of solids (M_s) per total soil volume (V_t).

$\rho_b = M_s / V_t$

$\rho_b = M_s / (V_s + V_a + V_w)$

V_s=volume of solids; V_a=volume of air; V_w=volume of water

Bulk density is always smaller than rs. Since in a general case pores constitute half the volume, rb is about half ofrs, namely 1.3-1.35 g/cm3 (or 1300-1350 kg/m3).

4.0 CONCLUSION

Soil is made up of an extensive variety of substances, minerals, and rocks. These substances can be categorised into four main groups. These groups are organic materials, inorganic materials, air, and water

5.0 SUMMARY

Because soils develop under a variety of conditions, the soil in one location can be very different from the soil in another location. In order to understand soil, and how one soil differs from another, geologists look at and measure the soils properties.

6.0 TUTOR-MARKED ASSIGNMENT

i. Briefly describe the soil components.
ii. Explain how organic matter and microorganisms influence soil fertility.
iii. Discuss the importance of knowledge of the soil component to a farmer who wants to undertake large-scale crop production.

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MODULE 2 SOIL-FORMING ROCKS AND MINERALS AND WEATHERING OF ROCKS AND MINERALS

UNIT 1 SOIL- FORMING ROCKS

CONTENTS

1.0 INTRODUCTION

Although many of us don't think about the ground beneath us or the soil that we walk on each day, the truth is, soil is a very important resource. Processes take place over thousands of years to create a small amount of soil material. Unfortunately the most valuable soil is often used for building purposes or is unprotected and erodes away. To protect this vital natural resource and to sustain the world's growing housing and food requirements it is important to learn about soil, how soil forms, and natural reactions that occur in soil to sustain healthy plant growth and purify water. Soil is important to the livelihood of plants, animals, and humans. However, soil quality and quantity can be and is adversely affected by human activity and misuse of soil.

Certain soils are best used for growing crops that humans and animals consume, and for building airports, cities, and roads. Other types of soil have limitations that prevent them from being built upon and must be left alone. Often these soils provide habitats for living creatures both in the soil and atop the soil. One example of soils that have use limitations are those that hold lakes, rivers, streams, and wetlands. Humans don't normally establish their homes in these places, but fish and waterfowl find homes here, as do the wildlife that live around these bodies of water.

Natural processes that occur on the surface of Earth as well as alterations made to earth material over long periods of time form thousands of different soil types. In the United States alone there are over 50,000 different soils! Specific factors are involved in forming soil and these factors vary worldwide, creating varied soil combinations and soil properties worldwide.

2.0 OBJECTIVES

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

- explain the soil-forming rocks and minerals

3.0 MAIN CONTENT

3.1 Soil- Forming Rocks and Minerals

The formation of soil happens over a very long period of time. It can take 1000 years or more. Soil is formed from the weathering of rocks and minerals. The surface rocks break down into smaller pieces through a process of weathering and is then mixed with moss and organic matter. Over time this creates a thin layer of soil. Plants help the development of the soil. How? The plants attract animals, and when the animals die, their bodies decay. Decaying matter makes the soil thick and rich. This continues until the soil is fully formed. The soil then supports many different plants.

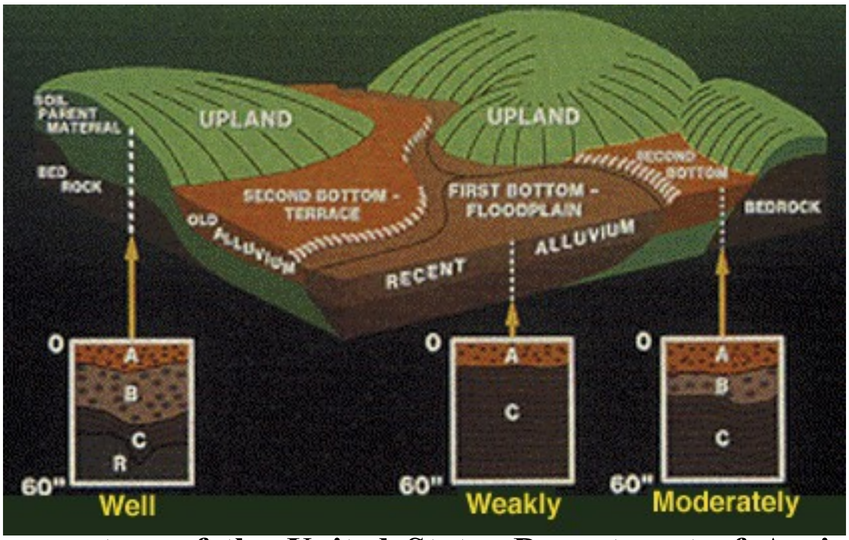
Certain soils are best used for growing crops that humans and animals consume, and for building airports, cities, and roads. Other types of soil have limitations that prevent them from being built upon and must be left alone. Often these soils provide habitats for living creatures both in the soil and atop the soil. One example of soils that have use limitations are those that hold lakes, rivers, streams, and wetlands. Humans don't normally establish their homes in these places, but fish and waterfowl find homes here, as do the wildlife that live around these bodies of water.

Natural processes that occur on the surface of Earth as well as alterations made to earth material over long periods of time form thousands of different soil types. In the United States alone there are over 50,000 different soils! Specific factors are involved in forming soil and these factors vary worldwide, creating varied soil combinations and soil properties worldwide:

The Five Soil -Forming Factors

1. **Parent material**: The primary material from which the soil is formed. Soil parent material could be bedrock, organic material, an old soil surface, or a deposit from water, wind, glaciers, volcanoes, or material moving down a slope.
2. **Climate**: Weathering forces such as heat, rain, ice, snow, wind, sunshine, and other environmental forces, break down parent material and affect how fast or slow soil formation processes go.
3. **Organisms**: All plants and animals living in or on the soil (including micro-organisms and humans!). The amount of water and nutrients, plants need affects the way soil forms. The way humans use soils affects soil formation. Also, animals living in the soil affect decomposition of waste materials and how soil materials will be moved around in the soil profile. On the soil surface remains of dead plants and animals are worked by microorganisms and eventually become organic matter that is incorporated into the soil and enriches the soil.
4. **Topography**: The location of a soil on a landscape can affect how the climatic processes impact it. Soils at the bottom of a hill will get more water than soils on the slopes, and soils on the slopes that directly face the sun will be drier than soils on slopes that do not. Also, mineral accumulations, plant nutrients, type of vegetation, vegetation growth, erosion, and water drainage are dependent on topographic relief.
5. **Time**: All of the above factors assert themselves over time, often hundreds or thousands of years. Soil profiles continually change from weakly developed to well developed over time.

Differences in soil -forming factors from one location to another influence the process of soil formation



(Image courtesy of the United States Department of Agriculture, Soil Conservation Service)

Parent Materials

Soil forms from different parent materials; one such parent material is bedrock. As rocks become exposed at Earth's surface they erode and become chemically altered. The type of soil that forms depends on the type of rocks available, the minerals in rocks, and how minerals react to temperature, pressure, and erosive forces. Temperatures inside the Earth are very hot and melt rock (lithosphere) that moves by tectonic forces below Earth's surface. Melted rock flows away from the source of heat and eventually cools and hardens. During the cooling process, minerals crystallise and new rock types are formed. These types of rocks are called igneous rocks, the original parent material rocks formed on Earth. Igneous rocks, under the right environmental conditions, can change into sedimentary and metamorphic rocks. Volcanoes produce igneous rocks such as granite, pumice, and obsidian.

Sedimentary rocks are formed when older rocks are broken apart by plant roots, ice wedges, and earth movements and become transported by glaciers, waves, currents, and wind. The transported particles then become bound together (cemented) as secondary minerals grow in the spaces between the loose particles and create a new, solid, sedimentary rock. Sandstone, limestone, and shale are types of sedimentary rocks that contain quartz sand, lime, and clay, respectively.

Metamorphic/Crystalline rocks form when pressure and temperature, below Earth's surface, are great enough to change the chemical composition of sedimentary and igneous rocks. Metamorphic rocks, such as quartzite, marble, and slate form under intense temperature and pressure but were originally quartz sandstone, limestone, and shale.

Other types of parent material that mineral soils form from are called **Recent Cover Deposits** and include alluvium, colluvium, eolian deposits, glacial deposits, lacustrine (lake) deposits, loess deposits , marine deposits, and volcanic ash deposits.

4.0 CONCLUSION

Soil is important to the livelihood of plants, animals, and humans. However, soil quality and quantity can be and is adversely affected by human activity and misuse of soil.

5.0 SUMMARY

Although many of us don’t think about the ground beneath us or the soil that we walk on each day, the truth is soil is a very important resource. Processes take place over thousands of years to create a small amount of soil material. Unfortunately the most valuable soil is often used for building purposes or is unprotected and erodes away. To protect this vital natural resource and to sustain the world's growing housing and food requirements it is important to learn about soil, how soil forms, and natural reactions that occur in soil to sustain healthy plant growth and purify water.

6.0 TUTOR-MARKED ASSIGNMENT

i. Discuss the characteristics of soil -forming rocks and minerals
ii. Write on soil -forming factors.

7.0 REFERENCES/FURTHER READING

Birkeland, Peter W.(1999). *Soils and Geomorphology*.(3rd ed.). New York: Oxford University Press.

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UNIT 2 WEATHERING OF ROCKS AND MINERALS

CONTENTS

1.0 INTRODUCTION

As you drive or ride in a car, take a train or plane, ride a bike ride, or go for a nature walk you see the spectacular and varied landscapes on Earth's surface. As Earth’s crust is built up by volcanic and tectonic forces (thrusting and deformation of Earth's crust), weathering forces simultaneously reduce landforms and release minerals from rocks. Natural weathering processes occur around us every day, continually rearranging and building landforms on Earth's surface.

2.0 OBJECTIVES

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

- explain weathering of rocks and minerals
- describe chemical weathering processes.

3.0 MAIN CONTENT

3.1 Weathering of Rocks and Minerals

Weathering is the process of the breaking down rocks. There are two different types of weathering: Physical weathering and chemical weathering. In physical weathering, it breaks down the rocks, but what it's made of stays the same. In chemical weathering, it still breaks down the rocks, but it may change what it's made of. For instance, a hard material may change to a soft material after chemical weathering.

3.2 Chemical Weathering Processes

Chemical weathering occurs as minerals in rocks are chemically altered, and subsequently decompose and decay. Increasing precipitation (rain) speeds up the chemical weathering of minerals in rocks, as seen on tombstones and monuments made of limestone and marble. In fact, **water is an essential factor of chemical weathering**. Increasing temperature also accelerates the chemical reaction that causes minerals to degrade. This is why humid, tropical climates have highly weathered landforms, soils, and buildings.

Carbonation and Solution: this weathering process occurs when precipitation (H_20) combines with carbon dioxide (CO_2) to form carbonic acid (H_2CO_3). When carbonic acid comes in contact with rocks that contain lime, soda, and potash, the minerals calcium, magnesium and potassium in these rocks chemically change into carbonates and dissolve in rain water. Karst topography, originally named after the Krs Plateau in Yugoslavia where it was first studied, is a result of this type of chemical weathering that possesses characteristic sinkholes, caves, and caverns.

- **Hydrolysis**: this chemical weathering process occurs when water (H_20), usually in the form of precipitation, disrupts the chemical composition and size of a mineral and creates less stable minerals, thus less stable rocks, that weather more readily.
- **Hydration:** water (H_20) combines with compounds in rocks, causing a chemical change in a mineral's structure, but more likely will physically alter a mineral's grain surface and edges. A good example of this is the mineral Anhydrite ($CaSO_4$). Anhydrite chemically changes to Gypsum ($CaSO_4$-$2H_20$) when water is added. Gypsum is used in the construction industry, to build buildings and houses.
- **Oxidation:** this process occurs when oxygen combines with compound elements in rocks to form oxides. When an object is chemically altered in this manner it is weakened and appears as "oxidized." A good example of this is a "rusting" sign post. The iron in the metal post is oxidizing. Increased temperatures and the presence of precipitation will accelerate the oxidation process.
- **Spheroidal Weathering:** water penetrates through cracks in rocks and dissolves the cement that binds particles together and also erodes sharp edges and corners of rocks, making a rock appear spheroidal. Physical weathering processes, such as frost wedging, can then act upon the enlargened cracks in rocks.

3.3 Physical Weathering Processes

Rocks that are broken and degrade by processes other than chemical alteration are physically or mechanically weathered. A rock broken in to smaller pieces exposes more surface area of the original rock. Increasing the exposed surface area of a rock will increase its weathering potential.

- **Animals and Plants:** Animals burrow into Earth's substrate and move rock fragments and sediment on Earth's surface, thereby aiding in the disintegration of rocks and rock fragments. Fungi and Lichens are acid-producing microorganisms that live on rocks and dissolve nutrients (phosphorus, calcium) within rocks. These microorganisms assist in the breakdown and weathering of rocks.
- **Crystallisation:** As water evaporates moisture from rocks located in arid climates mineral salts develop from mineral crystals. The crystals grow, spreading apart mineral grains in the process, and eventually break apart rocks.
- **Temperature Variation:** minerals in rocks expand and contract in climates where temperature ranges are extreme, like in glacial regions of the world, or when exposed to extreme heat, like during a forest fire. Crystal structures of minerals become stressed during contraction and expansion and the mineral crystals separate. For instance, repeated cycles of freezing and thawing (known as Freeze-Thaw) of water in rock cracks further widens cracks and splits rocks apart. Frost-wedging forces portions of rock to split apart.
- **Unloading and Exfoliation**: Cracks in rocks appear when pressure is released as overlying rocks or sediment are removed, thus allowing the expansion of the newly exposed rock. Exfoliation occurs as sheets or slabs of the cracked rock slip off and become further eroded. Domes form as the unloading and exfoliation weathering processes continue. Half Dome at Yosemite National Park, California is a result of unloading (pressure-release jointing) and exfoliation

4.0 CONCLUSION

A rock that is weathered into new minerals but still looks somewhat like the parent rock is called a saprolite. If the saprolite fragments are subsequently removed from the site by water, wind, gravity, or ice, erosion has taken place.

5.0 SUMMARY

Weathering is the alteration of rocks to more stable material from their exposure to the agents of air, water, and organic fluids. No rock is stable or immune to weathering. Many pathways and agents are involved in weathering, but most can be grouped into two main processes: mechanical and chemical weathering.

Mechanical weathering includes processes that fragment and disintegrate rocks into smaller pieces without changing the rock's mineral composition. Chemical weathering is the alteration of the rock into new minerals. Both pathways constitute weathering, but one process may dominate over the other.

The two processes can be demonstrated with a piece of paper. It can be torn into smaller pieces, which is analogous to mechanical weathering. It also can be burned into carbon dioxide and water, which is analogous to chemical weathering.

6.0 TUTOR-MARKED ASSIGNMENT

i. Describe the physical weathering processes.
ii. Write on chemical weathering processes.

7.0 REFERENCE/FURTHER READING

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UNIT 3 PROFILE DESCRIPTION AND SOIL SURVEY

CONTENTS

1.0 INTRODUCTION

A soil survey describes the characteristics of the soils in a given area, classifies the soils according to a standard system of classification, plots the boundaries of the soils on a map, and makes predictions about the behaviour of soils. The different uses of the soils and how the response of management affects them are considered. The information collected in a soil survey helps in the development of land-use plans, evaluates and predicts the effects of land use on the environment.

You might ask what a soil profile is. A profile is a side view of a person. So a soil profile must be the side view of soil. There are no fixed number of horizons a soil profile would much depend on the age and weathering processes going on in the soil. A soil could have the following horizons for example:

- **Horizon:** (1st layer). This is the top layer of soil. Animals live on this layer. It is made of fresh to partially decomposed organic matters. The colour varies from brown to black.
- **A Horizon:** (2nd layer). The top part of this soil is made of highly decomposed organic matter mixed up. The colour range from brown to gray.
- **E Horizon:** (3rd layer). This layer is made up of mostly sand and silt down migration of particles it has lost most of its minerals and clay due to eluviation.
- **B Horizon: (4th** layer). Unlike the other horizons, this one has more clay and bigger bedrock. It is reddish brown or tan in colour.
- **C Horizon:** (5th layer). This layer has mostly weathered bedrock. It is the cracked and broken surface of the bedrock.
- **R Horizon:** (Last Layer). This is the last layer in the profile. It is made of unweathered rocks

2.0 OBJECTIVES

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

- describe the sequential development of a soil from the various horizons
- list profile differences in various soil types
- relate differences in soil profile development to differences (possible) in land use.

3.0 MAIN CONTENT

3.1 Profile Description

Soil Profile refers to the layers of soil; horizon A, B, and C. Horizon A refers to the upper layer of soil, nearest the surface. It is commonly known as topsoil. In the woods or other areas that have not been plowed or tilled, this layer would probably include organic litter, such as fallen leaves and twigs. The litter helps prevent erosion, holds moisture, and decays to form a very rich soil known as humus. Horizon A provides plants with nutrients they need for a great life.

The layer below horizon A is the B. Litter is not present in horizon B and therefore there is much less humus. Horizon B does contain some elements from horizon A because of the process of leaching. Leaching resembles what happens in a coffee pot as the water drips through the coffee grounds. Leaching and in the case of cultivated soil, soil mixing may also bring some minerals from horizon B down to horizon C.

If horizon B is below horizon A, then horizon C must be below horizon B. Horizon C consists mostly of weatherised big rocks. This solid rock, as you discovered in Soil Formation, gave rise to the horizons above it. Soil profiles look different in different areas of the world. They are affected by climate and other things

Soils are structural and functional elements of terrestrial ecosystems, which are formed in a historical process of development through the interaction of geological, climatic and biotic factors at the respective site. Soil is the fundamental source of life for all living beings. As the physical and chemical properties of soils exert great influence in the distribution and development of vegetation, it needs to be studied and evaluated from time to time. The soil forming process is very slow and time taking. It takes normally thousands of years for the soil formation. Therefore, we are studying the past activities while analysing the soil profile at present. The parent material, topography, geological processes, climatic conditions, vegetation and human interferences play major roles in formation and development of soil profiles in particular area. Similarly, our activities at present will certainly influence the soil profiles in far future.

Geological factors include the type of parent material and its mineral composition, the relief of the area, its exposition and the groundwater regime. Climatic factors include the level of solar radiation, precipitation, humidity, air temperature and wind speed and the characteristics of the hydrological regime that result from these factors. Soils are affected by human activities, such as industrial, municipal and agriculture, that often result in soil degradation and loss or reduction in soil functions. In order to prevent soil degradation and to rehabilitate the potential of degraded soils, reliable soil data are the most important prerequisite for the design of appropriate land-use systems and soil management practices as well as for a better understanding of the environment. This is the main objective of soil science.

TYPES

Sand, silt, and clay are the basic particles in a soil. Most soils are made up of a combination of the three. The texture of the soil, how it looks and feels, depends upon the amount of each particle in that particular soil. The type of soil varies from place to place on our planet and can even vary from one place to another in your own backyard.

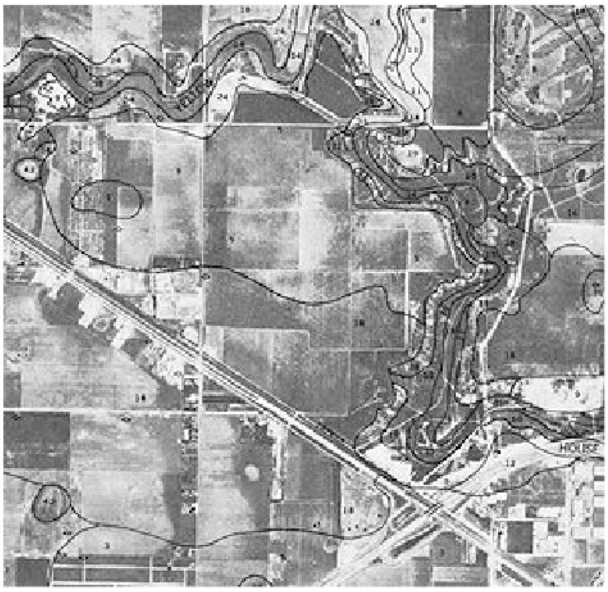
CONSERVATION

Soil erosion, caused by wind and rain, can change land by wearing down mountains, creating valleys, making rivers appear and disappear. It is a slow and gradual process that takes thousands, even millions of years. But erosion may be speeded up greatly by human activities such as farming and mining. Soil develops very slowly over a long period of time but can be lost very quickly. The clearing of land for farming, residential, and commercial use can quickly destroy soil. It speeds up the process of erosion by leaving soil exposed and also prevents development of new soil by removing the plants and animals that help build humus.

Today's farmers try to farm in a way that reduces the amount of erosion and soil loss. They may plant cover crops or use a no-till method of farming. Soil is an important resource that we all must protect. Without soil there is no life.

3.2 Soil Survey

Soil survey, or soil mapping, is the process of classifying soil types and other soil properties in a given area and geo-encoding such information. It applies the principles of soil science, and draws heavily from geomorphology, theories of soil formation, physical geography, and analysis of vegetation and land use patterns. Primary data for the soil survey are acquired by field sampling, supported by remote sensing, (principally aerial photography).



Sample of an aerial photo from a published soil survey

The term *soil survey* may also be used as a noun to describe the published results. In the United States, these surveys have been published in book form for individual counties by the National Cooperative Soil Survey. The information is used by farmers and ranchers to help determine whether a particular soil type is suited for crops or livestock and what type of management might be required. An architect or engineer might use the engineering properties of a soil to determine whether or not it was suitable for a certain type of construction.

Soil survey components

Typical information in a published soil survey report includes the following:

- a brief overview of the county's geography
- a general soil map with a brief description of each of the major soil types found in the area along with their characteristics
- detailed aerial photographs with specific soil types outlined and indexed

- photographs of some of the typical soils found in the area
- tables containing general information about the various soils such as total area, comparisons of production of typical crops and common range plants. They also include extensive interpretations for land use planning such as limitations for dwellings with and without basements, shallow excavations, small commercial buildings, septic tank adsorptions, suitability for development, construction, and water management.
- tables containing specific physical, chemical, and engineering properties such as soil depth, soil texture, particle size and distribution, plasticity, permeability, available water capacity, shrink-swell potential, corrosion properties, and erodibility.

A soil survey report should carry or contain information that is specific to a given form up land use. This is usually determined by the Terms of reference (TOR) after survey.

4.0 CONCLUSION

Soil surveys provide a field-based scientific inventory of soil resources that includes soil maps, information on the physical and chemical properties of soils, and information on the potentials and limitations of soil for various uses.

5.0 SUMMARY

Soil survey, or soil mapping, is the process of classifying soil types and other soil properties in a given area and geo-encoding such information. It applies the principles of soil science, and draws heavily from geomorphology, theories of soil formation, physical geography, and analysis of vegetation and land use patterns.

6.0 TUTOR-MARKED ASSIGNMENT

i. What is Soil Profile?
ii. Discuss the importance of a knowledge of the soil profile to a farmer who wants to undertake large-scale crop production.
iii. What are the soil survey components?

7.0 REFERENCES/FURTHER READING

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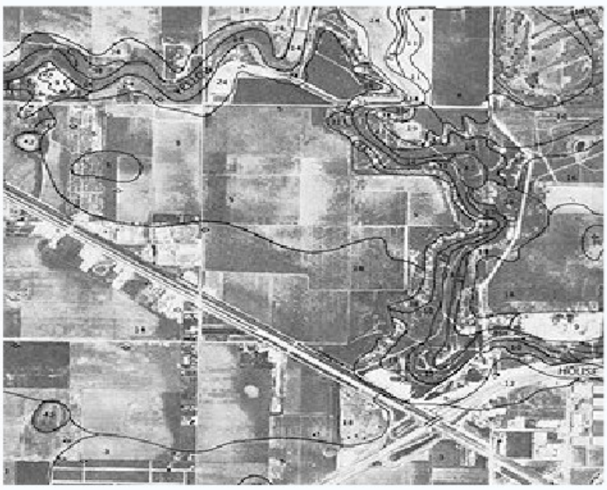
UNIT 4 SOIL MAPPING

CONTENTS

1.0 INTRODUCTION

A map unit is a collection of areas defined and named the same in terms of their soil components or miscellaneous areas or both. Each map unit differs in some respect from all others in a survey area and is uniquely identified on a soil map. Each individual area on the map is a delineation.

Soil survey, or soil mapping, is the process of classifying soil types and other soil properties in a given area and geo-encoding such information. It applies the principles of soil science, and draws heavily from geomorphology, theories of soil formation, physical geography, and analysis of vegetation and land use patterns. Primary data for the soil survey are acquired by field sampling, supported by remote sensing, (principally aerial photography).



Sample of an aerial photo from a published soil survey

2.0 OBJECTIVES

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

- analyse the procedure of soil survey/soil mapping.

3.0 MAIN CONTENT

3.1 Soil Mapping

The term *soil survey* may also be used as a noun to describe the published results. The information is used by farmers and ranchers to help determine whether a particular soil type is suited for crops or livestock and what type of management might be required. An architect or engineer might use the engineering properties of a soil to determine whether or not it was suitable for a certain type of construction.

Soil survey components
Typical information in a published soil survey includes the following:

- a brief overview of the areas geography
- a general soil map with a brief description of each of the major soil types found in the area along with their characteristics
- detailed aerial photographs with specific soil types outlined and indexed
- photographs of some of the typical soils found in the area
- tables containing general information about the various soils such as total area, comparisons of production of typical crops and common range plants. They also include extensive interpretations for Land use planning such as limitations for dwellings with and without basements, shallow excavations, small commercial buildings, septic tank adsorptions, suitability for development, construction, and water management.

It should be noted that a particular soil survey report would carry information relative to the use of the soil as contained in the Teams of reference (TOR). This means that a report intended for agricultural use would be use on agronomic soil data as compared to the report meant for engineering purposes which could develop more on engineering properties as outlined above.

Tables containing specific physical, chemical, and engineering properties such as soil depth, soil texture, particle size and distribution, plasticity, permeability, available water capacity, shrink-swell potential, corrosion properties, and erodibility.

4.0 CONCLUSION

Soil mapping is one of the pillars to the challenge of sustainable development"

There is a need for accurate, up-to-date and spatially referenced soil information. This need has been expressed by the modelling community, land users, and policy and decision makers. This need coincides with a enormous leap in technologies that allow for accurately collecting and predicting soil properties.

5.0 SUMMARY

Soil survey, or soil mapping, is the process of classifying soil types and other soil properties in a given area and geo-encoding such information. It applies the principles of soil science, and draws heavily from geomorphology, theories of soil formation, physical geography, and analysis of vegetation and land use patterns. Primary data for the soil survey are acquired by field sampling, supported by remote sensing, (principally aerial photography).

6.0 TUTOR-MARKED ASSIGNMENT

i. What is soil mapping ?
ii. Discuss the importance of a knowledge of the soil mapping to agriculturist.
iii. State the steps involved in soil mapping.

7.0 REFERENCES/FURTHER READING

Buol, S.W.*et al*. (2003). *Soil Genesis and Classification*. 5th ed. Iowa State Press - Blackwell, Ames, IA.

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UNIT 5 SOIL CLASSIFICATION

CONTENTS

1.0 INTRODUCTION

Soil classification deals with the systematic categorisation of soils based on distinguishing characteristics as well as criteria that dictate choices in use.

2.0 OBJECTIVES

Appliction in the field is a challenge due to the complex nature of soil formation and the inherent capacity of the soil resource. Classification of soil is obvious to farmers and researchers to enable effective utilisation by the farmer, scientific communication, easy study for research among others. This unit is to provide you with simple soil classification at a glance.

3.0 MAIN CONTENT

3.1 Soil Classification

Soil classification is a dynamic subject, from the structure of the system itself, to the definitions of classes, and finally in the application in the field. It can be approached from both the pespective of pedogenesis and from soil morphology. Differing concepts of pedogenesis, and differences in the significance of morphological features to various land uses can affect the classification approach. Despite these differences, in a well-constructed system, classification criteria group similar concepts so that interpretations do not vary widely.

Soil is classified into categories in order to understand relationships between different soils and to determine the usefulness of a soil for a particular use. One of the first classification systems was developed by the Russian scientist Dokuchaev around 1880. It was modified a number of times by American and European researchers and developed into the system commonly used until the 1960s. It was based on the idea that soils have a particular morphology based on the materials and factors that form them. In the 1960s, a different classification system began to emerge, that focused on soil morphology instead of parent materials and soil forming factors. Since then, it has undergone further modifications.

- The first unit of classification is the order.
- All soils fit into one of ten orders.
- Each order is broken down into a suborder, which is broken down into great groups, then subgroups, and then families.

Orders

Orders are the highest category of soil classification. Order types end in the letters sol. In the US classification system, there are 10 orders:

- Entisol - recently formed soils that lack well-developed horizons. Commonly found on unconsolidated sediments like sand, some have an A horizon on top of bedrock.
- Vertisol - inverted soils. They tend to swell when wet and shrink upon drying, often forming deep cracks that surface layers can fall into.
- Inceptisol - young soils. They have subsurface horizon formation but show little eluviation and illuviation.
- Aridisol - dry soils forming under desert conditions. They include nearly 20% of soils on Earth. Soil formation is slow, and accumulated organic matter is scarce. They may have a subsurface zone (calcic horizons) where calcium carbonates have accumulated from percolating water. Many aridiso soils have well-developed Bt horizons showing clay movement from past periods of more moisture.
- Mollisol - soft soils.
- Spodosol - soils produced by podsolisation. They are typical soils of coniferous and deciduous forests in cooler climates.
- Alfisol - soils with aluminum and iron. They have horizons of were clay accumulates, and form where there is enough moisture and warmth for at least three months of plant growth.
- Ultisol - soils that are heavily leached.
- Oxisol - soil with heavy oxide content.
- Histosol - organic soils.

Other order schemes may include:

- Andisols - volcanic soils, which tend to be high in glass content.
- Gelisols - permafrost soils.

For soil resources, experience has shown that a natural system approach to classification, i.e. grouping soils by their intrinsic property (soil morphology), behaviour, or genesis, results in classes that can be interpreted for many diverse uses. Differing concepts of pedogenesis and differences in the significance of morphological features to various land uses can affect the classification approach. Despite these differences, in a well-constructed system, classification criteria group similar concepts so that interpretations do not vary widely. This is in contrast to a technical system approach to soil classification, where soils are grouped according to their fitness for a specific use and their edaphic characteristics

4.0 CONCLUSION

Soil classification means that one finds categories of soils that are based on general characteristics as well as criteria that decide about the use that is possible.

5.0 SUMMARY

Soil classification can be approached from both the perspective of pedogenesis and from soil morphology. But in both cases interpretations do not vary widely. Soil (sometimes called dirt) is the combination of rock, mineral fragments (pieces) made by weathering (wind, rain, sun, snow, etc.), and organic matter (living things), water, and air. Soils are important to our ecosystem for six main reasons: first, soils are a place for plants to grow; second, soils control the speed and the purity of water that moves through them; third, soils recycle nutrients from dead animals and plants; fourth, soils change the air that surrounds the earth, called the atmosphere; fifth, soils are a place to live for animals, insects and very small living things called microorganisms; sixth, soils are the oldest and the most used building materials.

6.0 TUTOR-MARKED ASSIGNMENT

i. Why do we have to classify soils?
ii. Discuss the system of soil classification.
iii. Describe the various orders in soil classification.

7.0 REFERENCES/FURTHER READING

Birkeland, Peter W.(1999). *Soils& Geomorphology.* 3rd ed. New York: Oxford University Press.

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MODULE 3 PROPERTIES AND MANAGEMENT OF NIGERIAN SOILS

UNIT 1 NIGERIAN SOILS

CONTENTS

1.0 INTRODUCTION

Nigeria is situated entirely within the tropical zone and is located between latitudes 4° and 14° North of the Equator and longitudes 3° and 15° East. It is bounded on the west by the Republic of Benin, to the north by the Republic of Niger, to the east by the Republic of Cameroon and to the south is bathed by the Atlantic Ocean.

2.0 OBJECTIVES

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

- list the types of Nigerian soils
- state the nature of Nigerian soils.

3.0 MAIN CONTENT

3.1 Nigerian Soils

It has a total land mass of about 924,000km^2 and a population of 88.5 million (Anon., 1992). Physiographically the country consists of several extensive plateaux. The major plateaux surfaces are the Jos Plateau, Udi Plateau and the north central high plains. The coastal areas are usually covered by soft rocks which are prominent along the Niger Delta, Niger-Benue trough and Lake Chad Basin. The high plateau is underlain by basement complex and volcanic rocks. Examples of the volcanic hills are the remains of extinct volcanoes as seen in Jos, Biu plateaux and the Eastern borderlands. The craters created by these volcanoes are well preserved and several of them contain crater lakes. The Mount Cameroon volcano is still active on the eastern border of Nigeria; activity during which several lives were lost was recorded in 1989. The lowland areas are composed of sedimentary rock and cover the Sokoto plains, Chad Basin, Niger-Benue trough, western areas of Nigeria, south-eastern Nigeria and coastal margins and swamps. The major rivers of Nigeria are found in these lowland areas.

Nigeria has two major rivers, the Niger, after which the country is named, and the Benue. They meet at the Lokoja confluence and enter the Gulf of Guinea through a network of creeks and distributaries which form the Niger Delta. There are, however, a few other tributary rivers which drain into the Niger-Benue trough and Lake Chad. These include the Sokoto-Rima, Kaduna, Anambra, Gongola, Hadejia, Jama'are and Yobe rivers. The basins of these major rivers and their tributaries constitute the drainage pattern of the entire country. Other major rivers e.g. Cross, Imo, Ogun, Osun, Benin, Qua Iboe etc. empty directly into the Atlantic Ocean. The majority of small rivers are seasonal.

3.2 Climate

The climate, determining the different ecological zones, is influenced by two wind systems, the south-westerly that brings rain and the northwesterly from the Sahara Desert that brings the dry and dusty harmattan wind. According to Garnier (1967) and Iloeje (1980), Nigeria, and indeed all the West African countries which experience similar weather conditions, can be said to have four main climatic zones.

a. The Equatorial Climate which extends from the coast to about 150km inland. Rainfall is between 1500 and 3000mm per annum, with an average temperature range of 17-24°C and relative humidity ranges between 60-90%. It has two seasons, the wet season March to October, and dry season November to March. Both Port-Harcourt and Lagos are in this zone.

b. Tropical Hinterland, about 150-240km northwards from the coast, with 1000 to 1500mm rainfall, temperature range of 21-25°C and relative humidity range of 50-80%. It has a longer dry season, of 4-5 months, compared with the equatorial zone which lasts from October to April. Examples are Ibadan and Enugu.

c. Tropical Continental which falls into the Sudano-Sahelian vegetation zone with rainfall of 250-1000mm, temperature of 25-30°C (but with lower night temperatures especially during the harmattan) and low relative humidity of 20-40%. The characteristic dry hot, harmattan wind may last from October to May. Examples are Sokoto, Kano, Maiduguri and Yola.

d. Montane or Plateau type climate is limited to the highland areas, with a high annual rainfall of 1400-4000mm, relatively low temperatures of 5-20°C and high humidity of 30-90%. Example is Jos.

In general, rainfall, temperature and humidity have the following trends. The temperature is usually high, with an average of about 25°C and increases as one moves northwards although variations are influenced by season and latitude, while the rainfall and humidity increase towards the coastal areas.

Recent years have seen a general trend of increasing drought conditions compared with the weather conditions of the 1930s to late 1940s (Oguntoyinbo, 1983). There was a notable drought period between 1968-1973 and this led to an upsurge of water conservation strategies. These included the construction of several dams, boreholes, irrigation projects and the formation of small water bodies both for domestic use and for migrating animals (Illiasu & Alsop, 1987; Satia, 1990) plus the creation of several River Basin Authorities. Another change is in the harmattan which has now extended its frontiers into the tropical hinterland, and sometimes as far as the equatorial climatic areas. This is readily observed by obvious harmattan hazes and dry dusty winds.

The severity of the harmattan has been attributed to the encroaching desert due to deforestation as a result of human activities, bush burning, human settlement and development, logging and felling for firewood. There is also usually a drop in humidity causing dryness, coldness, and a dusty and hazy atmosphere. The unpleasant experiences which result from a severe harmattan include thick deposits of dust on buildings and furniture and increased incidence of conjunctivitis and cracking of human lips due to dryness.

3.3 Vegetation, Land Use and Population

Climate (particularly rainfall) has an important influence on the distribution of vegetation in Nigeria. There are ten main vegetation zones (Udo, 1970): the Sahel, Sudan and Northern Guinea zones. Jos Plateau, Montane forest and grassland, Rain forest, Oil palm bush, Southern Guinea zone, Swamp and Mangrove forest.

These major zones have different vegetation types which can be further subdivided into coastal forest and mangrove, deltaic swamp forest, swamp forest and wooded savanna, secondary forest, mixed leguminous wooded savanna. *Isoberlinia* savanna, *Afzelia* savanna and semideciduous forest, plateau grass savanna, mixed Combretaceous woodland, wooded savanna, mixed wooded savanna, floodplain complex, *Sorghum* grass savanna, *Burkeo africana* savanna, wooded tropical steppe and moist lowland forest.

An estimated 68 million hectares of land is utilised for farming with an average of two hectares per farming family. Because of the differing vegetation and climatic conditions and socio-cultural base, each ecological zone has some degree of specialisation in farming system, type of crops and animals reared.

The crop farming system is mainly the traditional rain fed agriculture, contributing about 95% of the farming activity, while mechanised and irrigated agriculture uses only 5% of the cultivated land. There are six main farming patterns: shifting cultivation, sedentary and permanent cultivation, terrace agriculture, irrigated agriculture and mixed farming. In animal husbandry, there are four main systems, free range, sedentary, migratory and intensive animal husbandry.

In the forest zone more tubers, such as cassava, yam, cocoyam and forest related crops such as cocoa, palm tree, coconut, banana, pineapple, orange and mango, are grown while in the savanna and arid zones of the Sahel, Sudan and Guinea vegetation more cereals such as sorghum, maize, rice, beans, soyabean, guineacorn and vegetables (including pepper, carrots, garden eggs, potatoes and some other vegetables) are grown. A higher population of livestock is raised in the savanna region because of the limiting effects of livestock diseases and the high humidity of the southern vegetation zones. Dwarf goats, sheep and Ndama cattle are more abundant under sedentary conditions in the southern vegetation zones.

The recent population figures from the National Population Commission indicate that Nigeria is a highly populated nation and as might be expected, the use of resources depends on the population and socioeconomic structure. Areas with a high population have greater pressures on the utilisation of both terrestrial and aquatic resources. The available resource commodities that are utilised would in turn influence the economic activities of such communities.

3.4 Soil and Soil Erosion

The abundance of water in a given area under natural conditions is partly a function of soil, types of geological formation, vegetation and other environmental factors. This is because the ability of any soil to retain moisture and its water-holding capacity determine the extent and formation of pools of available surface water.

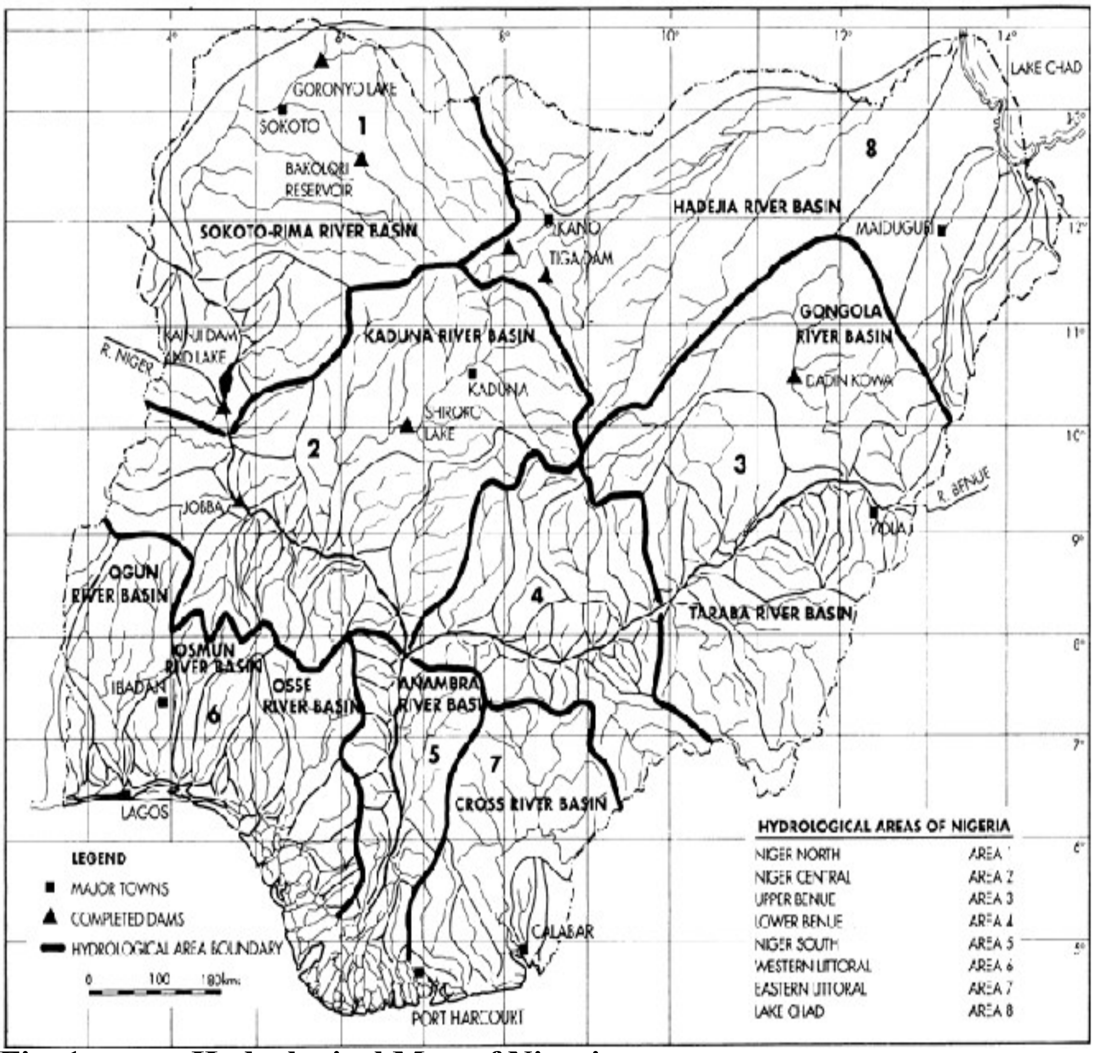

Fig. 1: Hydrological Map of Nigeria

Nigeria's fragile soils are susceptible to erosion, the various causes of which are both natural, and man-made due to abuse of the environment.

However, the natural phenomena are over-shadowed by the effects of human activities. While some of the causes of erosion are limited most have very wide distribution. Depending on the type, soil erosion is of concern because it can devastate human settlements, agricultural grounds and recreational development, can disrupt and destroy industrial structures and facilities and severely upset the hydrological regime. The deformation of hydrological regimes usually leads to increased rates of siltation. Hydrological disruption may also affect the pattern of water discharges, hence affecting the normal pattern of aquatic life

3.5 The Soils of Nigeria

The purpose of this section is to show the sketch map of the major soils in Nigeria with an illustration of how the distribution of soils follows the rainfall and vegetation patterns.

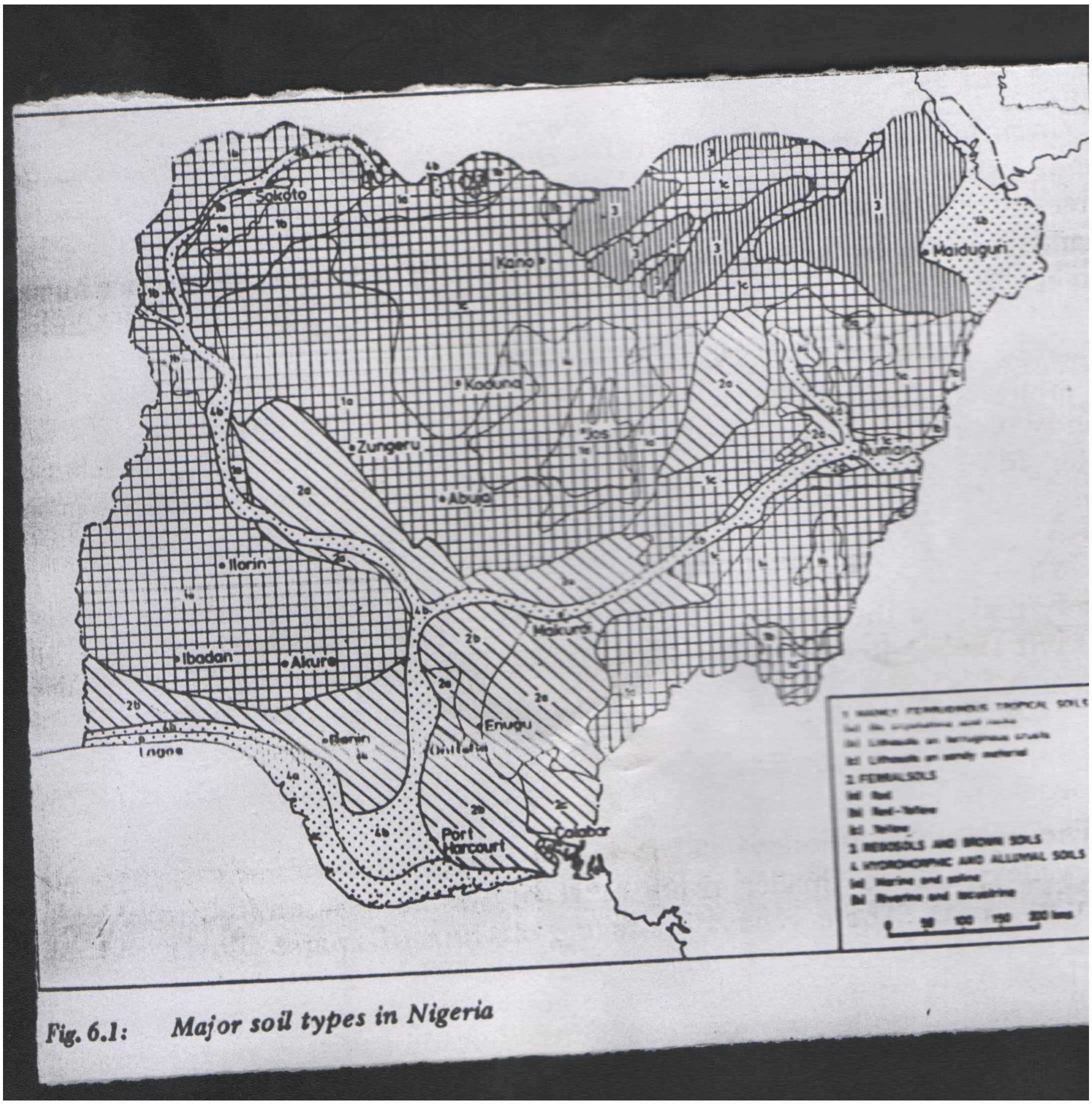

Fig. 6.1: Major soil types in Nigeria

Based on the FAO generic classification system, the four major groups of soils in Nigeria are shown in fig. 6.1 above. They are:

- The hydromorphic and organic soils developed on alluvial, marine and fluvio-marine deposits of variable texture, notably along the coast and river flood plains
- The regosols and brown soils developed on drift and continental sedimentary deposits in the north-eastern parts of the country,
- The ferrasols, some (the ochrosols) with iron concretions and some (the oxysols) without, developed essentially on sedimentary rocks and
- The highly ferruginous tropical red and brown soils of the Basement omplex rocks areas.

Climate Map of Nigeria

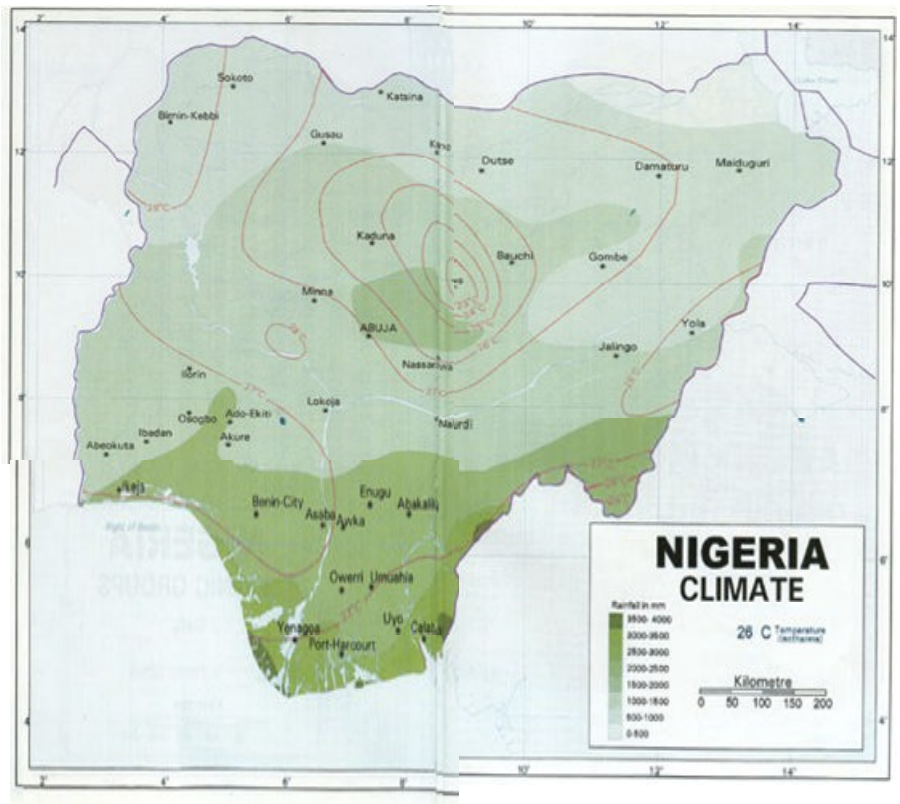

Fig.6.2: Climate Map of Nigeria

In Nigeria, the distribution of soils follows the rainfall and vegetation patterns as shown in Figure 6.2 above. Nigeria has two broad belts of vegetation types, namely, the forest and savannah types. There is, however, also the mountain vegetation of the isolated high plateau regions in the central and far eastern parts of the country.

4.0 CONCLUSION

Nigeria's soil is rated from low to medium in productivity. However, the Food and Agriculture Organisation of the United Nations (FAO) concluded that most of the country's soil would have medium to good productivity if this resource were managed properly.

5.0 SUMMARY

6.0 TUTOR-MARKED ASSIGNMENT

i. What is a Soil, briefly describe the nature of Nigerian soil
ii. State the importance of Nigerian soil to agriculture
iii. What is soil erosion? Describe the factors contributing to soil erosion in Nigeria

7.0 REFERENCES/FURTHER READING

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UNIT 2 PROPERTIES OF NIGERIAN SOILS

CONTENTS

1.0 INTRODUCTION

Nigerian soils are a mixture of different things; rocks, minerals, and dead, decaying plants and animals. Soil can be very different from one location to another, but generally consists of organic and inorganic materials, water and air. Together with physiography, it constitutes the most observable element of the landscape. Soil characteristics express and reflect environmental conditions, particularly climate. A fertile soil must supply adequate nutrients, be of good physical condition and hold enough water so that the nutrients in the soil will be available for plant uptake.

2.0 OBJECTIVES

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

- identify physical and chemical properties of the Nigerian soil
- mention the components of Nigerian soil.

3.0 MAIN CONTENT

3.1 Properties of Nigerian Soils

Broadly speaking, the natural vegetation over a geographical area is essentially a response to the climate in that area. Nigeria's vegetation belts reflect this very close link between vegetation and climate. Hence, the similarity in the west-to-east zonation of both climate and vegetation. With the south to north progressive decline in total rainfall and length of wet season, vegetation belts are demarcated on west-to-east zonation pattern characterised by transitional zones from one belt to another are influenced by soil type.

Nigeria has two broad belts of vegetation types, namely, the forest and savannah types. There is, however, also the mountain vegetation of the isolated high plateau regions in the central and far eastern parts of the country. Generally speaking, the properties of Nigerian soil deteriorate while the chemical properties follow a reverse pattern.

3.2 Soil is

- A layer of natural materials on the earth's surface containing both organic and inorganic materials and capable of supporting plant life.
- The material covers the earth's surface in a thin layer.
- It may be covered by water, or it may be exposed to the atmosphere.
- Soil contains four main components: inorganic material, organic matter, water, and air.
- Ideal soil should contain about 50% solid material and 50% pore space.
- About half of the pore space should contain water and half of the space should contain air.
- Inorganic material consists of rock slowly broken down into small particles.
- The organic material is made up of dead plants and animals in varying stages of decay.
- The percentages of the four main soil components vary depending on the kind of vegetation, amount of mechanical compaction, and the amount of soil water present.

4.0 CONCLUSION

A fertile soil must supply adequate nutrients, be of good physical condition and hold enough water so that the nutrients in the soil will be available for plant uptake.

5.0 SUMMARY

The chief factors contributing to soil fertility are:

- Adequate supply of soil nutrients
- Organic matter content
- Soil reaction or pH
- Absence of injurious substances
- The physical characteristics of texture, structure, consistency, depth and
- Nature of the soil profile.

6.0 TUTOR-MARKED ASSIGNMENT

i. Describe the properties of Nigerian soil.
ii. State the types of Nigerian soil.
iii. What is soil erosion? Describe the factors contributing to soil erosion in Nigeria.

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UNIT 3 PROFILE DESCRIPTION OF NIGERIAN SOILS

CONTENTS

1.0 INTRODUCTION

Soils are structural and functional elements of terrestrial ecosystems, which are formed in a historical process of development through the interaction of geological, climatic and biotic factors at the respective site. Soil is the fundamental source of life for all living beings. As the physical and chemical properties of soils exert great influence in the distribution and development of vegetation, it needs to be studied and evaluated from time to time. The soil forming process is very slow and time taking. It takes normally thousands of years for the soil formation. Therefore, we are studying the past activities while analysing the soil profile at present. The parent material, topography, geological processes, climatic conditions, vegetation and human interferences play major roles in formation and development of soil profiles in particular area. Similarly, our activities at present will certainly influence the soil profiles in far future.

2.0 OBJECTIVES

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

- describe the methods and techniques of identification
- analyse and evaluate Nigerian soils.

3.0 MAIN CONTENT

3.1 Profile Description of Nigerian Soils

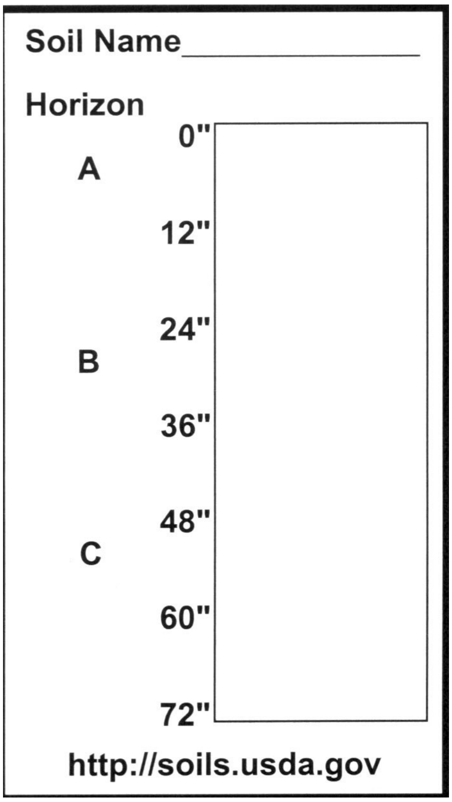
Nigeria can be divided into the 7 major ecological regions (Fig. 1):

(1) The Coastal Swamp Region which includes the coastal forest and mangroves as well as the deltaic swamp forest
(2) The Moist Lowland Region

(3) The Southern Guinea Savanna Region
(4) The Montane Region
(5) The Northern Guinea Savanna Region
(6) The Sudan Savanna Region
(7) The Sahel Savanna Region

The location and extent of most of the regions coincide with the vegetation zones of the country as described by Keay (1953), Areola (1978) and Areola *et al.* (1982). The 12 reference soils (NG 15 to NG 29) are located in the southern part of the country in the Coastal Swamp (Region 1), the Moist Lowland (Region 2), and the

The *Coastal Swamp Region* includes creeks, lagoons, the Niger delta and the coastal plain. The mean altitude of the creeks and lagoons area is about 40 m a.s.l. while along the coastal plain the elevation is about 160 m a.s.l. Total annual precipitation ranges from 429 mm at Bonny in the east to 1755 mm at Lagos in the west. The rainy season lasts for about 10 months. The soils are mainly hydromorphic and derived from marine and lacustrine parent materials. The vegetation consists of coastal forest, mangroves and deltaic swamp forest. The mangrove forest is dominated by varieties of red mangrove *(Rhizophera racemosa),* the swamp forest consist solely of slender trees. Reference Soils NG 19 and NG 20 are found in this region and described in Soil Brief Nigeria. The Moist Lowland Region is underlain by rocks of the System. The landscape is undulating and marked by numerous domed or sugar-loaf hills and by occasional flat-topped ridges. The summits of the hills range between 300 and 600 m a.s.l. Temperature is high throughout the year with an annual average between 28°C and 32°C. The rainy season lasts for 8 months and total annual rainfall is higher than 1100 mm. The region is covered with lowland forest consisting of evergreen hydrophytic plants with a large diversity. The forest is characteristically stratified. At the forest margins or in areas disturbed by man, woody lianas form an almost impenetrable tangle. The original or high forest is no longer as extensive as it used to be and is now restricted to a few forest reserves in Ondo, Benin and in the Cross River Basin along the border with Cameroon.



4.0 CONCLUSION

Soil profiles look different in different areas of the world. They are affected by climate, vegetation and other factors.

5.0 SUMMARY

Soil Profile refers to the layers of soil; horizon A, B, and C. Horizon A refers to the upper layer of soil, nearest the surface. It is commonly known as topsoil. In the woods or other areas that have not been plowed or tilled, this layer would probably include organic litter, such as fallen leaves and twigs. The litter helps prevent erosion, holds moisture, and decays to form a very rich soil known as humus. Horizon A provides plants with nutrients they need for a great life.

The layer below horizon A, of course, has to be horizon B. Litter is not present in horizon B and therefore there is much less humus. Horizon B does contain some elements from horizon A because of the process of leaching. Leaching resembles what happens in a coffee pot as the water drips through the coffee grounds. Leaching may also bring some minerals from horizon B down to horizon C. If horizon B is below horizon A, then horizon C must be below horizon B. Horizon C consists mostly of weatherised big rocks. This solid rock, as you discovered in Soil Formation, gave rise to the horizons above it.

6.0 TUTOR-MARKED ASSIGNMENT

i. What is soil profile?
ii. Discuss the various levels of soil profile you studied.
iii. Explain the effects of climate on soil profile.

7.0 REFERENCES/FURTHER READING

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UNIT 4 CLASSIFICATION OF NIGERIAN SOILS

CONTENTS

1.0 INTRODUCTION

Soil classification deals with the systematic categorisation of soils based on distinguishing characteristics as well as criteria that dictate choices in use. Soil classification is a dynamic subject, from the structure of the system itself, to the definitions of classes, and finally in the application in the field. Soil classification can be approached from the perspective of soil as a material and soil as a resource. Development of sustainable agricultural systems such as alley farming is an attempt to reduce degradation of natural resources and to find environmentally compatible ways of increasing production and promoting broad-scale development.

Intensification of agriculture on land currently used for traditional farming requires a thorough knowledge of the soil as a resource and attributes of the land. Information on distribution, potential and constraints of major soils is needed, so that the most appropriate soil management systems can be designed. In addition knowledge on land capability and suitability is also essential to determine the best land use for sustained crop production. This unit reviews current systems used to classify Nigerian soils and land capabilities.

2.0 OBJECTIVES

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

- describe the advantages of soil classification and list classification systems in Nigeria
- discuss the hierarchy of categories in the Soil Taxonomy classification
- explain the topographical regions of Nigeria
- classification of Nigerian soil both as a material and soil as a resource.

3.0 MAIN CONTENT

3.1 Classification of Nigerian Soil

Soil is the thin layer covering the entire earth's surface, except for open water surfaces and rock outcrops. The properties of soil are determined by environmental factors. Five dominant factors are often considered in the development of the various soils: (a) the climate, (b) parent materials (rocks and physical and chemical derivatives of same), (c) relief, (d) organisms (fauna and flora), and (e) the time factor. There are a large number of different soils, reflecting different kinds and degrees of soilforming factors and their combinations.

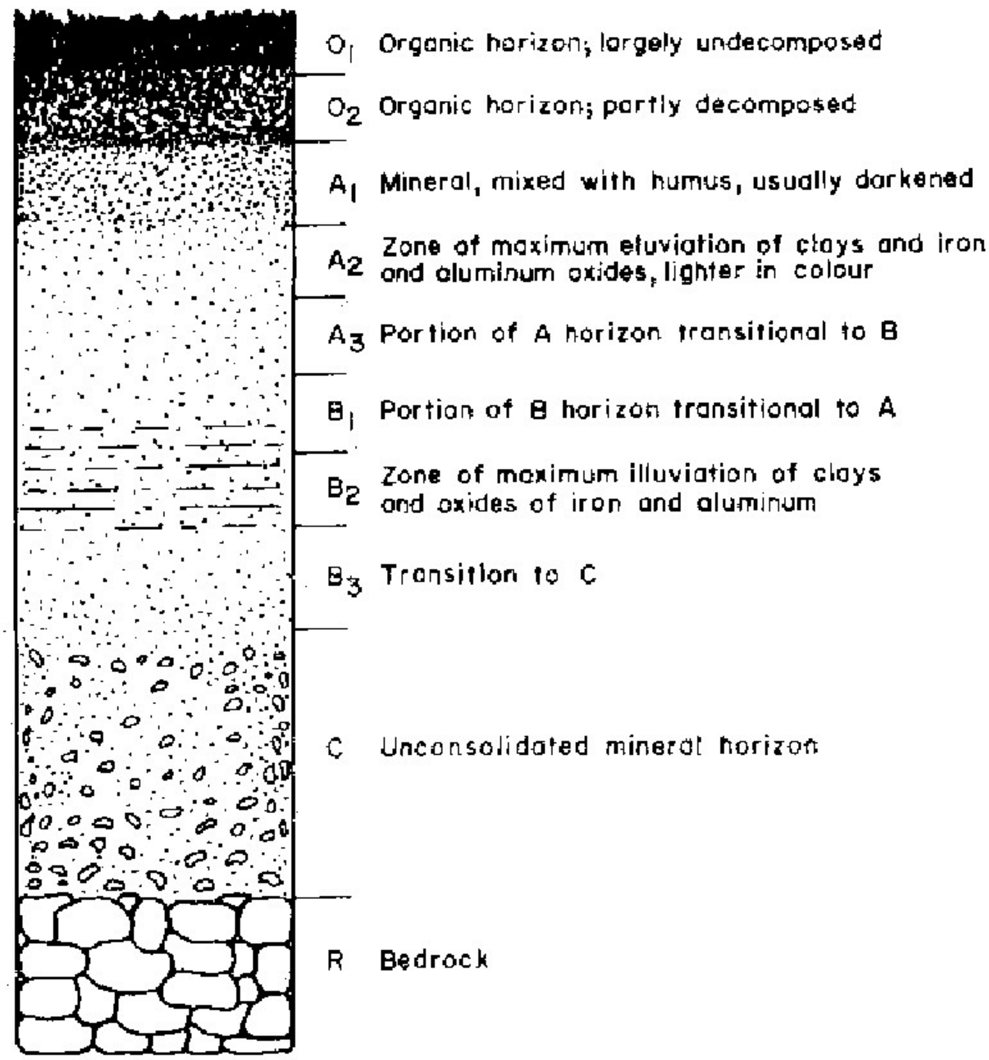

Fig. 1: A Hypothetical Soil Profile

Scientists have developed different systems of soil classification to group soils of similar properties in one class, allowing them to exchange information on soils found in different areas. Soil classification also helps in determining the best possible use and management of soils. Soil classification is however a controversial subject at both national and international levels. There is lack of agreement for a common classification system, because soil scientists do not agree on the characteristics for differentiating and classifying soils.

Although many soil classification systems exist; however, two systems are widely used: The USDA Soil Taxonomy and the FAO/UNESCO legend. The classification of soils starts with examination of soil profiles. Morphologically, soils are composed of a series of horizons. Soil horizons are layers of different appearance, thickness, and properties which have arisen by the action of various soil-forming processes. The horizons are normally parallel to the surface. Collectively, the horizons make up what is called the soil profile or soil "pedon". A soil profile is defined as a vertical section of the soil to expose layering. Figure 1 sketches a hypothetical soil profile having all the principal horizons, with a brief description of the characteristics of each horizon. Individual soils have one or more of these horizons. Very young soils may not yet have started the soil horizonisation process.

3.2 Hierarchy of Categories in the Soil Taxonomy

There are six levels in the hierarchy of categories: Orders (the highest category), suborders, great groups, subgroups, families and series (the lowest category) (USDA, 1978).

Orders
There are ten orders, differentiated on gross morphological features by the presence or absence of diagnostic horizons or features which show the dominant set of soil-forming processes that have taken place. The ten orders and their major characteristics are shown in Table 1. The occurrence of the major soils in the humid and subhumid tropics.

Suborders
It is the next level of generalisation. It permits more statements to be made about a given soil. In addition to morphological characteristics other soil properties are used to classify the soil. The suborder focusses on genetic homogeneity like wetness or other climatic factors. There are 47 suborders within the 10 orders. The names of the suborders consist of two syllables. The first connotes the diagnostics properties; the second is the formative element from the soil order name. For example, an Ustalf is an alfisol with an ustic moisture regime (associated with subhumid climates).

Great groups

The great group permits more specific statements about a given soil as it notes the arrangement of the soil horizons. A total of 230 great groups (140 of which occur in the tropics) have been defined for the 47 suborders. The name of a great group consists of the name of the suborder and a prefix suggesting diagnostic properties. For example, a Plinthustalf is an ustalf that has developed plinthite in the profile. Plinthite development is selected as the important property and so forms the prefix for the great group name.

Table 1: Brief Descriptions of the Ten Soil Orders according to Soil Taxonomy

SOIL ORDERS	DESCRIPTION
ALFISOLS	- Soils with a clayey B horizon and exchangeable cation (Ca + Mg + K + Na) saturation greater than 50% calculated from NH_4OAc-CEC at $p^H 7$.
ULTISOLS	- Soils with a clayey B horizon and base saturation less than 50%. They are acidic, leached soils from humid areas of the tropics and subtropics.
OXISOLS	- Oxisols are strongly weathered soils but have very little variation in texture with depth. Some strongly weathered, red, deep, porous oxisols contain large amounts of clay-sized Fe and Al oxides.
VERTISOLS	- Dark clay soils containing large amounts of swelling clay minerals (smectite). The soils crack widely during the dry season and become very sticky in the wet season.
MOLLISOLS	- Prairie soils formed from colluvial materials with dark surface horizon and base saturation greater than 50%, dominating in exchangeable Ca.
INCEPTISOLS	- Young soils with limited profile development. They are mostly formed from colluvial and alluvial materials. Soils derived from volcanic ash are considered a special group of Inceptisols, presently classified under the Andept suborder (also known as Andosols).
ENTISOLS	- Soils with little or no horizon development in the profile. They are mostly derived from alluvial materials.
ARIDISOLS	- Soils of arid region, such as desert soils. Some are saline.
SPODOSOLS	- Soils with a bleached surface layer (A2 horizon) and an alluvial accumulation of sesquioxides and organic matter in the B horizon. These soils are mostly formed under humid conditions and coniferous forest in the temperate region.
HISTOSOLS	- Soils rich in organic matter such as peat and muck.

4.0 CONCLUSION

Soil classification deals with the systematic categorisation of soils based on distinguishing characteristics as well as criteria that dictate choices in use. Topography, geological processes, climatic conditions, vegetation and human interferences play major roles in determination of soil types.

5.0 SUMMARY

In soil classification, the item to be classified is the soil profile. The classification or study of the entire profile consists of recognising and naming the horizons which make up the profile. In the study of soil profiles, sub-soil horizons are given greater emphasis than surface horizons which are frequently changed by human activity to such an extent that they bear hardly any relationship with genetic process.

6.0 TUTOR-MARKED ASSIGNMENT

i. Briefly Describe the system of soil classification
ii. State the major orders in soil classification
iii. Explain the importance of soil classification.

7.0 REFERENCES/FURTHER READING

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UNIT 5 MANAGEMENT OF NIGERIAN SOILS

CONTENTS

1.0 INTRODUCTION

A fertile soil must supply adequate nutrients, be of good physical condition and hold enough water so that the nutrients in the soil will be available for plant uptake in this unit we shall discuss the various ways of soil management in Nigeria.

2.0 OBJECTIVES

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

- analyse soil management methods in Nigeria

3.0 MAIN CONTENT

3.1 Management of Nigerian Soils

Maintenance of Soil Fertility
In maintaining soil fertility, the farmer is mainly concerned with keeping the soil at a satisfactory physical condition and maintaining the nutrient supply at a desired level. A fertile soil must be in a physical condition that is favourable for root growth. Thus, cultivation to break down the soil aggregates must be done. This important practice will accelerate the decomposition of organic matter which when present, aids in promoting the porosity and granulation of the soil. Maintaining good soil structure and providing good vegetative cover or mulching, together with minimal, timely and systematic cultivation also help to maintain soil fertility.

However, under annual cropping, it is not practicable to keep the soil covered throughout the whole year or to avoid some structure-destroying tillage. Nevertheless, the fertility of the soil must be maintained and this could be done effectively by crop rotation, cover cropping, green manuring, application of compost and farmyard manure as well as proper land use.

3.2 Crop Rotation in Soil Fertility Maintenance

A proper rotation programme of crops can be used effectively to maintain soil fertility. The alternation of legumes and non-legumes or the use of legumes in rotation helps to maintain soil fertility. This is because the residues of such crops as groundnuts and soya beans improve the nitrogen content of the soil through their ability to fix nitrogen in their roots. Moreover, with the incorporation of the plant residues left on the field into the soil, improves aeration, soil structure and water-holding capacity of the soil.

A good rotation can also benefit by minimising exposure of the soil to the risk of erosion. It reduces weed infestation of the land and checks the build-up of pests and diseases on the land.

3.3 Maintaining Fertility with Green Manures

Crop rotation is an intensive system of farming; as such the soil nutrients get depleted and exhausted at certain stages of the land use. So, green manure crops have to be planted to replenish the organic matter and nutrient content of the soil when ploughed into the soil. Growing annual legumes as green manure crops in rotation with other crops is likely to be of value where sufficient moisture is available. Moisture promotes vigorous growth of the crop and causes rapid decomposition during the period between ploughing the green manure crop with the soil, and planting of the next crop. This means that the green manure crop should be ploughed into the soil to decompose before the new crop is planted. This practice is therefore usually ineffective in drier areas because of moisture limitations. Thus, under fairly good rainfall conditions, it can be a useful aid in soil fertility maintenance. The beneficial effects of green manures are short-lived; consequently, they must be grown rather frequently in the rotation programme to maintain crop yields at reasonable levels.

The effects of green manuring in increasing the soil organic matter as well as the total and available nitrogen levels are very important and significant. These effects may even be more important than any increase in the availability of mineral nutrients that it may bring about. However, it is not practicable to maintain fertility alone with green manure crops since its effects are short-lived. Hence, other methods have to be employed too.

It is important to note that the green manure crop should:

(1) be able to grow rapidly
(2) have abundant and succulent tops since it will decay quicker,
(3) be able to grow even on poor soils, and
(4) not have the chance to persist and thus become a weed, competing with the crops.

3.4 Maintaining Soil Fertility with Farmyard Manure

Farmyard manure is unquestionably a most useful aid in maintaining soil fertility and should be used wherever it is economical and practical to do so. Farmyard manure or pen manure consists of a rotted mixture of the excreta of farm animals and the straw provided for their bedding, which should be sufficient to absorb the dung and the urine. Well rotted farmyard manure is usually best applied just before planting a crop. Applying it earlier in the dry season, especially if it is left partly exposed, may lead to some loss of nitrogen and possibly some soluble nutrients by leaching at the beginning of the rains.

Large yields of crops, especially root crops, are usually obtained. Also many experiments in various parts of the tropics have shown that the majority of annual crops respond well to the application of farmyard manure.

The value of farmyard manure is due to the nutrients it contains rather than from any special characteristics associated with its organic matter content.

3.5 Composting and the Maintenance of Soil Fertility

Compositing is a term used for the application of decomposed heaps of plant and animal remains to the soil. The decomposed mixture could include crop residues, household refuse, weeds and other waste vegetable material, either with or without additions of some animal or human excreta.

Compost preparation may be done in heaps or in pits depending on the climatic conditions. Heaps compost are better in wet climates and pit composts in dry areas. The compost is commonly made of alternate layers of vegetable matter or crop residues and manure. The manure or soil which is very high in organic matter supplies active decay organisms which start the decomposition process. The compost heap should be turned three times at intervals of 2-4 weeks to get all the material well rotted. The heap should, however, be kept moist to reduce the loss of ammonia and elemental nitrogen and also to encourage vigorous bacterial action. The soil pH should be suitable for the microbes to function efficiently.

The advantage of applying compost as opposed to burying raw crop residues and weeds is that it enables partially decomposed organic matter to be applied to the land at the proper time so that available plant nutrients are rapidly released for plant growth. Burying the undecomposed materials would mean taking nutrients away from soil (and the crop plants) until they are well rotted. Composting, therefore, is a worthwhile practice because of the nutrients it supplies to crops. Thus, it must be encouraged as a measure for maintaining soil fertility wherever it is practicable.

4.0 CONCLUSION

Soil management can be defined as the process of managing the use and development (in both urban and suburban settings) of land resources in a sustainable way. Land resources are used for a variety of purposes which interact and may compete with one another; therefore, it is desirable to plan and manage all uses in an integrated manner.

Soils are affected by human activities, such as industrial, municipal and agriculture, that often result in soil degradation and loss or reduction in soil functions. In order to prevent soil degradation and to rehabilitate the potential of degraded soils, reliable soil data are the most important prerequisite for the design of appropriate land-use systems and soil management practices as well as for a better understanding of the environment. This is the main objective of soil science.

5.0 SUMMARY

Soils are important to our ecosystem for six main reasons: first, soils are a place for plants to grow; second, soils control the speed and the purity of water that moves through them; third, soils recycle nutrients from dead animals and plants; fourth, soils change the air that surrounds the earth, called the atmosphere; fifth, soils are a place to live for animals, insects and very small living things called microorganisms; sixth, soils are the oldest and the most used building materials

6.0 TUTOR-MARKED ASSIGNMENT

i. What do you understand by the term soil fertility?
ii. How can the nutrient resources of a soil be depleted?

iii. Explain methods that can be used to conserve and improve the nutrient status of the soil.

7.0 REFERENCES/FURTHER READING

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