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NATIONAL OPEN UNIVERSITY OF NIGERIA

BIO 408 SOIL ECOLOGY (2 UNITS)

Module 1

Unit 1: Soil Formation

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Module 1

Unit 1: Soil formation

Contents

1.0 Introduction

Soil is a collection of individual soils, each with distinctive profile characteristics. Soils are crucial to life an earth because to a great degree, the quality of the soil determines the nature of plant ecosystems and the capacity of land to support animal life and society. In view of the above statements, a closer look will be taken to elucidate the mechanisms of soil formation processes.

2.0 Objectives

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

List factors determining soil formation

Explain processes of soil formation.

Explain weathering process.

3.0 Main Content

3.1 Factors determining soil formation

Based on observation and careful field and laboratory research, five major factors that control the formations of soils have been recognized. These factors are parent materials, climate, biota, topography and time. However, in certain situation one of the factors could have had dominant influence in determining difference among a set of soils, such a set of soils are referred to as a lithosequence, climosequence, biosequence, toposequence, or chronosequence as the case may be. That is to say the dominating influence is by the parent material (lithosequence), climate (climosequence), biota (biosequence), topography (toposequence) or time (chronosequence).

3.1.1 Parent Materials

The nature of the parent materials profoundly influences soil characteristics. For example, a soil might inherit a sandy texture that is a coarse–grained, quartz–rich parent materials such as granite or sandstone. Furthermore, the chemical and mineralogical composition of parent material also influence the characteristics of soil formed as shown in Table1.

Table 1 Soil-forming rocks and their composition

	Rock type	**Example**	**Composition**
Igneous	Quartz rich (acid magmas)	Ganite	Mica, alkali feldspar, discrete crystals.
	Quartz poor (basic)	Basalt	Fine crystal structure of plagioclase, feldspar and augite
Sedimentary	Coarse texture water deposited	Sandstone	Quartz grains cemented with Fe_2O_3 or loose.
	Fine texture water deposited	Mudstones, shales, clays	Predominantly finely particulate alumino-silicate with various cementation such

			as Fe_2O_3, $CaCO_3$.
Metamorphic	Metamorphosed sedimentary	Marble, Slate	Metamorphosed limestone, Metamorphosed shale.
	Metamorphosed igneous	Gneiss	Metamorphosed quartzites and ganitic rocks.

3.1.2 Climate

The most influential factor acting on parent material is perhaps climate. It determines the nature and intensity of the weathering that occurs over large geographic areas. Precipitation and temperature both affect the rate of chemical, physical and biological processes.

3.1.3 Biota

Activities of living organisms (Flora and Fauna) potentially enhance organic matter, nutrient cycling and aggregate stability. For example, leading of soil mineral and erosion of surface soil could be slowed down by natural vegetative cover. Moreover, animals play significant role in soil – formation processes, change animals like bush rates, moles and smaller ones like earthworms bone tunnels in soil, thereby enhancing movement of water and air into the subsurface layers.

3.1.4 Topography

The elevation, slope and landscape position may either hasten or retard the work climate forces for example; steep slopes generally encourage rapid soil loss by erosion and allow less rainfall to enter the soil before running off.

3.1.5 Time

Soil forming processes take time to show their effects because time interacts with the order factors of soil formation.

3.2 Weathering Processes

Weathering is a biochemical process that involves both destructs and synthesis. Without appreciably affecting soil composition, physical disintegration breaks down rock into smaller rocks and eventually into sand and silt particles. Also, the minerals decompose chemically, releasing soluble materials and synthesizing new minerals. During the chemical changes, particle size continues to decrease, and constituents continue to dissolve in the aqueous weathering solution.

3.2.1 Physical Weathering (Bio-integration)

Temperature, abrasion by water, ice and wind, and living organisms (flora & fauna) all act together brining, about physical weathering. For instance, rocks heat up during the day and cool down at might, causing alternate expansion and contraction of the rocks. Furthermore, water has tremendous cutting power especially when loaded with sediments. Physical weathering is also enhanced by plant roots which sometimes enter cracks in rocks resulting in further breakdown of the rocks.

3.2.2 Biochemical Weathering

Water, oxygen, microbes and plant – root exudates are various agents acting in concert to convert primary minerals (e.g. feldspars and micas) to secondary minerals (e.g. clays and carbonates) and release plant nutrient elements in soluble forms. Chemical weathering is governed by six basic types of reactions.

- Hydration
- Hydrolysis
- Dissolution
- Carbonation and order acid reactions

- Oxidation – reduction (redox)
- Chelation

3.3 Soil formation processes

During the formation (genesis) of a soil from parent material, the regolith

(loose earth materials above solid rock) undergoes many profound changes. These changes are brought about by variations in the four broad soil forming processes.

3.3.1 Transformations

This occurs when soil constitutions are chemically or physically modified or destroyed and others are synthesized from the precursor materials.

3.3.2 Translocations

Translocations involve of movement of in organic and organic materials laterally within a horizon or vertically from one horizon up or down to another.

3.3.3 Additions

Inputs of materials to the developing soil profiled from outside sources are considered additions.

3.3.4 Losses

Materials are lost from the soil profile from outside source are considered additions.

4.0 Conclusion

The parent materials from which soils develop vary widely around the world. Knowledge of these materials, their sources, mechanism for their weathering, and means of transport and deposition are essential to understanding soil genesis.

5.0 Summary

In this unit, students have learnt:

- Factors determining soil formation.
- Processes of weathering
- Soil formation processes.

6.0 Tutor –Marked Assignment

1. What is meant by the statement, weathering combines the processes of destruction and synthesis? Give example of these two processes in the weathering of a primary mineral.

2. Describe the processes of weathering

7.0 References/ Further Reading

Brady, N. C. and Weil, R. R. (2002). *The Nature and Properties of Soils* Prentice Hall 13th Edition.

David, C. C. and Crossley, D. A. (1996) *Fundamentals of Soil Ecology* Academy Press.

Module 1

Unit 2 Soil taxonomy

Contents

1.0 Introduction

Soil classification system, called soil taxonomy, provides a hierarchical grouping of natural soil bodies. In this unit, we shall be looking at soil properties and nomenclature employed in classification. Classification based on soil properties lessens the likelihood of controversy over the classification of a given soil which can occur when scientists deal with systems based on presumed mechanism of soil formation.

2.0 Objectives

- At the end of this unit, students should be able to:
  Classify soil based on surface and subsurface horizons.
- List different types of soil moisture regional and apply them to soil taxonomy.
- Distinguish soils based on soil temperature regimes.

3.0 Main Content

3.1 Basis of Soil Classification

Soil taxonomy based on observable properties of soils as they are found today. Such properties for example include moisture, temperature status, soil colour, texture and structure of the soil. Chemical and mineralogical properties, such as the contents of organic matter, clay, iron and aluminum oxides, silicate clays, salts, the pH, the percentage base saturation (cation exchange capacity), and soil depth are other important criteria for classification. Precise measurements are also employed in defining soil horizons, the presence or absence of the help to determine the place of a soil in the classification system.

3.2 Diagnostic surface Horizons

The epipedon (from the Greek-epi, over and pedon, soil) includes the upper part of the soil darkened by organic matter, the upper eluvial horizons, or both. Seven epipedons are recognized, but only five (comollic, Umbric, Ochric, Melanic, Histic) occur naturally over wide areas. The other two, anthropic and plaggen, are the result of intensive human use. They are common in parts of Europe and Asia where soils have been utilized for many centuries.

The mollicepipedon (Latin mollis, soft) is a mineral surface horizon noted for its dark colour due to accumulated organic matter. The Umbricepipedon (Latin Umbra, Shade; hence, dark) has the same general characteristics as the mollicepipedon except that the cation exchange capacity is less than 50%. Umbricepipedon commonly develops in areas with somewhat higher rainfall and where the parent material has lower content of calcium and magnesium.

The Ochricepipedon(Greek Ochris, pale) is a mineral horizon that is either too thin, too light in colour, or too low in organic matter to be either a mollic or umbric horizon. It is usually not as deep as the mollic or umbricepipedon.

The melanicepipedon (Greek melas, black) is a mineral horizon that is very black in colour due to its high organic matter content (organic carbon >6%), it is characteristic of soils developed from volcanic ash.

And the histicepipedon (Greek histos, tissue), a 20- to 60-cm-thick layer of organic solid materials overlaying a mineral soil that is formed in wet areas, is a layer of peat or muck with a black to dark brown colour and very low in density.

3.3 Subsurface Horizons

Many subsurface horizons (18) are used to characterize different soils in soil taxonomy. Each horizon provides a characteristic that helps place a soil in its proper class in the system. For example the argillic horizon is a subsurface accumulation of high-activity silicate clays that have moved downward from the upper horizons or have formed in place. The natric horizon likewise has silicate clay accumulation, but the clays are accompanied by more than 15% exchangeable sodium on the coloidal complex and by columnar or prismatic soil structural units.

The kandic horizon has an accumulation of Fe and Al oxides as well as low activity silicate clays. The oxic horizon is a highly weathered subsurface horizon that is very high in Fe and Al oxides, and in low – activity silicate clays. The spodic horizon is an illuvial horizon that are characterized by the accumulation of colloidal organic matter and aluminum oxide (with or without iron oxide).

The sombic horizon is also an illuvial horizon, dark in colour because of high organic matter accumulation. It has a low degree of cation exchange capacity. The albic horizon is a light-coloured eluvial horizon that is low in clay and oxides of Fe and Al.

Calcic horizons contain an accumulation of carbonates ($CaCo_3$) that often appear as white chalklike nodules. Gypsic horizons have an accumulation of gypsum ($CaSQ_4.2H_2O$), and salic horizons an accumulation of soluble salts. These are found mostly in soils of arid and semiarid regions.

In some subsurface horizons, the materials are cemented or densely packed, resulting in relatively impermeable layers called pans (duripan, fragipan and placic horizons). These can resist water movement and the penetration of plant roots. Such pans constrain plant growth and may encourage water runoff and erosion because rainwater cannot move readily downward through the soil.

3.4 Classification based on soil moisture regions

A soil moisture regime refers to the presence or absence of either water-saturated conditions (usually groundwater) or plant-available soil water. Soil moisture regime classes are used to characterize soils.

(a) Aquic - Soil is saturated with water and virtually free of gaseous oxygen.

(b) Udic - Soil moisture is sufficiently high year-round in most years to meet plant needs.

(c) Ustic - Soil moisture is intermediate between Udic and Aridic regimes.

(d) Aridic - The soil is dry for at least half of the growing season and moist for less than 90 consecutive days. This regime is characteristic of arid regimes.

(e) Xeric - This soil moisture regime is found in typical Mediterranean – types climates.

3.5 Classification based on soil temperature regime

Soil temperature regimes, such as frigid, mesic, and thermic, are used to classify soils at some of the lower levels in soil taxonomy.

4.0 Conclusion

In this unit, we have learnt that soil which covers the earth is actually comprised of many individual soils, each with distinctive properties.

5.0 Summary

In this unit we have learnt the bases of soil classification such as;

- Surface horizons
- Subsurface horizons
- Soil moisture regime

- Soil temperature regime

6.0 Tutor-Marked Assignment

- Explain the relationships among a mollic, umbric and ochricepipedons.
- Explain why soil Taxonomy is said to be a hierarchical classification system.

7.0 References/Further Readings.

Brady, N. C. and Weil, R. R. (2002). *The Nature and Properties of Soil.* Prentice Hall 960pp.

Module 1

Unit 3 Categories and nomenclature of Soil taxonomy I

Contents

Introduction

There are six categories of classification in soil Taxonomy:

(1) Order (the highest categories), (2) suborder (3) great group (4) Sub-group (5) family and (6) series (the most specific category). Therefore, in this unit and unit 4, we will be looking at nomenclature of soil taxonomy.

2.0 Objectives

At the end of this unit, students should be able to

- Explain categories of soil taxonomy
- Know the characteristics of each soil order.
- Distinguish soil orders
- Explain each soil order distribution and use.

3.0 Main Content

3.1 Nomenclature of soil Taxonomy

The nomenclature system is logical and conveys a great deal of information about the nature of soils. The names of the classification units are combinations of syllables, most of which are derived from Latin or Greek and are root words in several modern languages. Since each part of a soil name conveys a concept of soil character or genesis, the name automatically describes the general kind of soil being classified. For instance, soils of the order Aridisols (from the Latin aridus; dry, and solum, soil) are characteristically dry soils in arid regions.

With this brief explanation of the nomenclature of soil taxonomy, we will consider the general nature of soils in each of the soil orders.

3.2 Soil Orders

Each of the world's soils is assigned to one of 12 orders, largely on the basis of soil properties that reflect a major course of development. A general knowledge of the 12 soil orders is essential for understanding the nature and function of soils in different environments. In this unit and unit 4, we will now consider each of the soil orders, beginning with those characterized by little profile development and progressing to those with the most highly weathered profiles.

3.2.1 Alfisols

Alfisols are formed in cool to hot humid areas, but also one found in the semiarid tropics and mediterranian climates. Most often, Alfisols develop under native deciduous forests and grasslands.

Distribution and Use

Alfisols occupy about 10% of the land area globally. In general, alfisols are productive soils. Good hardwood forest growth and crop yield are favoured.

3.2.2 Andisols

Andisols are usually formed on volcanic ash deposited in recent geological times. They are commonly found near the volcano source or in areas downward from the volcano, where a sufficiently thick layer of ash has been deposited during eruptions.

Distribution and use

Andisols are found in areas where significant depths of volcanic ash and other ejecta have accumulated. Globally, they make up less than 1% of the soil area. Andisols are widely cultivated in Japan, producing enough food to support very high population densities. Andisols also occur along the Rift valley of Eastern Africa.

3.2.3 Aridisols

Aridisols occupy a larger area globally than any other soil order (more than 12%) except Entisols. Water deficiency is a major characteristic of these soils. The soil moisture level is sufficiently high to support plant growth for no longer than 90 consecutive days. The natural vegetation consists mainly of scattered desert shrubs and short bunchgrasses.

3.2.4 Entisols

Weakly developed mineral soils without natural horizons or with only the beginnings of such horizons belong to the Entisols order. Most have an ochricepipedon and a few have human-made anthropic or agricepipedons.

Some have albic subsurface horizons. Soil productivity ranges from very high for certain entisols formed in recent alluvium to very low for forming in shifting sand or on steep rocky slopes.

Distribution and Use

Globally, entisols occupy about 16% of the total ice-free land area and are found under a wide variety of environmental conditions. Poorly drained and seasonally flooded entisols occur in major river valleys. The agricultural productivity of the entisols varies greatly depending on their location and properties, with adequate fertilization and a controlled water supply, some entisols are productive.

3.2.5 Gelisols

These are young soils with little profile development. The principals defining feature of these soils is the presence of a permafrost layer (layer of material that remains at temperatures below 0^oC for more than two consecutive years).

In gelisols, the permafrost layer lies within 100cm of the soil surface, in some cases rocks forced to the surface form rings or netlike patterns.

Distribution and Use

Gelisols cover over 11 million Km^2 or 8.6% of the earth's land area. Blanketed under snow and ice for much of the year, most gelisols support tundra vegetation of lichens, grasses, and low shrubs that grow during the brief summers.

4.0 Conclusion

In this unit, we have learnt about soil orders their characteristics distribution and use.

5.0 Summary

In this unit we have learnt about soil orders such as:

- Alfisols, Andisols, Aridisols, Entisols, and Gelisols.

6.0 Tutor-Marked assignment

(1) What is soil taxonomy?

(2) What is the principal soil property by which ultisols differ from Alfisols? Inceptisols from entisols?

7.0 References/Further Readings

Brady, N. C. and Weil, R. R. (2002). *The Nature and Properties of Soil.* Prentice Hall 960pp.

Module 1

Unit 4 Categories and nomenclature of soil taxonomy II

Contents

5.0 Summary

6.0 Tutor-Marked Assignment

7.0 References/Further Readings

4.0 Introduction

As we learnt in unit 3, there are six categories of classification in soil taxonomy, and order is the highest categories, we have learnt about 5 soil orders. In this unit, consideration will be given to other seven soil orders.

2.0 Objectives

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

- List and explain soil orders.
- Distinguish soil orders
- Enumerate soil orders distribution and use.

3.0 Main Content

3.1 Nomenclature of soil taxonomy

As in unit 3

3.2 Soil Orders

The Same as in Module 1, Unit 3.

3.2.1 Inceptisols

In inceptisols the beginning or inception of profile development is evident. Inceptisols show more significant profile development than entisols, but are defined to exclude soils with properties that characterize certain other soil orders. Thus soil with only slight profile development occurring in arid regions or containing permafrost or andic properties, are excluded from the inceptisols.

Distribution and Use

Inceptisols are widely distributed throughout the world and constitute more than 9% of the world's land area. They are prominent in mountainous areas, especially in the tropics and low-land rice-growing areas of Asia.

3.2.2 Histosols

Histosols are soils that have undergone little profile development because of the anaerobic environment in which they form. The main process of soil formation in histosols is the accumulation of partially decomposed organic parent material.

Distribution and Use

Histosols cover only about 1% of the world's land areas in cold, wet regions of Alaska, Canada, Finland and Russia. Some histosols make very productive farmlands.

3.2.3 Vertisols

Vertisols develop from limestone, basalt or other calcium and magnesium rich parent materials, and are found mostly in subhumid to semiarid environments in warm region, where the climate features dry periods of several months.

Distribution and Use

Globally, vertisols comprise about 2.5% of the total land area. Large areas of vertisols are found in India, Ethiopia, the Sudan, and Northern and eastern Australia. Smaller areas occur in sub-Saharan Africa and in Mexico, Venezuela, Bolivia and Paraguay. Large areas of vertisols in the tropics can produce greatly increased yields of food crops with improved soil management practices.

3.2.4 Mollisols

Mollisols are formed by the accumulation of calcium-rich organic matter, largely from dense root/systems of grasses. This humus-rich surface horizon is often 60 to 80cm in depth and high in calcium and magnesium. Mollisols in humid regions generally have higher organic matter and darker, thicker mollicepipedons than their lower-moisture-regime counterparts.

Distribution and Use

The largest area of Mollisols in the world stretches from east to west across the heartlands of Kazakhstan, Ukraine and Russia. Mollisols are among the most productive soils, though some fertilization is generally required.

3.2.5 Ultisols

The processes involved in farming Ultisols are clay mineral weathering, translocation of clays to accumulate in an argillic or kandic horizon, and teaching of base-farming cautions from t he profile. Most ultisols have developed under moist conditions in warm to tropical climates.

Distribution and Use

About 9% of the soil area in the world is classified in the ultisols order. Ultisols are not naturally as fertile as alfisols or mollisols, they respond well to good management, where adequate levels of fertilizers and lime are applied, ultisols are quite productive.

3.2.6 Spodosols

This soil order occurs mostly on coarse-textured, acid parent materials subject to ready teaching. They occur only in moist to wet areas. Intensive acid teaching is the principal soil-forming process.

Distribution and Use

Large areas of spodisols are found in northern Europe and Russia and central and eastern Canada. Spodosols are found on about 3% of the land area globally. Spodosols are not naturally fertile, but when properly fertilized, these soils can become quite productive.

3.2.7 Oxisols

The oxisols are the moist highly weathered soils in the classification system. They form in hot climates with nearly year-round moist conditions; hence the native vegetation is generally thought to be tropical rain forest. However, some oxisols are found in areas which are today much drier than was the case when the soils were forming their oxic characteristics. The clay content of oxisols is generally high, but the clays are of the low-activity, nonsticky type.

Distribution and Use

Oxisols are found on about 8% of the world's land, most occur in the tropics such as south America and Africa. They equally occur in large geographic areas, often associated with ultisols.

The best use of oxisols, other than supporting rain forests, is the culture of mixed-canopy perennial crops, especially tree crops, which can restore the nutrient cycling system that characterized the soil. Plant relationships before the rain forest was removed.

4.0 Conclusion

In this unit, we have learnt the remaining soil orders characteristics, distribution and use.

5.0 Summary

In this unit, we have learnt the soil orders such as histosols, Vertisols, Mollisols, Ultisols, Spodosols and Oxisols.

6.0 Tutor – Marked assignment

- List and explain soil orders found in the sub-Saharan Africa.

7.0 Reference/Further Readings.

Module 1

Unit 5 Categories and nomenclature of soil taxonomy III

Contents

6.0 Tutor-Marked Assignment

7.0 References/Further Readings.

1.0 Introduction

Within each soil order described in unit 3 and 4, are grouped into suborders, great groups, sub-groups, families and series on the basis of soil properties that reflect major environmental controls on current soil-forming processes.

2.0 Objectives

At the end of this Unit, student should be able to:

- List lower-categories in soil taxonomy
- Identify and highlight lower-level categories
- Determine the relationship between lower-categories in soil taxonomy.

3.0 Main Content

2.1.1 Suborders

Many suborders are indicative of the moisture regime or the temperature regime under which the soils are found. Thus, soils formed under wet conditions generally are identified under separate suborders (e.g Aquents, Aquerts and Aquepts), as being wet soils.

To determine the relationship between suborder names and soil characteristics, the formative elements for suborder names are identified and their connotation given. Thus, the ustolls are dry mollisols. Likewise soils in the Udolls suborder (from the latin udus, humid) are moist ultisols.

3.1.2 Great groups

The great groups are subdivisions of suborders. More than 300 great groups are recognized. They are defined largely by the presence or absence of diagnostic horizons and the arrangements of those horizons. These horizon designations are included in the list of formative elements for the names of great groups shown in Table 1 below:

Formative element	Connotation
Acr	Extreme weathering
Agr	Agric horizon
Al	High aluminum, low iron
Anhy	Anhydrons
Dur	Duripan

3.1.3 Subgroups

Subgroups are subdivisions of the great groups. More than 2,000 subgroups are recognized. The central concept of a great group makes up one subgroup, termed.

Typic - Thus, the typichapludolls subgroup typifies the hapludolls great group. A hapludoll with restricted drainage would be classified as an aquichapludoll. One with evidence of intense earthworm activity would fall in the vermichapludolls subgroup. Some intergrades may have properties in coming with other orders or with other great groups.

3.1.4 Families

Within a subgroup, soils fall into a particular family, if at a specified depth, they have similar physical and chemical properties affecting the growth of plant roots.

About 8,000 families have been identified. The criteria used include broad classes of particle size, mineralogy, cation exchange activity of the clay, temperature, and depth of the soil penetrable by roots. Terms such as loamy, sandy and clayey are used to identify the broad particle size classes. Terms used to describe the mineralogical classes include <u>smectitic</u>, <u>kaolibnitic</u>, <u>siliceous</u>, <u>carbonatic</u> and <u>mixed</u>. The clays are described as <u>superactive</u>, <u>active</u>, <u>semiactive</u>, or <u>subactive</u> with regard to their capacity to hold cations. For temperature classes, terms such as <u>cryic</u>, <u>mesic</u>, and <u>thermic</u> are used. The terms shallow and micro are sometimes used at the family level to indicate unusual soil depths.

3.1.5 Series

The series category is the most specific unit of the classification system. It is a subdivision of the family, and each series is defined by a specific range of soil properties involving primarily the kind, thickness, and arrangement of horizons. Features such as a hardpan within a certain distance below the surface, a distinct zone of calcium carbonate accumulation at a certain depth, or striking colour characteristics greatly aid in series identification.

4.0 Conclusion

In this module, we have learnt that soil consists of many individual soils, each having mosaic of properties used in its classification. This classification based on physical and chemical properties influences the behaviour of soils with regard to plant growth, hydrology, environmental management, and engineering uses.

5.0 Summary

In this unit, we have learnt about lower categories in soils taxonomy.

6.0 <u>Tutor-Marked Assignment</u>

1. Explain why soil taxonomy is said to be a hierarchical classification system.
2. Write a hypothetical solid profile description and land-use suitability interpretation for a hypothetical soil that is classified in the Aquicargixerolls subgroup.

7.0 References/Further Readings

Brady, N. C. and Weil, R. R. (2002).*The Nature and Properties of soils.* Prentice Hall.

Module 2

Unit 1 Chemical Components of Soil.

1.0 Introduction

2.0 Objective

3.0 Main Content

3.1 Characteristics of Rocks and Minerals

3.2 Weathering

3.2.1 Physical weathering

3.2.2 Biogeochemical weathering

4.0 Conclusion

5.0 Summary

6.0 Tutor – marked assignment

7.0 References

1.0 Introduction

The chemical components of soil is chiefly determined by weathering – the physical and chemical break down of particles. Weathering rocks minerals, modifies or destroys their physical and chemical characteristics, and carries away the soluble products. Furthermore, it synthesizes new minerals of great significance in soils.

In this unit, we will study the characteristics of rocks and determinants of soil minerals.

2.0 Objectives

At the end of this unit, the student must be able to:

1. Enumerate features of rocks and minerals.
2. Explain weathering.
3. Highlight the effects of weathering on soil chemical components.

2.0 Main Context

3.1 Characteristics of rocks and minerals

Rocks are commonly classified as igneous, sedimentary and metamorphic. Igneous originated from molten magma and include rocks as granite and biorite.

Igneous rocks are made up of primary minerals (minerals that have not been altered chemically) such as light – coloured quartz, muscovite, and feldspars and dark-coloured biotite, augite, and harnblevide (Table). Generally, dark-coloured minerals contain iron and magnesium and are more easily weathered. In view of this dark-coloured igneous rocks like gabbro and basalt and more easily broken down than are granites and other light – coloured igneous rocks.

Sedimentary rocks are made up of cemented or compacted weathering products from older, preexisting rock. For instance, quartz sand weathered from a granite rock and washed into the ocean may settle on the ocean floor becoming cemented into a solid mass called sandstone. Also, clays may be compacted into shale. Sedimentary rocks cover about 75% of the Earth's land surface.

Metamorphic rocks are those formed due to change in form of other rocks. For example, igneous rocks are commonly modified to form schist or gnesis in which light and dark minerals have been reoriented into bands. Also Sedimentary rocks, such as limestone and shale, may be metamorphosed to marble and slate respectively.

Table 2 shares sedimentary rocks and metamorphic rocks and the mineral components.

Dominant mineral	Sedimentary rock	Metamorphic rock
Calcite ($CaCo_3$)	Limestone	Marble
Dolomite ($CaCO_3MGCO_3$)	Dolomite	Marble
Quartz ($Si0_2$)	Sandstone	Quartzite
Clays	Shale	Slate
Variable	Conglomerate of minerals	Gneiss
Variable	Conglomerate of	Schist

	minerals	

Table 1

Primary and secondary minerals in soils.

Quarts	Sio_2
Muscovite	KAl_3 SiO_3 $O(OH)_2$
Microcline	$KAlSi_3O_8$
Orthoclase	$KAlSi_3O_8$
Biotite	$KAl(Mg, Fe)_3$ $Si_3O(OH)_2$
Albite	$NaAlSi_3O_8$
Hornblende	Ca_2 Al_2 $Mg_2Fe_3Si_6o_{22}$ $(OH)_2$
Augite	Ca_2 $(Al,Fe)_4$ $(Mg, Fe)_4$ Si_6 O_{24}
Anorthite	$CaAl_2Si_20_8$
Olivine	$(Mg, Fe)_2SiO_4$

Secondary minerals	Molecular formula

Goethite	FeOOH
Hematite	Fe_2O_3
Gibbsite	$Al_2O_3.3H_2O$
Clay minerals	Al silicates
Dolomite	$CaCo_3$. $MgCo_3$
Calcite	$CaCO_3$
Gypsum	$CaSo_4.2H_2O$

3.2 Weathering

Weathering – a biochemical process that involves both destruction and synthesis. In this process, rocks and minerals are destroyed by the physical disintegration and chemical decomposition. Without affecting their composition, physical disintegration breaks down rock into smaller rocks and eventually into sand silt particles that are commonly made up of individual minerals. Furthermore, the minerals are decomposed chemically. Releasing soluble materials and synthesizing new materials, primary minerals e. g. quartz, silicate clays, oxides of Fe and Al, organic complexes of Al^{3+}, and Fe^{3+} and Fe^{3+}, silicic acid, soluble materials such as; Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Fe^{2+} and $SO_4{}^{2}$- are some of the groups of minerals that remain in well – weathered soils.

3.2.1 Physical weathering

Physical disintegration involves change in temperature abrasion by water, wind and ice, and activities flora and fauna.

Temperature

The process of heating and cooling during the day and might causes alternate expansion and contraction of rock minerals. As some minerals expand more than others, temperature changes set up differential stresses that eventually cause the rock to crack.

Abrasion

Water has tremendous cutting power, likewise wind blown dust and sand. Furthermore, huge moving ice masses embedded with soil and rock fragments grind down rocks in their path, resulting into physical disintegration of the rocks and minerals.

Plants and Animals

Plant roots sometimes enter cracks in rocks and pry them apart, resulting in some disintegration. Burrowing animals may also help in physical weathering of rocks.

3.2.2 Biogeochemical Weathering

Both physical and chemical weathering occur together for example, physical abrasion decreases the size of particles and therefore increases their surface area, making them more susceptible to rapid chemical reactions. Furthermore, chemical weathering is encouraged by the presence of water, oxygen acids produced by microbes and plants root metabolism. There are six basic types of chemical weathering reactions, and all of these reactions are enhanced by the presence of water.

4.0 Conclusion

Soil minerals vary widely around the world, the parent materials, origin and mechanisms of their weathering determine the chemical component of soils.

5.0 Summary

- In this unit, we have learnt the characteristics of rocks and minerals, the dominant minerals in different classes of rocks and the mechanism of weathering.
- **6.0 Tutor-Marked Assignment**

1. What is meant by the statement, weathering combines the process of destruction and synthesis?
2. Give an example of these two processes in the weathering of a primary mineral.
3. How is water involved in the main types of chemical weathering reaction?

7.0 References/Further Reading

Birkeland, P. W. (1999). *Soil and Geomorphology* 3rd Edition (New York; Oxford University Press).

Module 2

Unit 2 Soil analysis

1.0 Introduction
2.0 Objective
3.0 Main Content
    3.1 Soil sampling
    3.2 Chemical analysis of soil
    3.3 Interpretation of analytical result
    3.4 Advantages of soil analysis
4.0 Conclusion
5.0 Summary
6.0 Tutor – marked assignment
7.0 References /Further reading.

1.0 Introduction

The total amount of an element in a soil tells us very little about the ability of that soil to supply that element to plants, therefore, soil analyses have been developed, soil analysis is the routine analysis of soils for the purpose of guiding nutrient management.

Soil analysis involves three phases:

1. Soil sampling
2. Chemical analysis of soil
3. Soil analysis result interpretation.

2.0 Objective

At the end of this unit, the students must be able to:

- explain soil analysis
- discuss soil sampling
- highlight chemical analysis of soil.

3.0 Main Content

3.1 Soil sampling

Due to variability in nutrient levels from spot to spot, a given field mis divided into many distinct areas when taking soil samples to determine nutrient needs.

3.1.1 Composite samples

A soil auger or probe is used to remove a thin cylindrical cove of soil from at least 12 to 15 randomly scattered places within the land area to be represented. The 12 to 15 subsamples are thoroughly mixed in a plastic bucket, and about 0.5 L of the soil is placed in a labeled container and sent to the laboratory. If the soil is moist, it should be air – dried without sun or heat prior to packaging for routine soil tests. Two questions must be addressed when sampling a soil

1. The depth to which the sample should be taken, and.
2. The time of year when the soil should be sampled.

3.1.2 Depth to sample

The standard depth of sampling for a plowed soil is the depth of the plowed layer, about 15 to 20cm, in forest soils about 15 to 20cm in forest soils, about 20 -40cm while sampling the soil for nitrates a depth of 60-80cm should be sampled.

3.1.3 Time of year

Seasonal changes are often observed in soil test results for a given area. The time of sampling is especially important if year to year comparisons are to be made. A good practice is to sample each area every year or two (always at the same time of year), so that the soil test levels can be tracked.

3.2 Chemical analysis of soil

Different extraction solutions are employed by various laboratorires. For example, buffered salt solution, such as sodium or ammonrium acetate, or a mixture of dilute acids and chelating agents are the extracting agents most commonly used. The extractions are accomplished by placing a small measured quantity of soil in a bottle with the extracting agent and shaking the mixture for a certain number of minutes. The whole process is usually automated so that a modern laboratory can handle hundreds of samples each day.

3.3 Interpretation of soil analysis result.

The soil test values are indices of nutrient – supplying power. They do not indicate the actual amount of nutrient that will be supplied. Therefore, it is best to think of soil test reports as more indicates than quantitative.

The interpretation of soil test date is best accomplished by experienced and technically trained personnel who fully understand to scientific principles underlying the common field procedure.

3.4 Advantages of soil analysis

Soil testing is an invaluable tool in making fertilizer recommendations, mostly when they are correlated with the results of field fertilizer experiments.

Furthermore, soil analysis equip the soil managers in decision making on adequate provision of nutrients for plants, conservation of nutrient resources and prevention of contamination of the environment with utilized nutrients.

4.0 Conclusion

The continuous availability of plant nutrients is critical for the sustainability of most ecosystems.

5.0 Summary

In this unit, we have learn about soil analysis and merits of soil analysis.

6.0 Tutor – Marked Assignment

Discuss the value and limitations of soil tests as indicators of plant nutrient needs and water pollution risks.

Module 2

Unit 3 Plant Tissue Analysis

Introduction

1.0 Objectives

2.0 Main Content

3.1 Plant tissue analysis – nutrient concentration

3.2 Tissue analysis

4.0 Conclusion

5.0 Summary

6.0 Tutor – marked assignment

7.0 Reference /Further readings

1.0 Introduction

One of the basic tools of available for diagnosing soil fertility problems is plant tissue analysis. Plant tissue analysis effectively guides the application of nutrients, as well as various other problems as they arise in the field. This unit will throw light on plant tissue analysis and its applications.

Objectives.

At the end of this unit, the student must be able to:

Explain plant tissue analysis

Highlight the problems elucidated using tissue analysis.

3.0 Main Content

3.1 Plant tissue analysis- nutrient concentration of essential elements in plant is related to plant growth or crop yield. The range of tissue concentrations at which the supply of a nutrient is sufficient for optimal growth is termed the sufficiency range. At the upper end of the sufficiency range, plants may be considered to be participating in luxury consumption, as the additional nutrient uptake has not produced additional plant growth.

At concentrations above the sufficiency range, plant growth may decline as nutrient elements reach concentrations that are toxic to plant cells or interfere with the use of other nutrients. If tissue concentrations are in the critical range, the supply is just marginal and growth is expected to decline if the nutrient becomes any less available, even though visible foliar symptoms may not be exhibited. Similarly, plants with tissue concentration lower than the smaller value given in the sufficiency range for a particular nutrient are likely to respond to additions of that nutrient if no other factor is more limiting.

3.2 Tissue analysis consists of sampling of the tissues, analyzing them for their chemical constituents and interpreting the results. The rationale behind tissue analysis is that concentration or contents of nutrients with a specified plant part reflects the nutritional status at that plant of its ability to acquire nutrients from the ambient soil and thus, its growth potential on the site. The measurements are intended to give a direct measure of the nutrients that the plant derives from the soil rather than a measure of the nutrients in the soil itself. In plant tissue analysis, certain precautions must be taken, for example; (1) The correct plant part must be sampled. (2) The plant part must be sampled at the specified stage of growth, because the considerably as the plant matures. (3) It must be recognized that the concentration of one nutrient may be affected by that of another nutrient, due to uncertainties and complexities in interpreting tissue concentration data, plants must be sampled from the best and worst areas in a field. The difference between samples may provide valuable clues concerning then nature of the nutrient problem.

3.3 Plant –Stalk Nitrate

The nitrate content of mature plant stalk is measured at the end of the season, in order to improve future nitrogen management of crops. The test is helpful in identifying excessive levels of nitrogen in the plant at harvest time, which, in turn, is an indication of excessive levels in the soil at the end of the season. High levels of nitrate in plants alert farmers to reduce their nitrogen applications to avoid excess nitrogen leaching in future years.

4.0 Conclusion

For a sustainable plant ecosystem, availability of nutrients is critical. Likewise efforts must be made to prevent pollution of the ecosystem with unused or excess nutrients.

5.0 Summary

In this unit, we have learnt about plant tissue analysis and its implications for sustainable ecosystem.

6.0 Tutor-marked assignment

Why are nutrient cycling problems in agricultural systems more prominent than in those in forested areas?

A cornstalk nitrate test at harvest time shows a farmer that the soil likely contains considerable unused nitrates. To minimize nitrate leaching the farmer wants to grow a cover crop. What characteristics would the farmer look for in choosing a cover crop to ameliorate this situation?

7.0 References/Further Reading

Westerman, R. L. (1990) (ed.) *Soil testing and Plant Analysis* 3rd ed. Madison Wisconsin Soil Sci. Soc. Amer.)

Module 2

Unit 4 Importance of soil and plant tissue analysis content

1.0 Introduction

2.0 Objectives

3.0 Main content

3.1 Application of plant analysis

3.1.1 Problem solving

3.1.2 Monitoring

3.2 Application of soil analysis

4.0 Conclusion

5.0 Summary

6.0 Tutor – Marked Assignment

7.0 Reference/Further Readings.

1.0 Introduction

Soil constantly undergoes changes. Therefore the quantity and availability of plant nutrient element in the soil change as a result of removal by the growing or harvested crops, leaching, erosion or the addition of fertilizer, manure or compost. The soil and plant analysis reveal fertility status and provides information necessary to maintain the optimum fertility conditions for the plants to be grown. Therefore, in this unit we will consider application of soil and plant analysis.

2.0 **Objectives**

At the end of this unit, the student must be able to.

Itemize different applications of soil and plant analysis.

Explain the significance of soil and plant analysis

3.0 Main content

3.1 Application of plant analysis

Plant analysis is very effective in documenting response to nutrient applications. For example, leaf concentration has been correlated with yield and soil test values calibration work using plant analysis, crop requirement have been well established. Nutrient uptake patterns, accumulation and partition have been defined for many crops. Likewise, fertilizer efficiency has been effectively studied.

3.1.1 Application of plant analysis – problem solving

Comparative samples for good and bad areas of production field are very effective in pinpointing the limiting elements. Matching soil samples from the roots zones of plant in each of these areas provides additional evidence of the problem and helps to determine the best corrective measure.

3.1.2 Application of plant analysis – monitoring

Plant analysis has become integral part of managing healthy crops to enhance yield and quality while also maximizing efficiency and protecting the environment. Also, plant analysis have provided a means for monitoring waste products on farm lands in order to ensure maximum crop performance while avoiding pollution of the environment with interest in precision agriculture and prescription fertilizer application, monitoring will become even more important in the future.

3.2 Application of soil analysis

The only way to determine whether a soil is acidic, neutral or alkaline is by carrying out a soil analysis. Therefore, soil analysis is carried cent for these reasons:

- To provide an index of nutrient availability or supply in a given soil. The soil analysis is designed to evaluate a portion of the nutrients from the same pool used by the body.
- To predict the probability of obtaining a profitable response to fertilizer application to given crop.
- To evaluate the fertility status of the soil and plan a nutrient management program.

4.0 Conclusion

Many plants grow well while others suffer retarded growth, in view of this, soil and plant analysis is necessary in order to provide good growing conditions for the crop and at the same time keeping an eye on the health of the environment.

5.0 Summary

In this unit, students have learnt about applications of soil and plant analysis.

6.0 Tutor – Marked Assignment

Discuss applications of plant and soil analysis.

7.0 References /Further Reading

Southern Cooperative Series Bulletin No: 394,July, 2009.

Accessed from: www.ncagr.gov/agronomi/scsb394.pdf

Module 2

Unit 5 Plant, Soil and Water relationship

1.0 Introduction
2.0 Objectives
3.0 Main content
   3.1 Soil water content – potential
   3.2 Soil compaction effects on matrix potential, aeration, and root growth.
   3.3 Osmotic potential
   3.4 Soil depth and layering

1.0 Introduction

Water content potential relationship for each soil horizon, soil strength and density effects on root growth, soil depth, rooting depth and soil stratification or layering all determine the amount of soil water available for plant uptake. In this unit, we will look at the relationships in plant, soil and water.

2.0 Objectives

At the end of this unit, student should be able to

- Explain water content – potential relationship
- Explain effects of soil compaction on root growth.

- Give a brief idea on osmotic potential
-
- Describe soil depth and layering in relation to plant, soil and water.

3.0 Main Content

3.1 Soil Water Content – Potential Relationship

There is a relationship between the water potential of a given soil and the amount of water held at the field. For examples as fineness of texture increases, there is a general increase in available moisture storage growing on sandy soils are more prone to drought than are those growing on a silt loan in the same area.

Likewise, the influence of organic matter descries attention because, the available water holding capacity of a well – drained mineral soil containing 5% organic matter is generally higher than that of a comparable soil with 3% organic matter.

This is, organic matter indirectly affects the amount of water available to plants through its influence on soil structures and total pore space. Also, organic matter helps stabilize soil structure and it increases the total volume as well as the size of the pores. This results in an increase in water infiltration and water – holding capacity of the soil. Therefore, recognizing the beneficial effects of organic matter on plant available water is essential for wise soil management.

3.2 Soil Compaction Effects on Matric Potential, Aeration and Root Growth.

Soil compaction generally reduces the amount of water that plants can take up. Four factors accord for this negative effect:

- First, compaction crushes many of the macrospores and large microspores into smaller pores and the bulk density increases, limiting root penetration.
- Second, compaction decreases the total pore space which generally means that less water is retained at filed capacity.

- Third, reduction in macropore size and numbers generally means less air pore space when the soil is near field capacity.
- Fourth, the creation of more very fine micropores will increase the permanent wilting coefficient (the moisture content of soil at which plants wilt and fail to recover their turgidity) and so decrease the available water content.

Therefore, plant – available water is that which is not held too tightly for roots to take up and yet is not held so loosely that it freely drains away by gravity.

3.2.1 Soil Aeration

Soils are too wet for normal root growth when so much of the soil pore .air. At this water content, lack of oxygen for respiration limits root growth. However, in a compacted soil with very few large pores, oxygen supply may become limiting at lower water contents and potentials because some of the smaller pores will be needed for air.

3.2.2 Root growth in dry soil

The least limiting water range concept tells us that soils are too dry for normal root growth when the soil strength (measured as the pressure required to push a pointed rod through the soil exceeds about 2000 kpa. That is root growth is limited by lack of oxygen at the wet end of the range and by the inability of roots to physically push through the soil at the dry end.

3.3 Osmotic Potential

For soils high in salts, the total moisture stress includes the osmotic potential of the soil solution as well as the matric potential. The osmotic potential tends to reduce available moisture in such soils at the permanent willing coefficient than would be the case due to matric potential alone.

In humid region soils, these osmotic potential effects are in significant, but they become of considerable importance for certain soils in dry regions which may accumulate soluble salts through irrigation or natural processes.

3.4 Soil depth and layering

The total volume of available water will depend on the total volume of soil explored by plant roots. This volume may be governed by the total depth of soil above root–restricting layers, or by the rooting depth characteristic of a particular plant species. The depth of soil available for root exploration is of particular significance for deep – rooted plants, especially in sub humid to arid regions.

Likewise, soil stratification or layering can influence the available water and its movement in the soil. Impervious layers drastically slow down the rate of water movement and also restrict the penetration of plant roots, thereby reducing the soil depth from which moisture is drawn.

Furthermore, the capacity of soils to store available water determines to a great extent their usefulness for plant growth. For instance forest productivity is often related to soil water holding capacity. This capacity provides a buffer between an adverse climate and plant production.

4.0 Conclusion

Water is crucial to life. The interactions and movement of this simple compound in soils help determine whether these impacts are positive or negative. An understanding of the principles that govern the attraction of water for soil solids and for dissolved ions can help maximize the positive impacts while minimizing the less desirable ones.

5.0 Summary

In this unit, we have learn

- Soil water content potential
- The effects of soil compaction on plant available soils.
- Soil depth, water potential and soil stratification or layering, and their effects on water – available plant.

6.0 Tutor Marked Assignment

Give four reasons why compacting a soil is likely to reduce the amount of water available to growing plants.

7.0 Reference/Further Readings.

Brady, N. C. and Weil, R. R. (2002).*The Nature and Properties of Soil.* 13th ed. Prentice Hall.

Module 3

Unit 1: Physical properties of the soil.

Contents

1.0 Introduction

Soil physical properties profoundly influence how soils function in an ecosystem and how they can best be managed, likewise the growth of many plant species are closely related to soil physical properties, also the movement over and through soils of water and its dissolved nutrients and chemical pollutions.

The basis soil physical properties such as colour, texture, pore sizes and other physical properties of soil horizons are used by soil scientists in classifying soil profiles and in making decisions about soil suitability for agricultural and environment projects.

2.0 Objectives

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

- Highlight the physical properties of soil.
- Explain the influence of physical properties on soils.
- Enumerate the application of physical properties of soil in agriculture.

3.0 Main Content

3.1 Physical properties of soil – colour

Soils display a wide range of colours like red, yellow and even green. Some soils are nearly black, white, bright and dull grays.

Soils typically change with depth through the various layers within a soil profile. Soil colours have little effects on the behavior and use of soils. However, they do provide valuable dues to the nature of other soil properties and conditions.

A standard system for accurate colour description has been developed using munseu colour charts. In this system, a small piece of soil is compared to standard colour chips jin a soil colour book. Each colour chip is described by the three components of colour i.e the hue (in soils, usually redness or yellowness), the chroma (intensity or brightness) and the gray (lightness or darkness).

Three major factors have the greatest influence on the colour of soil (1) organic matter content (2) water content and (3) presence and oxidation states of iron and manageress oxides.

3.2 Soil Texture

Soil texture describes the size of the soil particles three broad groups of textural classes are recognized sandy soils, clayey soils. Within each group, specific textural class names convey an idea of the size distribution of particles and indicate the general native of soil physical properties.

The twelve textural classes form a graduated sequence from the sands, which are coarse in texture and easy to more about, to the clays which are very fine and difficult to handle physically.

Table 3.1: Soil Textural class name

Soils	Texture	Basic soil textural class names
Sandy soils	Coarse	Sands loamy sands
Loamy soils	Medium	Very fine sandy loan, loan silt loan.
	Moderately fine	Sandy clay loam silt clay loan clay
Clayey soils	Fine	Sandy clay Silty clay Clay

Source: US Department of Agriculture Classification System

3.3 Soil Structure

Soil structure describes the manner in which soil particles are aggregated, in other words, this property defines the native of the system of pores and channels in a soil. The term structures relates to the arrangement of primary soil particles in grouping called aggregates or peds. The pattern of pores and peds defined by soil structure greatly influences water movement, heat transfer, aeration, and porosity in soils.

Soil structure is characterized in terms of the shape (or type), size, and distinctness (or grade) of the peds. The four principal shapes of soil structure are spheroidal, platy, prim like, and block like.

3.3.1 Spheroidal soil structure

Granular, usually separated from each other in a loosely packed arrangement. They typically range from less than 1 to greater than 10mm in diameter. Gramular structures are characteristics of many surface soils, particularity those high in organic matter. They are prominent in grassland soils and soils that have been worked by earth worms.

3.3.2 Plate like soil structure

It is characterized by thin horizontal peds or plates and may be found in both surface and sub surface horizons. Platy structure may be inherited from soil parent materials, and in some cases compaction of clayey soils by heavy machinery can create plate like soil structure.

3.3.3 Prism like soil structure

Columnar and prism like structure are characterized by vertically oriented prism or pillar like peds that very in height among different soils and may have a diameter of 150mm or more. They commonly occur in subsurface horizons in arid and semiarid regions.

3.3.4 Block like soil structure

Blocky peds are irregular, roughly cubelike and range from about 5 to 50mm across. The individual blocks are not shaped independently, but are molded by the shapes of the surrounding blocks. Blocks like soil structures promote good drainage, aeration and root penetration.

3.4 Soil Density

Soil particle density (Dp) is defined as the mass per unit volume of soil solides. Particle density is essentially the same as the specific gravity of a solid substance.

The chemical composition and crystal structures of a mineral determines its particle density. Dp is not affected by pore space, and therefore is not related to particle size or to the arrangement of particles.

A second important mass measurement of soils is bulk devisity (Db) which is defined as the mass of a unit volume of dry soil. This volume includes both solids and pores. Bulk density is affected by soil texture and depth in soil profile. Changes in bulk devisity for a given soil are easily measured and can alert soil managers to changes in soil quality and ecosystem function for example, increase in bulk density indicate a poorer environment for root growth, reduced aeration, and undesirable changes in hydrologic function, such as reduced water infiltration.

3.5 Soil pore sizes

One of the main reasons for measuring soil bulk density is that this value can be used to calculate the pore space. For soils with the same particle density the lower the density, the higher the percent pore space (total porosity):.

$$\text{Percentage pore space} = 100 - \left(\frac{Db}{Dp} \times 100\right)$$

Soil pores occur in a wide variety of sizes and shapes that largely determine what role the pore can play in soil. Pores can be grouped by size into macropores, mesopores and miropores. Continuous cropping of soils originally high in organic matter, often results in a reduction of macropore spaces.

4.0 Conclusion

Physical properties exert a marked influence on the behavior of soils with regard to plant growth, hydrology and environment management uses. The nature and properties of the individual particles, their size distribution, and their arrangement in soils determine the total volume of non – solid pore space, as well as the pore sizes, thereby impacting on water and air relationships.

5.0 Summary

In this unit, we have learn about:

- The physical properties of soil such as colour, texture, structure etc.
- Influence of soil physical properties on its behavior.
- Uses of physical properties of soil in agricultural and ecosystem management.

6.0 Tutor – Marked Assignment

1. You are considering the purchase of some farmland in a region with variable soil texture. The soils on one farm are mostly sandy loams, while those on a second farm are mostly clay loams and clays. List the potential advantages and disadvantages of each farm as suggested by the texture of its soils.

2. Discuss the positive and negative impact of tillage on soil structure.

7.0 References/Further readings

David, C. C. and Crossely D. A. (1996). *Fundamentals of Soil Ecology.* Academy Press 205pp.

Module 3

Unit 2 Chemical Properties of Soil

Contents

1. 0 Introduction

The soil is developed through the process of weathering of the parent rocks that make up the earth's crust. It is considered as a natural entity, a biochemically weathered and synthesized product of nature. Many elements are found within the earth's crust and most of which are in the soil. These elements combine in different ways to make the chemical constituents of the soil. These take part in all various reactions of the soil to ensure that nutrients are made available to the plants. Through this the plant and animal lives are supported.

3.0 Objectives

At the end of this unit, the students should be able to know the followings

1. The chemical properties of the soil
2. The mineral matrix of the soil
3. The reactions that take place in soil that bring about availability of nutrients to the plants.

3.0 Main Content

3.1 Chemical Nature of Soils

Soil is an entity that has its chemical nature that arises from the parent materials from which it is made. Rocks are the main soil forming materials. Each type of rock has its composition that eventually form the chemical content of any soil that is formed after the weathering processes. About 92 chemical elements are known to exist in the earth's crust. When one considers the number of possible combinations of large number of these elements, it is not surprising that 2000 minerals have been recognized. However, a few of these elements predominate and of real importance. These are hydrogen (H), carbon (C), oxygen (O), nitrogen (N), phosphorus (P), silicon (Si) and alkali and alkaline earth metals. Various trace elements also called micronutrients, are present as enzyme cofactors and include iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), magnesium (Mg), manganese (Mn), molybdenum (Mo) and zinc (Zn). Furthermore, approximately 98% of the crust of the earth is composed of 8 chemical elements. O-46%, Si-27.7%, Al-8.1%, Fe-5%, Ca-3.6%, Na-2.8%, K-2.6%, and Mg=2.1%. Silicon and oxygen compose about 75% of all these elements. These elements are evenly distributed throughout the earth surface. These elements have combined with themselves and some others to constitute the minerals. With all these put together, the soil can be described as predominantly a sand-silt-clay matrix, containing living (biomass) and dead (necromass) organic matter, with varying amounts of gases and liquids within the matrix.

3.2 Mineral matrix (inorganic)/organic

The soil is predominantly minerals or inorganic in composition. Even in their surface layer organic matter contents of mineral soils are comparatively low, generally ranging from 1-10%. In contrast, soils in swamps, bogs and marshes commonly contain 80-90% organic matter. These organic soils when drained and cleaned are most productive, especially for high value crops such as fresh market vegetables. It is this organic soil deposits that are excavated, bagged and sold as organic supplements for home gardens and plants.

The inorganic portion is variable in size and composition made of small rock fragments and minerals of various kinds. The minerals are extremely variable in size-some are large as the smaller rock fragments, other such as colloidal clay particles. Quartz and some other minerals have persisted with little change in composition. Other minerals such as the silicate clays and iron oxides have been formed by weathering of less resistant minerals.

Table 1 Primary minerals found in soils

Size Fraction	Common Name	Means of observation	Dominant composition
Very coarse	Stone	Naked eyes	Rock fragments

Coarse	Sands	Naked eyes	1^0 minerals
Fine	Silt	Microscope	1^0 & 2^0 minerals
Very Fine	Clay	Electron micro	Most 2^0 minerals

In general, primary minerals dominate the coarser fraction of soils, whereas secondary minerals are most prominent in the fine materials, especially clays. Clearly, mineral particle size will have much to do with the properties of the solid in the field. The minerals present in soils depend on the types of rocks that were weathered for their formation. It also depends on the type reactions that have taken place in the process of weathering. Some of these reactions particularly chemical processes of weathering bring about new forms of minerals from the rock forming soils. Several of examples of the new forms of minerals have been listed in Module 2, unit 1.

3.3 Soil reactions

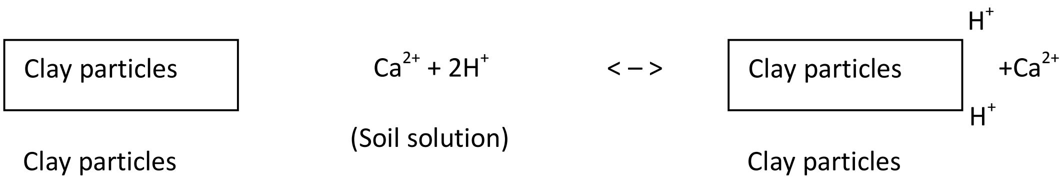
The degree of soil acidity or alkalinity, usually expressed as soil pH, is a master variable that affects a wide range of soil properties–chemical, biological, and, indirectly, even physical. This chemical variable greatly influences the availability for root uptake of many elements including both nutrients and toxins. The activity of soil microorganisms is also affected. The mix of plant species that dominate a landscape under natural conditions often reflects the pH of the soil. So for people attempting to produce crops or ornamental plants, soil pH is a major determinant of which species will grow well or even grow at all in a given site.

pH is a measure of the active hydrogen ion (H^+) concentration. It shows the acidity or alkalinity of a soil, and also called soil reaction. pH scale ranges from 0-14, which value below seven 7 acidic and above 7 is alkaline. pH7(neutral) i.e. H^+ and OH^- are equal (10-7moles/liter). pH of 4.0 is ten (10) times more acidic than pH of 5.0. Important effect pH in soil is on ion solubility, which in turn affects microbial and plant growth. A pH range of 6.0-6.8 is ideal for most crops because it coincides with optimum solubility of the most important plant nutrients. Some minor elements e.g. iron and most heavy metals are more soluble at lower pH that is at acidic conditions. This makes pH management important in controlling movement of heavy metals (and potential ground water contamination) in soil. In an acid soil, H^+ and Al^+ are dominant exchangeable cations. Al^+ is soluble under the acid conditions, and its reactivity with water hydrolysis produces H^+. Calcium (Ca^+) and magnesium ion (Mg) are basic cations, as their amounts increase the relative amount of acidic cations will decrease. Factors that affect soil pH include parent materials (PM), vegetation and climate. Some rocks and sediments produce soils that are more acidic than others. Quartz-rich sandstone is acidic whilst limestone is alkaline. Vegetation e.g. conifers produce organic acid which can contribute to lower soil pH values. In humid conditions, soil becomes more acidic as a result of rainfall (runoff) which brings about ashing of cations and replaced with hydrogen ion. Also, addition of fertilizer to replenish soil fertility also produces some hydrogen ion (H^+).

3.4 Cation Exchange Capacity/ Cation Adsorption Capacity (CEC)

Soil is the store house of plant nutrients which exist in solution as positively charged cations and negatively charged anions. Both the clay and organic component have a net negative charge, however, clay particles are known to have excess negative charge at the edges and surfaces of their crystals. These charged sites attract cations, which would otherwise be moving in solution and hold them to the crystals surface that depends upon the cation and the type of clay involved. In soil, the attracted nutrient cations are usually not permanently fixed to the particle, they bind loosely to negatively charged site until they are adsorbed by the plant roots or exchanged for other nutrient cations in the soil solution. This replacement is called cation adsorption or more commonly known as cation exchange. The ability of a soil to hold cations in readily exchangeable positions is considered good for plant nutrition. This ability is measured quantitatively centimoles of exchangeable charge per kilogram of substrate (c mol kg-) and is called the cation exchange capacity or cation adsorption capacity (CEC.)

Some plants nutrients and metal exist as positively charged ions or cations in the soil environment. Among the cations found in soils are hydrogen (H^+), Aluminum (Mg^+) and Potassium (K^+), Calcium (Ca^{++}), Sodium (Na^+) and Ammonium (NH_4^+). Most heavy metals also exist as cations in the soil environment. Clay and organic matter particles are predominantly negatively charged (anions) and have ability to hold cations from being leached or



wash

leached away. The adsorbed cations are in a rapid reversible process called cation exchange (CE). Cations leaving the exchange sites enter the soil solution, where they can be taken up by plants, react with other soil constituents, or be carried away with drainage water. The cation exchange capacity or CEC of a soil is a measurement of the magnitude of the negative charge per unit weight of soil, or the amount of cations a particular sample of soil can hold in an exchangeable form. The greater the clay and organic matter content, the greater the CEC. Though, different types of clay minerals and organic matter can vary in CEC. During cation exchange, hydrogen ions arre released from the root hairs. These root hairs in turn exchange with nutrients cations adsorbed on the surfaces of the clay particles forcing them into solution where they can be assimilated by plants. The uptake of these nutrient cations depends not only on the solubility of the nutrient cations and their being in an exchangeable position but also on their being in close proximity of the root surfaces. The process of diffusion can be achieved. The action site of the cation exchange is the interface where soil colloid meets root surfaces in a bath of soil solution. The moment a plant rootlet comes in contact with a root surface holding adsorbed cation, the root gives out hydrogen ions in exchange for these nutrient cations. Some of the cations then migrate from the swarm of cations adsorbed unto the clay surface and move from the root hairs. The places of these cations are then taken by hydrogenions released from the root hairs. The nutrient cations are then translocated into the water transporting through xylem tissue of the plant to the stem and leaves for plant nutrition hence, this is why the cation exchange capacity quantifies the ability of a soil to provide nutrient reserve for plant uptake. CE is an important mechanism in soils for retaining and supplying plant nutrients, and for absorbing contaminants. CE plays an important role in waste water treatment in soils. Indeed, adsorption of cations and their exchange, is probably second only to photosynthesis, as it is the primary mechanism in plant nutrition.

4. Conclusion

The chemical properties are of utmost importance to plant nutrition. The presence of the various elements from the soil forming rocks combining to form many inorganic substances which are essential to plant and animal lives cannot be over-emphasized. The different soil reactions that bring about the formation of the nutrients are also very important. The cation exchange which brings about the uptake of the various nutrients in solution and which is as important as photosynthesis is of many advantages to the entire ecosystem. It provides a major retention mechanism within the soil which prevents leaching of essential elements. The process also acts as a buffer for soil ecosystem in cases of abrupt fluctuations in soil salinity and pH. CE also improves the water-holding capacity of the soil and forms a biotic-mineral complex which is of utmost importance to the soil ecosystem, as many microbes adsorbed on the soil particles at interface of cation exchange, play vital roles in the decomposition of organic materials to simpler compounds that can be utilized by the plants for food.

5. Summary

The unit has discussed the followings

The chemical properties from the viewpoint of the chemical nature of the soil

The soil reactions with explanation on the importance of acidity and alkalinity and the way these processes affect uptake of nutrients by plants

And cation exchange capacity has been elucidated. The importance of this process to the functioning of the ecosystem has also been emphasized.

6. Tutor-Marked Assignments

1. Which are the essential elements that are present in the soil?
2. Give names of the micro-elements present in the soil.
3. What is soil reaction? Why is it important?
4. What is the primary source of acidity in the soil?
5. Discuss cation exchange and its benefits to the ecosystem.

7. References/Further Reading

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Module 3

Unit 3 Detritus Organisms-Microflora and Microfauna

Contents

3.1 Organisms in the soil

3.1.1Microbial diversity

3.1.2 Sizes of soil organisms

3.1.3 Ecosystem dynamics of soil organisms

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3.4 Merits of soil organisms

3.4.1 Organic material; decomposition

3.4.2 Detoxification

3.4.3 Inorganic Transformation

3.4.4 Nitrogen Fixation

4.0 Conclusion

5.0 Summary

6.0 Tutor–marked assignment

7.0 references/ Further Reading

1.0 Introduction

Like a savanna, rainforest or an estuary, a soil is an ecosystem in which thousands of different creatures interact and contribute to the global cycles that make all life possible. Most of the work of the soil community is carried out by soil microorganisms, the collective vitality, diversity, and balance among these organisms engender a healthy ecosystem and make possible the functions of a high-quality soil. In this unit, we shall learn about detritus organisms, their characteristics and the benefits derived from them.

2.0 Objectives

This unit will provide information to students on

- The diversity of soil organisms
- Factors affecting the growth of soil organisms
- Advantages of soil organisms

3.0Main Content

3.1 Organisms in the soil

Soil organisms spend all or part of their lives in the soil environment. These organisms interact with the soil and soil conditions. This is by engineering a myriad of biochemical changes as decay takes place. They also physically churn the soil and help stabilize soil structure. These microflora and fauna assimilate plant and animal residues and waste products, creating soil humus, also recycling carbon and mineral nutrients, and supporting plant growth. Therefore, there is need to lay emphasis on proper management of soils in order to encourage a healthy and diverse microflora and fauna community that will make nutrients readily available for plants and also protect the environment.

3.1.1 Microbial Diversity

The populations of soil organisms tend to be concentrated in zones of favorable conditions, rather than evenly distributed throughout the soil. Because within a handful of soil, there may be areas of good and poor aeration, high and low acidity, cool and warm temperatures, moist and dry conditions, and localized concentrations of dissolved nutrients, organic substrates, and competing organisms. Therefore, a high biological diversity of microbes is an indication of good soil quality.

3.1.2 Sizes of soil organisms

Soil microbes range in size from macrofauna such as earthworms and millipedes, through mesofauna e.g. mites to microfauna such as nematodes and single-celled protozoans as shown in table below.

Table 1 Important groups of soil organisms

Generalized Grouping	Specific Grouping	Examples
Macrofauna(>2mm)	Vertebrates, Annelids Arthropods, Molluscs	Mice, ants spiders
Macroflora	Vascular plants Bryophytes	Herb plant Mosses

Mesofauna(0.1-2mm)	Arthropods Annelids	Mites etc.
Microfauna(<0.1mm)	Nematodes, Rotifers Protozoa	Ciliates Flagellates
Microflora(<0.1mm)	Fungi, algae Bacteria, Actinomycete	Diatoms Yeasts, Molds Mushroom

3.1.3 Ecosystem dynamics of soil organisms

In most healthy soil ecosystems, there are several different species capable of carrying out of the thousands of different enzymatic and physical processes that occur on daily basis. While the action of the microflora is mostly chemical, that of the fauna is both physical and chemical. The activities of soil flora and fauna are so interrelated as to make it rather difficult to study them independently. So given a high degree of diversity, no single organism is likely to become completely dominant. In the same vein, the loss of any one species is unlikely to cripple the entire system, except certain processes, such as, ammonium oxidation, methane oxidation and low nitrifying bacteria population, because their populations may indicate the health of the entire soil ecosystem.

3.2 Detritivores

Detritivores are the soil organisms that depend mainly on detritus also called debris of the ecosystem. For soil organisms, their principal source of food is the debris of dead tissues left by plants on the soil and within the soil pores. It is from this that the organisms get their own energy.

3.3 Factors affecting the growth of soil organisms

3.3.1 Organic matter

The addition of any energy-rich organic substance including the compounds excreted by plant roots, stimulates microbial growth and activity. For example, bacteria tend to respond rapidly to additions of simple compounds such as starch and sugars.

3.3.2 Oxygen

Most microorganisms are aerobic, while some are anaerobic and use substances other than oxygen such as nitrates and sulphate ions. Meanwhile, facultative bacteria can use either aerobic or anaerobic forms of metabolism.

3.3.3 Moisture and Temperature

Moisture and temperature vary from time to time in the soil environment. Too high water content will limit oxygen supply, therefore, optimum moisture level for higher plants is usually best for most aerobic microbes. Soil temperature extremes seldom kill bacteria but microbial activity is generally greatest when temperatures are 20 to 40^0 C.

3.3.4 Calcium and pH

Levels of exchangeable calcium and pH help determine which specific organisms thrive in a particular soil. High calcium and near-neutral pH generally result in the largest, most diverse bacterial populations.

3.3 Advantages of Soil Organisms

3.4.1 Organic Material Decomposition

The soil detritivores are indispensable to the plant productivity and ecological functioning of soils. This is accomplished by decomposition of dead leaves, roots and other plant tissues. The detritivores also assimilates wastes from animals.

3.4.2 Detoxification

Soil bacteria and fungi are especially important in helping maintain a nontoxic soil environment by breaking down toxic compounds such as agrochemicals.

3.4.3 Transformation of inorganics

Nitrate, sulphate and phosphates ions are present in soils primarily due to the action of microorganisms. For instance, bacteria and fungi assimilate some of the N, P, and S in the organic materials they digest. Excess amount of these nutrients may be excreted into the soil solution in inorganic form. In this manner, the soil food web converts organically bound forms of nitrogen, phosphorus and sulfur into mineral forms that can be taken up by higher plants.

3.4.4 Nitrogen Fixation

Enormous quantities of atmospheric nitrogen are fixed annually into forms usable by higher plants by actinomycetes in the forest ecosystems, cyanobacteria in flooded rice paddies, wetlands and deserts, also rhizobia bacteria in agricultural soils.

4.0 Summary

In this unit, students have learned

- Varieties of soil detritivores
- Diversity of soil detritivores
- Advantages of soil microorganisms

5.0 Conclusion

Soil organisms are numerous, of varying sizes and vital to the cycle of life on earth. The detritivores incorporate plant and animal residues into the soil and digest them, returning carbon dioxide to the atmosphere. They also create humus, the organic matter needed for good physical and chemical conditions of the soil.

6 Tutor-Marked Assignment

1. What are detritivores?
2. What role does O_2 play in aerobic metabolism? What other elements take its place in anaerobic conditions?
3. Describe some of the ways in which microfauna play significant roles in soil metabolism.

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MODULE 3 UNIT 4: NUTRIENT RESOURCES AND LIMITATIONS

Contents

1.0 INTRODUCTION

Nutrient sources are generally classified as organic, mineral or biological. Organic nutrient sources are often described as manures, bulky organic manures or organic fertilizers. Most organic nutrient sources, including waste materials, have widely varying composition and often only a low concentration of nutrients, which differ in their availability. Some of these, such as cereal straw, release nutrients only slowly (owing to a wide C:N ratio) while others such as the N-rich leguminous green manures decompose rapidly and release nutrients quickly.

2.0 OBJECTIVES

At the end of this unit, students must have learned:

- The sources of soil nutrient
- Limiting factors of nutrients in the soil

3.0 MAIN CONTENT

3.1 SOURCES OF NUTRIENTS

Plants need water, carbon dioxide and a range of trace minerals k]nown as 'nutrients' to grow. They obtain these nutrients from the soil. The nutrients available in a given soil ultimately depend on the rock from which the soil was made. If the plants grown from this soil die and decay where they have grown then their nutrients are recycled. However, if the plants have been grown for agriculture then they are removed from the area in which they have grown and their nutrients cannot be recycled. So in soils that are used for cropping, essential nutrients continually have to be replaced. Aside from decomposition of organic substances, the atmosphere and soil or sediments are also sources of nutrients in soils.

3.1.1 ATMOSPHERE

The atmosphere serves as a reservoir for many elements. These elements when released may increase the availability of minerals for uptake by autotrophs. The inorganic substances which include Carbon, Nitrogen and Water among others are part of the air and are involved in the mineral cycles of the ecosystem.

3.1.2 SOIL OR SEDIMENTS AS SOURCES OF NUTRIENT

Apart from peat, which is derived from plant material, soil is composed of silicate minerals of various types, composed largely of oxygen and silicon, with smaller amounts of aluminium, iron, sodium, potassium, calcium and magnesium, and variable and much smaller amounts of all the other elements. As rainwater saturated with carbon dioxide percolates through silicate minerals it dissolves out the simple soluble cations, such as Na^+, K^+ and Ca^{2+}, and anions such as Cl^-, in the process of weathering. The residue consists largely of oxides of silicon, aluminium and iron. Without the ability of soils to bind both cations and anions the essential plant nutrients would be rapidly washed out of the soil, and plant life would probably not have developed in the forms we know.

3.1.3 DECOMPOSITION OF ORGANIC SUBSTANCES

Soil organic matter is the fraction of the soil that consists of plant or animal tissue in various stages of breakdown (decomposition). The quickest increases are obtained with sources that are high in carbon such as compost or semi-solid manure.

Sources of organic materials include:

- Crop residues.
- Animal manure.
- Compost.
- Cover crops (green manure)
- Perennial grasses and legumes.

With careful management the preservation and accumulation of soil organic matter can help to improve soil productivity resulting in greater farm profitability.

3.2 NUTRIENT LIMITATIONS

Many factors affect the growth of crops in any agricultural system, particularly climatic conditions and soil characteristics. The climatic environmental factors include temperature, moisture, and light energy. Soil characteristics include soil structure and composition, pH, soil biology, nutrient availability and any processes affecting availability. All of these factors are interrelated.

TEMPERATURE

Most agricultural plants grow between 15^0 and 40^0, each crop requiring a specific range for different growth processes. Soil temperature affects soil air composition and therefore soil moisture, which in turn alter soil biological processes affecting nutrient availability. Nutrient absorption and uptake are also affected. Soil pH may experience changes with temperature, which is thought to be relative to microorganism activity.

MOISTURE

Movement of nutrients to roots and nutrient uptake are limited by inadequate water, as most soil nutrients are water-soluble. Too much water can result in nutrient loss by leaching. Micro-organism activity is subject to soil moisture levels, too high or too low results in decreased nutrient transformations that process nutrients into plant-available forms.

SOIL STRUCTURE AND COMPOSITION

Soil texture (determined by size of mineral and organic matter particles) and soil structure (how soil particles are aggregated) influence nutrient retention capacity by altering porosity, compaction, and the cation exchange capacity (CEC: the capacity of a soil for ion exchange of positively charged ions between the soil and the soil solution; most plant nutrients are cations).

pH

Plant nutrients are most available between pH of 6.2 to 6.8. In acidic soils below pH 5.5, and in alkaline soils, most (cationic) nutrients change form and are unavailable to plants.

BIOLOGICAL ACTIVITY

Biological activity responsible for nutrient transformations, making them more available for plant uptake, is most active in soil containing organic matter; soil that is warm and moist for some part of the year, pH between 6.2 and 6.8 is ideal for many beneficial organisms.

OTHER NUTRIENTS

Some nutrients become less bioavailable when another nutrient is in excess.

4.0 SUMMARY

In this unit, students have learnt that:

- There are many sources of plant nutrients such as the atmosphere, soil or sediments and organic substances decomposition.
- Some factors such as climatic conditions like temperature, rainfall e.t.c. could limit nutrient availability in the soil.

5.0 CONCLUSION

Since nutrient resources influence plant fitness, it is therefore important to analyze nutrient – climate interactions to know how plants function and how soil structure will change under varying climatic conditions.

6.0 TUTOR MARKED ASSIGNMENT

1) Identify some limiting factors for plant growth, other than available nutrients. Explain how these factors can affect plant development.

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MODULE 3 UNIT 5: CYCLING OF MINERALS AND NUTRIENT POOL

Contents

1.0 INTRODUCTION

The movement of nutrient elements through the various components of an ecosystem is called nutrient cycling. Nutrients are never lost from the ecosystems; they are recycled time and again indefinitely. The amount of nutrients, such as carbon, nitrogen, phosphorus, calcium, etc., present in the soil at any given time, is referred to as the **standing state.** It varies in different kinds of ecosystems and also on a seasonal basis. Another name of nutrient cycling is biogeochemical cycles (bio: living organism, geo: rocks, air, and water). Nutrient cycles are of two types: (a) **gaseous and (b) sedimentary.** The reservoir for gaseous type of nutrient cycle (e.g., nitrogen, carbon cycle) exists in the atmosphere and for the sedimentary cycle (e.g., sulphur and phosphorus cycle); the reservoir is located in Earth's crust.

2.0 OBJECTIVES

At the end of this unit, students must have learned:

- The characteristics of biogeochemical cycle
- Types of biogeochemical cycle
- Nutrient pool or reservoir
- How to describe the flow of nutrients in each biogeochemical cycle.

3.0 MAIN CONTENT

3.1 CHARACTERISTICS OF BIOGEOCHEMICAL CYCLES

In biogeochemical cycles, nutrient elements usually enter the living system through vegetation. This is because animals are unable to free and absorb the nutrient elements from the soil or the atmosphere as plants can. Therefore, an ecosystem depends on plants not only to supply the necessary nutrients to maintain the flow of energy but also to fix the solar energy. The solar energy keeps the earth warm enough so that chemical reactions are possible and living organisms can carry out their vital life processes. Any type of biogeochemical cycle must have the following characteristics:

- Must be able to circulate nutrient element from the environment to organisms and back to the environment.
- There must be involvement of plants, animals and microbes

- Presence of nutrient reservoir
- Occurrence of chemical changes.

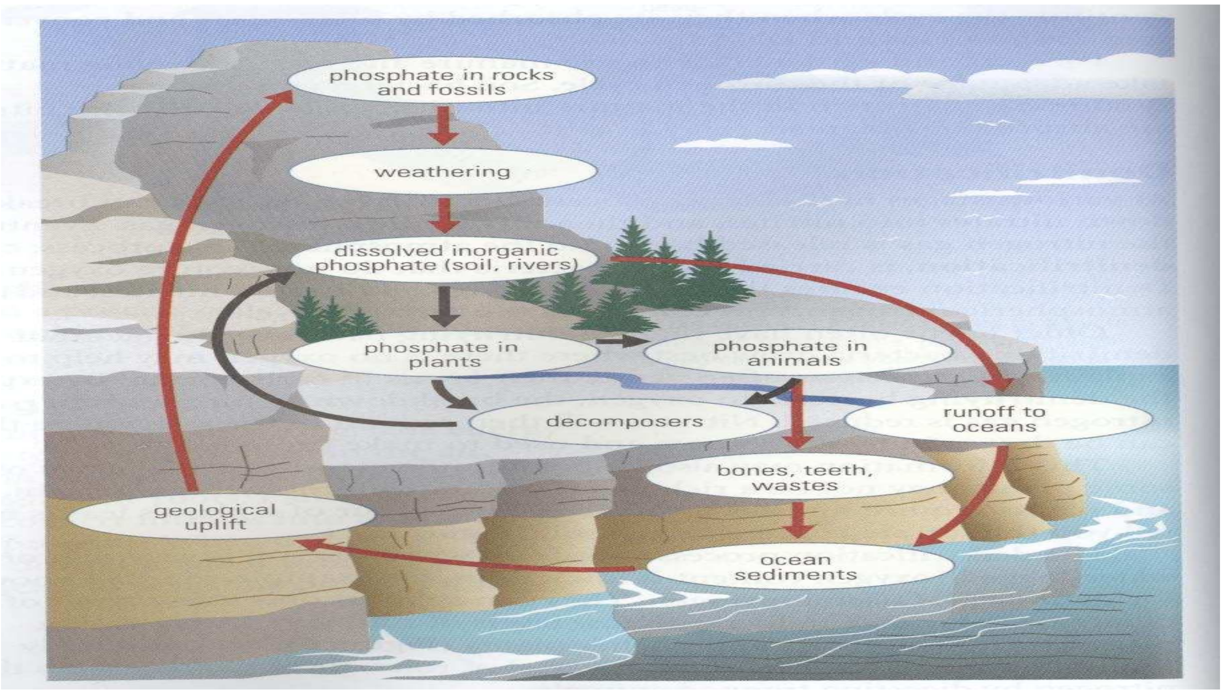
3.2 TYPES OF BIOGEOCHEMICAL CYCLES

There are two basic types of biochemical cycles. These are

- Sedimentary and
- Gaseous cycles.

The sedimentary cycles have the soil and sediments as reservoir and safety valve of the system while the gaseous cycles, it is the air that acts as the reservoir and safety valve. Some typical examples of sedimentary cycle are; Sulphur, phosphorus, and Gaseous cycle are Nitrogen and Carbon.

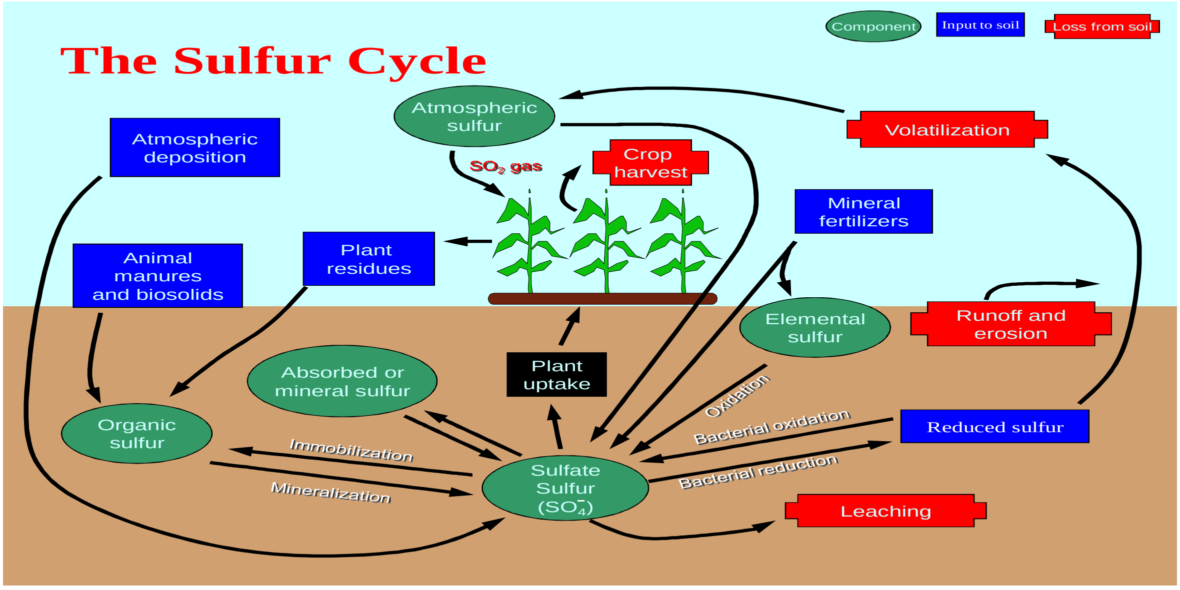
3.3 PHOSPHORUS CYCLE



All organisms need abiotic phosphorus to make biotic phosphates for DNA and other cell molecules. The short time cycle of phosphorus occurs when organisms die, are decomposed and the phosphorus is reabsorbed into an organism. Most phosphorus is stored in abiotic rocks and erosion can make this phosphorus available for organisms to absorb in the phosphorus long cycle time. Although very little phosphorus is needed by plants, it is very important and needed for all plant growth. The Phosphorus that plants use is contained mostly in the earth`s crust rather than in the atmosphere, this phosphorus is released with the weathering of rock caused by wind, water and geologic uplift. The recycling of phosphorus tends to be much localized, with plants up taking the phosphorus from the soil. Animal's uptake the phosphorus in the plants they eat, and return it to the environment in their waste. The phosphorus excreted by animals is in an organic form, which is converted to an inorganic form by microorganisms. Some of the phosphorus in the system is lost, by leaching and erosion this phosphorus eventually reaches the oceans where it remains until it undergoes geologic uplift. The erosion of exposed rock or the use of manmade phosphate fertilizers replaces this lost phosphorus.

3.4 SULFUR CYCLE

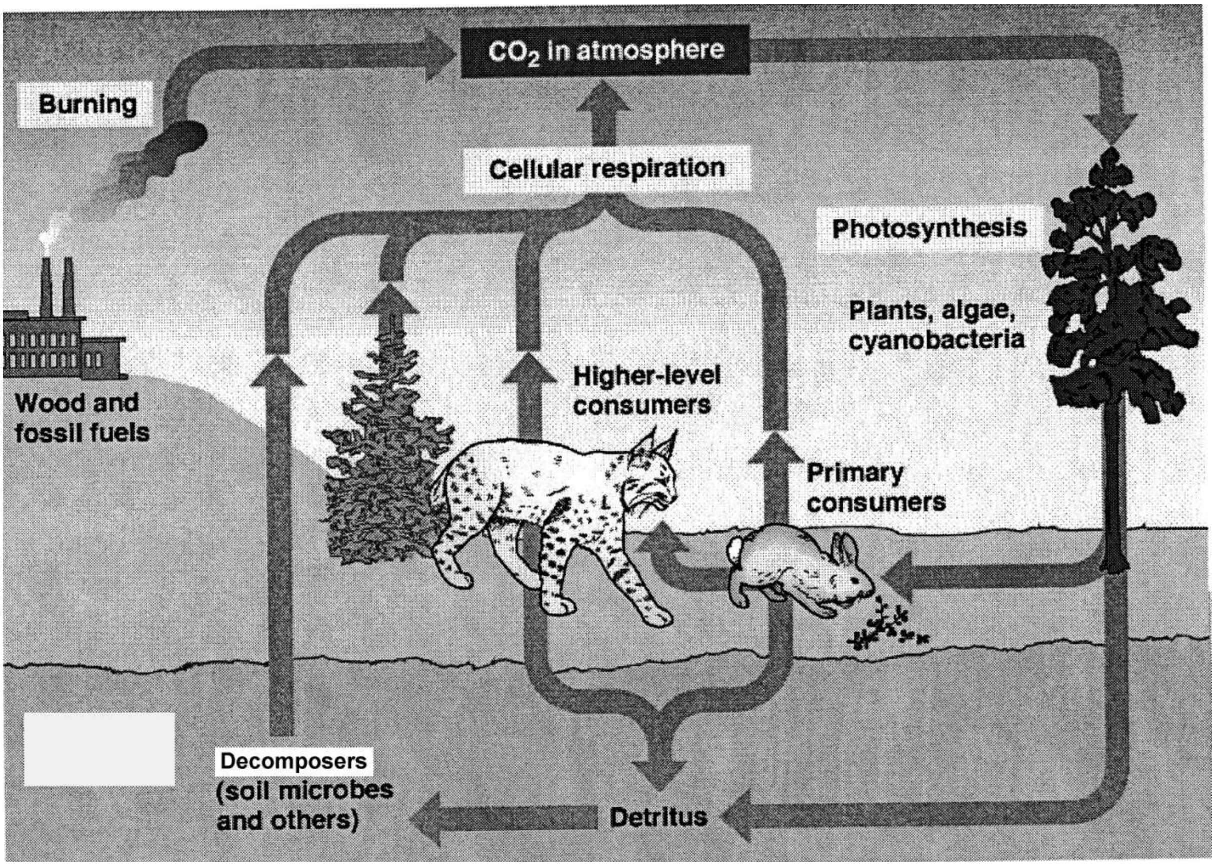
Sulfur is a component of proteins, enzymes and other compounds. It is rarely a limiting nutrient and is usually absorbed as sulfate.



Sulphur is important for the functioning of proteins and enzymes in plants, and in animals that depend upon plants for sulphur. Plants absorb sulphur when it is dissolved in water. Animals consume these plants, so that they take up enough sulphur to maintain their health. Most of the earth's sulphur is tied up in rocks and salts or buried deep in the ocean in oceanic sediments. Sulphur can also be found in the atmosphere. It enters the atmosphere through both natural and human sources. Natural resources can be for instance volcanic eruptions, bacterial processes, evaporation from water, or decaying organisms. When sulphur enters the atmosphere through human activity, this is mainly a consequence of industrial processes where sulphur dioxide (SO_2) and hydrogen sulphide (H_2S) gases are emitted on a wide scale. When sulphur dioxide enters the atmosphere it will react with oxygen to produce sulphur trioxide gas (SO_3), or with other chemicals in the atmosphere, to produce sulphur salts. Sulphur dioxide may also react with water to produce sulphuric acid (H_2SO_4).
All these particles will settle back onto earth, or react with rain and fall back onto earth as acid deposition. The particles will than be absorbed by plants again and are released back into the atmosphere, so that the sulphur cycle will

start over again.

3.5 CARBON CYCLE

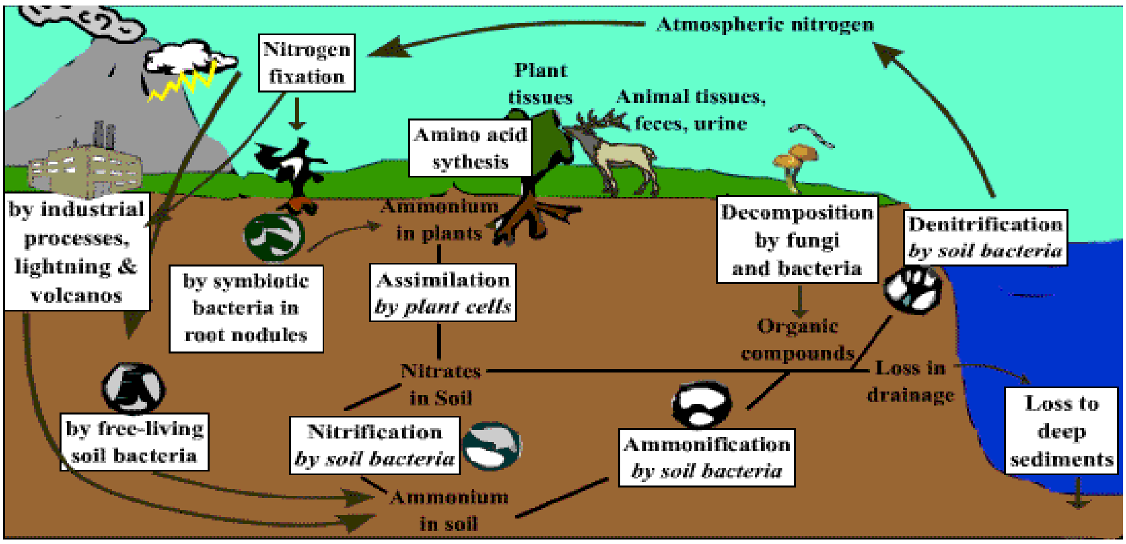


During photosynthesis organisms convert carbon dioxide in the atmosphere into carbon containing compounds such as sugars and cellulose. These compounds are then utilized by primary consumers such as cattle, which by the process of respiration; convert the carbon containing compounds into carbon dioxide and water. These processes viewed on a global scale, is called the Carbon Cycle.

In the carbon cycle the primary photosynthesizers are the plants, phytoplankton, marine algae, and cyanobacteria. These organisms utilize carbon dioxide and water to produce carbohydrates and oxygen which the photosynthesizers use themselves. Plants do release carbon dioxide from their leaves and roots, and phytoplankton and marine algae and cyanobacteria, release carbon dioxide into the water where it maintains in equilibrium with the carbon dioxide of the air.

Not only is carbon dioxide released by plants, it is also released by animals which eat the plants and animals which eat those animals during the process of respiration. Carbon dioxide is also released by the combustion of organic carbon sources such as wood, coal and oil. An enormous amount of organic carbon resides in the bodies of dead plants and animals, along with the wastes of living animals. Decomposers, such as fungi and other small invertebrates, consume this Carbon; these decomposers also released carbon dioxide.

3.6 NITROGEN CYCLE



The cycling of the earth's limited amount of nitrogen is known as the nitrogen cycle and has three principal stages; these are ammonification, nitrification and assimilation.

1. Ammonification also known as nitrogen mineralization occurs when soil dwelling saprophytic bacteria decompose dead organic matter, which are composed of complex nitrogen containing compounds such as proteins and amino acids, and nucleic acids these bacteria use the nitrogen they obtain to create their own amino acids and proteins and release the excess nitrogen as ammonium which can then be used by plants.

2. Nitrification occurs when bacteria oxidize ammonia or ammonium ions, this chemical reaction produces energy, which the bacteria use to convert carbon dioxide into nitrite, hydrogen, and water. Since the nitrite produced by the bacteria is toxic to plants it must be converted to nitrate by another species of bacteria, once converted to nitrate, the nitrogen is available for absorption by plants
3. The assimilation of inorganic nitrogen in the form of ammonium or nitrate into organic compounds such as proteins, amino acids and nucleic acids is one of the most important processes on earth and is almost equal to photosynthesis and respiration. The greatest source of nitrogen to crop plants is in the form of nitrate, which is broken-down and reduced to ammonia, which can be quickly incorporated into organic compounds like amino acids. Although most plants receive their nitrogen in an inorganic form like nitrate some plants in the artic, where nitrogen availability is limited, are able to utilize organic nitrogen from dead organisms, these specialized plants are able to do so without going through the process of Ammonification.

Although natural nitrogen fixation is one of the most effective ways in which nitrogen can be made available to plants it is very slow and requires an entire growing season to accomplish.

3.7 NUTRIENT POOL OR RESERVOIR

The primary pools or reservoirs of nutrients in a soil are:

- Soil solution
- Exchangeable cations and anions
- Sorbed cations and anions
- Organic matter
- Primary and secondary minerals

With the exception of carbon, hydrogen and oxygen, essential plant nutrients originate primarily from soil pools. The importance of each of these pools varies greatly between elements. For example, the primary pool of nitrogen is organic matter while plant-available calcium originates predominately from the exchangeable cation pool. Furthermore, the plant availability of nutrients varies greatly between the different nutrient pools. Nutrients contained in the soil solution are readily available for plant uptake while nutrients contained in organic matter and primary minerals must first undergo mineralization and chemical weathering, respectively.

Because of the great spatial variability of soil properties on a given landscape, a large number of replicate samples is required to estimate nutrient pools on a landscape scale. Thus, to estimate soil nutrient pools, it realistically requires a tremendous effort due to the large number of replicate samples and analytical measurements required to produce reasonably rigorous estimates.

4.0 SUMMARY

In this unit, students have learnt:

- The characteristics of biogeochemical cycle
- Types of biogeochemical cycle
- Primary nutrient pool or reservoir
- About the flow of nutrients in each biogeochemical cycle.

5.0 CONCLUSIONS

Soil chemical properties control the availability of nutrients to plants. Therefore, nutrients must be present in sufficient quantities, or yields will be limited. It is imperative then that the natural reservoir of these nutrients must be maintained so as to support plant life and by extension animals well being.

6.0 TUTOR MARKED ASSIGNMENT

1. Explain why nutrients are said to cycle rather than flow within ecosystems.
2. Describe the four nutrient reservoirs and the processes that transfer the elements between reservoirs.
3. Name the major reservoirs of carbon.
4. Describe the nitrogen cycle and explain the importance of nitrogen fixation to all living organisms. Name three other key bacterial processes in the nitrogen cycle.
5. Describe the phosphorus cycle and explain how phosphorus is recycled locally in most ecosystems.
6. Explain how decomposition affects the rate of nutrient cycling in ecosystems.

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