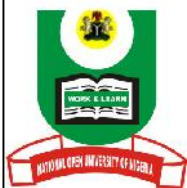


COURSE GUIDE

SLM 514 SOIL ECOSYSTEM

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INTRODUCTION

The study of soil ecosystem is mainly concerned with its physical, biological and chemical components, as well as modification caused by the interaction of these components. The soil physical components are continuously modified by the chemical and biological products of their associated life-forms. The ecosystem evolves towards a steady-state dictated by the interaction of each of the components. Soil organisms derive their energy mostly from sunlight and chemical components of the ecosystem in form of nutrients obtained from the parent rock, decomposed living organisms and the atmosphere. The interaction of living and non-living components; the soil, plants, animals, atmosphere regulates the release and uptake of nutrients in the environment such as carbon and nitrogen, which are among the most common ones. The exchange between the various forms of the nutrients, known as nutrient cycling, takes place either in the presence or absence of oxygen referred to as aerobic or anaerobic conditions, respectively.

Among the most important living microscopic components of the ecosystem are rhizobia or root nodule bacteria; a group of bacteria that infect the roots of legumes to form root nodules. They then engage in symbiotic association with the legumes, having shelter and deriving their energy in the form of photosynthetic products from the legumes. In turn, they reciprocate the legumes by converting atmospheric nitrogen in the soil atmosphere into forms that the legumes could take for their growth and development, such as ammonium and nitrates. The nitrogen (N) may subsequently be released to the soil and the N-cycle through the decomposition of the legumes nitrogen-rich residues. Another important symbiotic association between micro-organisms and the plants, not necessarily legumes is mycorrhiza. This interaction between the roots of the various plants species and certain fungi to form mass of mycelia that increases the surface area for the uptake of moisture and nutrients, especially phosphorus. All these portray the direct relationship among the soil, vegetation and landscape in influencing the various nutrients' cycling. This course has to do with knowledge of the interaction among the various components of the soil ecosystem as it influences nutrient cycling in the soil environment that in turn directly affect agricultural production.

WHAT YOU WILL LEARN IN THIS COURSE

This course guide which carries two credit units, tells you briefly what to expect from reading this course material. The study of soil ecosystem could be described as the study of a central aspect of modern ecology to do with understanding the flows of energy and elements between organisms and their abiotic surroundings with special reference soil as a major component. The process of soil formation depends on a complex network of biological, chemical and physical components of the ecosystem. The role of soil microbes is at the fore front, being responsible almost all biological transformations and engineering the development of stable and labile pools of carbon (C), nitrogen (N) and other nutrients. This enhances the subsequent establishment of the associated plant communities.

COURSE AIM

The course aims to provide good understanding of the various components of the soil environment, their interaction and influences on each other with emphasis on the benefits that could be derived from their relationships to increase and sustain agricultural productivity.

COURSE OBJECTIVES

If you attend the course, you are expected to be able to:

- explain the concept, structure and function of the soil ecosystem
- explain the sources of energy and nutrients for soil organisms
- explain how soil ecosystem develops
- describe how organic matter decomposition contributes to energy supply for soil organisms
- describe the process of nutrient cycling with particular reference to c and n and the roles of aerobic and anaerobic processes
- explain the contribution of rhizobia and mycorrhizae to nutrient cycling and energy flow in the soil ecosystem
- explain inter relationship between soil and vegetation in the landscape.

You should able to vividly describe how the soil ecosystem could be used or modified to improve crop production.

WORKING THROUGH THIS COURSE

This course has been put together bearing in mind that you had courses that have introduced you to the concepts of the soil habitat and soil

organisms, particularly the microorganisms. Therefore, it has been designed to further your knowledge on how to understand interrelationship among the components of the ecosystem as related to energy, nutrients flow and cycling as linked to their influence on crop growth. Tables and Figures have been used, where relevant to facilitate your understanding. Study the work carefully and also attend the tutorials, where you will interact with colleagues and tutors to socially learn what this document could not provide.

COURSE MATERIALS

You will be provided with; A course guide and study units.

A list of some text books are also provided at the end for your reference. Though not compulsory to buy, that could be very useful in enhancing your knowledge and understanding of various aspects of the soil ecosystem discussed.

STUDY UNITS

This course is divided into 15 units. The following units are contained in the course.

Module 1

- Unit 1 The Concept of Ecosystem
- Unit 2 The Soil Ecosystem
- Unit 3 Structure and Function of Organisms in the Soil Ecosystem
- Unit 4 Development of the Soil Ecosystem
- Unit 5 Microbial Ecology

Module 2

- Unit 1 Organic Matter Decompositions and Energy.
- Unit 2 Role of Different Components of Organic Matter.
- Unit 3 The Soil Food Web
- Unit 4 Biogeochemistry and Nutrient Cycling, C and N Cycling
- Unit 5 Aerobic and Anaerobic Processes

Module 3

- Unit 1 Contributions of Rhizobia to Nutrient Cycling to Energy Flow.
- Unit 2 Contributions of Mycorrhizae to Nutrient Cycling and Energy Flow.

Unit 3	Inter Relationship Between Soil and Vegetation.
Unit 4	Role of Plant Roots
Unit 5	The Concept of Rhizosphere.

MODULE 1

You will be introduced to the concept of ecosystem in unit 1. General meaning and description of what is called an ecosystem and it constitutes will be covered. In unit 2 the focus is the soil ecosystem as it differs from other ecosystems and its peculiarities. While in unit 3 the structure and functions of the different types of organisms existing in an ecosystem as they contribute to their mutual existence and maintenance of the system. Unit 4 will dwell on how an ecosystem develops, from when it was not there to a full-fledged ecosystem with all the components. Unit 5 on the other hand, will describe the microbial ecology as different from other ecologies. The contribution of microorganism to the general existence of an ecosystem will be explained fully.

MODULE 2

Unit 1 will expose you to details on how decomposition of organic matter is key to the generation of energy for the activities of all organism and their functions in the ecosystem. Unit 2 will describe the role of the different components of organic matter in decomposition. While unit 3 will describe the soil food web and its nature, unit 4 will introduce you to general nutrient cycling in the ecosystem. C and N cycles as central to the survival of the ecosystem and involves all its components, the living and non-living. While unit 5 will discuss aerobic and anaerobic processes i.e. those requiring oxygen for their completion and those not requiring oxygen.

MODULE 3

Unit 1 will focus on how rhizobia act as a converter of atmospheric nitrogen into forms directly usable by the plants for development of its biomass, known as nitrogen fixation. This is done in symbiotic relationship with legumes. The N in the plant shoots is subsequently released on decomposition of the plant residues into the N cycle. Unit 2 discusses mycorrhizae; symbiotic association between certain fungal species with over 90% of species of plants facilitating the uptake phosphorus moisture and other nutrients by the plants, which are also subsequently released into their natural cycles. Unit 3, on the other hand will focus special role of vegetation and how it relates with the soil and other components of the ecosystem. While unit 4 will explain the role of plant roots in influencing the soil and plant growth. While chapter 5 will

dwell on the meaning and nature of the rhizosphere as the most important component of the soil that influences plant growth, which exerts the highest influence on plant growth.

TEXT BOOKS AND REFERENCES

Paul, E. A. (2007). *Soil Microbiology, Ecology and Biochemistry*. (3rd ed). Academic Press. Elsevier Inc. USA and UK.

Bot, E. & Benites, J. (2005). *The Importance of Soil Organic Matter*. FAO Soils Bulletin 80. Rome, Italy.

Isirimah, N. O., Dickson, A. A. & Igwe, C. (2003). *Introductory Soil Chemistry and Biology for Agriculture and Biotechnology*. OSIA International Publishers Ltd.

ASSESSMENT

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

TUTOR-MARKED ASSIGNMENT

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

FINAL EXAMINATION AND GRADING

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

SUMMARY

The course provides you with knowledge about the soil ecosystem, mainly concerned with the study of the physical, biological and chemical components of the soil and modifications caused by the interaction of these components in relation to their influence on plant growth. At the end of the course you will be able to answer the following questions:

1. Explain the general concept of ecosystem
2. Explain the meaning of soil ecosystem.
3. Describe the soil ecosystem structure?

4. What are the functions of the organisms in the soil ecosystem?
5. What are the sources of energy and nutrients for the organisms in the soil ecosystem?
6. How does the soil ecosystem develop?
7. Give a description of soil microbial ecology.
8. What is the relationship between soil organic matter decomposition and energy supply to soil organisms?
9. Describe nutrient cycling in relation to C and N in the soil ecosystem.
10. Differentiate between aerobic and anaerobic processes in the soil ecosystem.
11. What is the role of rhizobia in nutrient cycling and energy flow in soil ecosystem?
12. What is the role of mycorrhizae in nutrient cycling and energy flow in soil ecosystem?
13. What is the relationship between soil and vegetation on the landscape?
14. What are the roles of plant roots in soil development and plant growth?
15. What is rhizosphere and what role does it play in the relationship between the soil and vegetation.

We wish you a successful study of the course and proper understanding of the soil ecosystem as it relates to plant growth.

Best of luck.

**MAIN
COURSE**

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MODULE 1

Unit 1	The Concept of Ecosystem
Unit 2	The Soil Ecosystem
Unit 3	Structure and Function of Organisms in the Soil Ecosystem
Unit 4	Development of the Soil Ecosystem
Unit 5	Microbial Ecology

UNIT 1 THE ECOSYSTEM CONCEPT

CONTENTS

1.0	Introduction
2.0	Objectives
3.0	Main Content
3.1	Discrete Categories of Organisms in the Ecosystem
3.2	Food Chain and Metabolic Network
3.3	Ecosystem Productivity
4.0	Conclusion
5.0	Summary
6.0	Tutor-Marked Assignment
7.0	References/Further Reading

1.0 INTRODUCTION

The ecosystem concept is central to modern ecology; it provides a framework for understanding the flows of energy and nutrients among organisms in their mutual existence and their relationship with the abiotic or non-living environment. This leads to the concept of food chains, which specifies the direction of energy flows between several trophic levels of organisms. This begins with primary producers that involve in photosynthesis to consumers at different levels and eventually to the decomposers.

2.0 OBJECTIVES

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

- describe the general concept of ecosystem
- state the different categories of organisms in the ecosystem
- state the functions of the organisms in the ecosystem
- describe the basis for ecosystem productivity.

3.0 MAIN CONTENT

3.1 Discrete Categories of Organisms in the Ecosystem

1. Producers, the autotrophic organisms (photosynthetic plants as well as photo- and chemosynthetic bacteria) building their body tissues from CO₂ and other inorganic compounds. These organisms form the base of the food chain.
2. Herbivores are animals that consume plants.
3. Primary carnivores are meat-eating animals that consume herbivores.
4. Secondary carnivores consume other animals (in some ecosystems we can find also tertiary carnivores feeding on the secondary ones).
5. Decomposers are the majority of microorganisms (bacteria, archaea, and fungi) and small animals that utilize the dead organic matter (plant litter and animal residues) as source of energy and building blocks for their bodies. As a result of decomposition, they release (mineralize) inorganic nutrients from dead bodies of both plant and animals, making them available for plants to keep the primary production going.

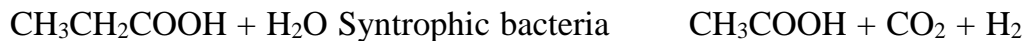
Groups 2-5 are also called heterotrophs, contrary to autotrophs they require organic compounds as nutrients. Herbivores and carnivores belong to the consumer category (holozoic type of nutrition characteristic for all animals using jaws and tooth or equivalents for food intake), while in Group 5, decomposers are organisms with osmotrophic type of nutrition (transporting soluble nutrients through cellular membrane). We can also sub-divide organisms as biophages (eating other living organisms) and saprophages or detritophages (consuming dead organic matter). Microbial biophages include (a) parasites (*Bdellovibrio*) which invade host cells and multiply inside causing cell lysis, (b) predators attacking other cell with extracellular lytic enzymes (mixobacteria, nematode-trapping fungi), and (c) symbiotic heterotrophic microorganisms closely associated with autotrophic macroscopic partners (mycorrhiza, rhizobia, mycobiont in lichen, etc). Majority of soil and aquatic microbes belong to the category of saprophages or saprotrophs using dead organic matter as source of nutrients and energy.

Generally, food chains are rarely longer than four to five trophic levels, and lower trophic levels contain more individuals (higher number of species and bigger biomass) than higher trophic levels. The latter pattern came to be known as Elton's "pyramid of numbers" (Figure 1). The progressive reduction in the size of each trophic level is explained by the fact that only approximately 10% of the total energy in a trophic level is

passed along to the next trophic level. The rest are lost as indigestible material and heat from metabolic respiration. Purely microbial food chain is generally more efficient, e.g., grazing of bacterial prey by protozoa can be characterised by conversion of at least 20-40% of consumed bacterial mass into cell mass of protozoa. An even higher efficiency of conversion is observed for decomposers growing on easily available organic substrates.

3.2 Food Chain and Metabolic Network

Microbial populations either *in situ* or *ex situ* (in laboratory culture) produce a significant amount of extracellular metabolites. These compounds form a pool of C-compounds in natural habitats, which encourage both competition for common substrates and cooperation through the so-called metabiotic interactions, in which the product of one species is utilized by other species. Several simple compounds often participate in such interspecific exchange of mass and energy that are called central metabolites or centrobolite. Examples include molecular hydrogen, acetate, methane, etc. For instance, H₂ is produced by cyanobacteria and by microbes with active nitrogenase, as well as by fermenting bacteria and fungi; it is consumed by methanogens, acetogens, sulfate-reducers and aerobic H₂-oxidizing bacteria. Removal of H₂ by methanogens is essential to sustain anaerobic degradation of plant residues; otherwise, equilibrium is shifted toward the formation of toxic fatty acids:



Interestingly, the functional group of syntrophic bacteria can catalyze this reaction in both directions depending on the activity of complementing microbial population, e.g., methanogens or acetogens (the syntrophy stands for the cross-feeding that occurs when two organisms mutually complement each other in terms of nutritional factors or catabolic enzymes related to substrate utilisation). The metabolic network and food chain have one common feature: both provide flows of energy and matter between organisms and abiotic environment. The difference is that metabolic interspecific exchange occurs within the same trophic level of osmotrophic organisms, while the food chain or food web (the highly branched chain) assumes the flow of energy between different trophic levels.

3.3 Ecosystem Productivity

The primary productivity of ecosystem shows the rate of photosynthetic production, the conversion of solar energy into phytomass. Gross primary production (GPP) is the sum of net primary production (NPP) and plant respiration (R), which is the reverse process of photosynthesis, the oxidation of phytomass to CO₂. The secondary productivity (SP) of the ecosystem is the rate of biomass formation by heterotrophic components of the ecosystem, consumers and decomposers. All terms of ecosystem's energy balance are rates, and should not be confused with instant biomass of producers, consumers and decomposers.

4.0 CONCLUSION

The concept ecosystem provides a framework for understanding the flows of energy and nutrients among organisms and between them and their abiotic environment.

5.0 SUMMARY

In unit 1, we have learnt that:

- Ecosystem provides a framework for understanding the flows of energy and nutrients among organisms and their abiotic surroundings.
- There exists food chain of organisms, indicating dependence of different groups of organisms with each other for mutual survival.
- Organisms in an ecosystem include; producers, herbivores, primary carnivores, secondary canivores and decomposers, all performing different functions.
- Extracellular metabolic compounds form a pool of C-compounds that encourage competition and cooperation through metabiotic interactions.
- The productivity of the ecosystem depends on its members and their activities, ranging from primary production in photosynthesis to consumptions and decomposition, which determine energy flow.

6.0 TUTOR-MARKED ASSIGNMENT

Organisms and their activities are the basis for the existence of an ecosystem, discuss.

7.0 REFERENCES/FUTHER READING

Isirimah, N. O., Dickson, A. A. & Igwe, C. (2003). *Introductory Soil Chemistry and Biology for Agriculture and Biotechnology*. OSIA International Publishers Ltd.

David, P. & Parker, V. (1998). *Ecological & Scale*. Columbia University Press.

UNIT 2 THE SOIL ECOSYSTEM

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- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 The Soil Ecosystem Engineers
 - 3.2 Factors Effecting the Soil Ecosystem Functions
- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor-Marked Assignment
- 7.0 References/Further Reading

1.0 INTRODUCTION

Soils are the part of the earth's surface, which form a narrow interface between the atmosphere and the lithosphere. Soils are made up of water, gases and mineral matter together with a diverse range of organisms and materials of biological origin. Organic materials in and on the soil are broken down and transformed - mainly by soil organisms - into nutrient elements, which are, in turn taken up by plants and micro-organisms.

Soil organisms are the main mediators of soil functioning at different scales. These functions can be described as having a hierarchical relationship. The determinants of soil processes are climate, soil characteristics - especially the abundance and types of clays and nutrients and the quality of the organic materials input. These factors affecting soil functioning are determined by both spatial and temporal scales.

2.0 OBJECTIVES

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

- differentiate the soil ecosystem from other ecosystems.
- identify and describe the roles of the soil 'ecosystem engineers'.
- state the factors effecting the soil ecosystem functions.

3.0 MAIN CONTENT

3.1 The Soil Ecosystem Engineers

The so-called "ecosystem engineers" are of major importance in both the ecosystem and soil development and maintenance. These species control the availability of resources to other species, either directly or indirectly. These organisms physically modify, maintain and create new

habitats for other organisms. One effect of such organisms is to create higher habitat diversity, which may in turn increase species diversity. An example of physical and ecological engineers is plant roots that create large voids (spaces) in the soil through their decay. Other ecosystem engineers are termites and earthworms that play a major role in moving, mixing and aerating the soil through their burrowing, other organisms, including higher plants and animals also play substantial roles in this respect.

3.2 Factors Affecting the Soil Ecosystem Functions

The functioning of the soil system is determined by the decomposition rates of dead organic materials. The balance between mineralisation, which releases nutrients available to plants and microorganisms and humification, which forms reserves of soil organic matter (SOM) and colloidal organic compounds as well as the degree of synchronisation of nutrient release with plant demand. Soil physical structure also determines the rates and patterns of gas exchange, soil water movement into and through the soil and erosion rates that in turn determines the ecosystem functions. The texture of the soil (% of sand, silt and clay) also influences the activity of soil organisms and hence the soil biological functioning. Texture is an important characteristic of soil because it influences many aspects of soil fertility, especially the amount of water held by the soil, its capacity to retain plant nutrients, and the ability of roots to develop and grow through the soil. Soils with a high percentage of clay are said to be “heavy” soils and have a capacity to retain water due to the small pore spaces and high surface tension forces. Soils with a high percentage of sand are considered “light” soils, and tend to hold very little water. Water infiltrates rapidly into sandy soils and is readily drained through the large pores spaces, unless they also contain a lot of organic matter.

5.0 CONCLUSION

The soil ecosystem is peculiar from other ecosystems, mainly effected by the decomposition rates of organic matter, existing organisms and the texture and structure of a soil.

5.0 SUMMARY

- Soil ecosystem is peculiar from the general ecosystem as determined by particular soil characteristics.
- There are organisms that derive the soil ecosystem, known as ecosystem engineers, such as plants and termites.

- The determinants of soil processes are climate, soil characteristics - especially the abundance and types of clays and nutrients and the quality of the organic materials input.
- The main factors effecting the soil ecosystem functions are decomposition of organic matter, structure and texture through direct influence on the other components.

6.0 TUTOR-MARKED ASSIGNMENT

Describe the peculiarities of the soil ecosystem, stating clearly the factors effecting the soil ecosystem functions.

7.0 REFERENCES/FURTHER READING

Richard, D. B. (2005). *The Biology of Soil, a Community and Ecosystem Approach*. Oxford University Press.

Isirimah, N. O., Dickson, A. A. & Igwe, C. (2003). *Introductory Soil Chemistry and Biology for Agriculture and Biotechnology*. OSIA International Publishers Ltd.

David, P. & Parker, V. (1998). *Ecological Scale*. Columbia University Press.

UNIT 3 STRUCTURE AND FUNCTION ORGANISMS IN THE SOIL ECOSYSTEM

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- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 diversity of the organisms in the soil ecosystem.
 - 3.2 classification of organism in the soil ecosystem.
 - 3.3 functions organisms in the soil ecosystem.
- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor Marked Assignment
- 7.0 References/Further Reading

1.0 INTRODUCTION

The Soil is a porous, semi-aquatic medium within which temperature and moisture conditions are highly buffered. Soils are among the first terrestrial environments to be colonized because they possess environmental conditions that are intermediate between aquatic and aerial media. Hence the Soil is a large reservoir of biodiversity, often little known. Soil communities are among the most species-rich compartments of terrestrial ecosystems. It is believed that there are twice as many species of organisms living in the soil than there are in tropical rainforest canopies. Soil organisms carry out a range of processes that are important for soil health and fertility in soils of both natural ecosystems and agricultural systems. They perform and regulate a major proportion of the organic matter transformations and of the carbon (C) and nutrient fluxes in terrestrial ecosystems.

2.0 OBJECTIVES

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

- describe the diversity of organisms in the soil ecosystem
- classify the organism in the soil ecosystem
- state the functions of the organism in the soil ecosystem.

3.0 MAIN CONTENT

3.1 Diversity of the Organisms in the Soil Ecosystem

The diversity of life in the soil, known as soil biodiversity, is an important but poorly understood component of terrestrial ecosystems. Soil biodiversity comprises of the organisms that spend all or a portion of their life cycles within the soil or on its immediate surface (including surface litter and decaying logs). The easiest and most widely used system for classifying soil organisms is to group them by size into three main groups: macrobiota, mesobiota and microbiota.

3.2 Classification of Organism in the Soil Ecosystem

Microbiota comprises microorganisms, both microflora and microfauna (Table 1). Microorganisms are the smallest of the soil organisms, which range from 20 - 200 μm . They are extremely abundant and diverse. They include: algae, bacteria, cyanobacteria, fungi, yeasts, myxomycetes and actinomycetes that are able to decompose almost any existing natural material. Microorganisms transform organic matter into plant nutrients that are assimilated by plants. Microfauna includes small Collembola and mites, nematodes and protozoa, that generally live in the soil-water film and feed on microflora, plant roots, other microfauna and sometimes larger organisms. Microfauna form the link between the primary decomposers (i.e. microorganisms) and the larger fauna in the food-web in the soil. They are also important to the release of nutrients immobilized by soil microorganisms. The mesofauna is the next largest group and range in size from 200 μm to 10 mm in length (0.1-2 mm in diameter). These include mainly microarthropods, such as pseudoscorpions, protura, diplura, springtails, mites, small myriapods (Pauropoda and Symphyla) and the worm-like enchytraeids. Mesofauna organisms have limited burrowing ability and generally live within soil pores, feeding on organic materials, microflora, microfauna and other invertebrates.

Soil macrofauna groups include organisms like earthworms, millipedes, centipedes, ants, coleoptera (adults and larvae), Isopoda, spiders, slugs, snails, termites, Dermaptera, Lepidoptera larvae and Diptera larvae. In terms of their abundance and soil forming roles, earthworms, termites and ants are the most important macrofauna components of soils. Indeed, the importance of their activities has caused them to be called “ecosystem engineers”. They burrow and are important in mixing the soil - known as bioturbation. Macroarthropods and Mollusca are constant inhabitants of litter and to a lesser extent, soils, but they have generally more specific ecological roles. Thus, most of them live in the

litter or in the upper few centimetres of the soil; saprophagous arthropods play a major role in the breakdown of surface litter.

3.3 Functions Organisms in the Soil Ecosystem

Most soil animals occur in the top 30 cm of soil, although some also occur at lower depth. Soil animals may move to lower soil layers when conditions at the surface are harsh. Most soil animals occur in the surface layer because it contains the highest amount of food (C and nutrients) in the form of organic matter and other organisms. In both natural and agricultural systems, soil organisms perform vital functions in the soil. The interactions among organisms enhance many of these functions, which are often controlled by the enormous amount of organisms in the soils. These functions range from physical effects, such as the regulation of soil structure and edaphic (in soil) water regimes, to chemical and biological processes such as degradation of pollutants, decomposition, nutrient cycling, greenhouse gas emission, carbon sequestration, plant protection and growth enhancement or suppression. To reduce the huge complexity of organisms that live in the soil, a division of soil organisms into functional groups has been proposed (Table 2).

Table 1. Classification of soil organisms

Serial No.	Major groups	Smaller groups	Size	Examples
1.	Microorganisms	Microflora	< 5 μm	Bacteria Fungi
		Microfauna	< 100 μm	Protozoa Nematodes
2.	Macroorganisms	Mesoorganisms	100 μm - 2mm	Springtails Mites
		Macroorganisms	2 - 20 mm	Earthworms Millipedes Woodlice Snails and Slugs
3.	Plants	Algae	10 μm	
		Roots	>10 μm	

Note Clay particles are smaller than 2 μm Source: FAO (2005).

Table 2. Essential functions performed by soil organisms

Serial No.	Functions	Organisms involved
1	Maintenance of soil structure	Bioturbating invertebrates and plant roots, mycorrhizae and some other microorganisms
2	Regulation of soil hydrological processes	Most bioturbating invertebrates and plant roots
3	Gas exchange and carbon sequestration (accumulation in soil)	Mostly microorganisms and plant roots, some C protected in large compact biogenic invertebrate aggregates
4	Soil detoxification	Mostly microorganisms
5	Nutrient cycling	Mostly microorganisms and plant roots, some soil and litter feeding invertebrates
6	Decomposition of organic matter	Various saprophytic and litter-feeding invertebrates (detritivores), fungi, bacteria, actinomycetes and other microorganisms
7	Suppression of pests, parasites and diseases	Plants, mycorrhizae and other fungi, nematodes, bacteria and various other microorganisms, Collembola, earthworms, and various predators
8	Sources of food and medicines	Plant roots, various insects (crickets, beetle larvae, ants, termites), earthworms, vertebrates, microorganisms and their by-products
9	Symbiotic and asymbiotic relationships with plants and their roots	Rhizobia, mycorrhizae, actinomycetes, diazotrophic bacteria and various other rhizosphere microorganisms, and ants
10	Plant growth control (positive and negative)	Direct effects: plant roots, rhizobia, mycorrhizae, actinomycetes, pathogens, phytoparasitic nematodes, rhizophagous insects, plant growth promoting rhizosphere microorganisms, biocontrol agents

4.0 CONCLUSION

There are diverse organisms in the soil ecosystem, classified as macrobiota, mesobiota and microbiota living in or on its immediate surface performing different functions to keep the ecosystem in place.

5.0 SUMMARY

- There are diverse organisms in the soil ecosystem constituting the soil biodiversity and performing different functions.
- They comprise organisms that spend all or a portion of their life cycles within the soil.
- These are classified as macrobiota, mesobiota and microbiota both of animal nature (fauna) and or of plant nature (flora).
- Earthworms, termites and ants play very important roles of in soil formation.
- The organisms perform functions such ranging from physical, like regulation of soil structure, chemical and biological such as degradation of pollutants.

6.0 TUTOR-MARKED ASSIGNMENT

Explain the diversity, structure and functions of organism in the soil ecosystem.

7.0 REFERENCES/FURTHER READING

- Maria, J. I. B. (2018). *Fundamentals of Soil Ecology*. (3rd ed).. London Academic Press.
- David, P. & V. Parker, (1998). *Ecological Scale*. Columbia University Press.

UNIT 4 DEVELOPMENT OF THE SOIL ECOSYSTEM

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- 2.0 Objectives
- 3.0 Main Content
 - 3.1 Autotrophic and Heterotrophic Successions or Evolution of the Soil Ecosystem
 - 3.2 Role Of Biotic Components in The Development of The Soil Ecosystem
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- 7.0 References/Further Reading

1.0 INTRODUCTION

The development of ecosystems is usually called ecological succession. The English word “succession” and scientific term “ecological succession” are not identical. The second term is defined in many ways, starting from the simplistic version “the replacement of populations by other populations better adapted to fill the ecological niche” to a descriptive inclusive one: “The gradual and orderly process of ecosystem development brought about by changes in community composition and the production of a climax characteristic of a particular geographic region”. We can observe changes in community composition in seasonal or multiyear dynamics because of fluctuation. Contrary to fluctuations and seasonal dynamics which are cyclic or random, the ecological succession proceeds as an orderly, unidirectional and irreversible process. Succession is usually initiated by dramatic changes in the state of abiotic environment: climatic warming or cooling, flooding or desertification, fire, volcano eruption with lava-stream and so on.

2.0 OBJECTIVES

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

- describe how soil ecosystem develops
- distinguish between autotrophic and heterotrophic development or succession of the soil ecosystem
- explain the meristic approach to soil ecosystem development.

3.0 MAIN CONTENT

3.1 Autotrophic and Heterotrophic Successions of the Soil Ecosystem

There are differences between autotrophic and heterotrophic succession. The former assumes the development of plants or other autotrophic community on an initially bare land (e.g. on the magma rocks). Heterotrophic succession takes place after heavy deposition of organic matter, e.g., amendment of poor soil with manure. Succession is called primary if the development of the ecosystem starts from zero on the suddenly released rocks, lava-stream or sand dune. Secondary succession is much quicker and takes place as reforestation of abandoned arable field or after forest fire. Succession in microbial community takes place concurrently with the evolution of an entire ecosystem because gradual and orderly replacement of plant and animal species affects the microbial microenvironment.

3.2 Role of Biotic Components in the Development of the Soil Ecosystem

Purely microbial succession in the laboratory or field experiments could be observed with microcosms (microecosystems). The mechanisms of succession are viewed entirely differently by ecologists supporting one of the two competing paradigms: holistic or meristic. The holistic concept views the biotic component of the ecosystem as a kind of superorganisms. It has stable structure and strong deterministic interactions based on differentiation of niches, similar to interactions between specialized tissues and cells within multicellular organisms. Here succession is analogous to ontogenetic development of individually differentiated organisms. It can be accurately predicted and is driven by changes in the physical state of the habitat, caused by the community. The early populations modify the physical state of the habitat, providing better growth conditions for the next stage organisms. Such replacement continues until the equilibrium is attained between the biotic and abiotic components in climax. According to this concept, the biotic component of ecosystem is a community.

3.3 The Meristic Approach to Soil Ecosystem Development

The meristic approach assumes that various species have a relatively high degree of freedom. Although there are some biotic interactions between species, they can enter and leave a community through immigration and emigration. The replacement of species during succession is also not strictly deterministic and has clearly expressed stochastic nature.

The replacement occurs mainly as a result of competition between organisms occupying the same econiche. One cannot accurately predict the temporal profile of the transient community (i.e., the list of species and schedule of replacement) due to significant effects of chance, local conditions and past history.

4.0 CONCLUSION

Development of the soil ecosystem, also known as ecological succession is the gradual and orderly process of ecosystem development brought about by changes in the community composition and the production of climax characteristics of a particular geographic region.

5.0 SUMMARY

- The development of ecosystems is usually called ecological succession.
- It is brought about by changes in the community composition and the production of climax characteristics of a particular geographic region.
- The process could be autotrophic, if it starts from plants on a bare land, while terotrophic takes place after heavy composition of organic matter.
- It could be primary succession, when it starts from zero or secondary succession, such as afforestation.

6.0 TUTOR-MARKED ASSIGNMENT

Describe how the soil ecosystem develops, differentiating between autrophic and heterotrophic, as well as primary and secondary successions.

7.0 REFERENCES/FURTHER READING

David, C. C., Grossley D. A. & Paul F. H. (1996). *Fundamentals of Soil Ecology*. (2nd ed.). Elsevier Academic Press.

Maria, J. I. B. (2018). *Fundamentals of Soil Ecology*. (3rd ed).. London Academic Press.

UNIT 4 MICROBIAL ECOLOGY

CONTENTS

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 Definition and meaning of Microbial Ecology
 - 3.2 Importance of Microbial Ecology
- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor-Marked Assignment
- 7.0 References/Further Reading

1.0 INTRODUCTION

The word ecology was coined by the German zoologist Ernst Haeckel, who applied the term oekologie to the “relation of the animal both to its organic as well as its inorganic environment.” The word comes from the Greek word oikos, meaning “household, home, or place to live.” Thus, ecology deals with the organism and its environment. The word environment includes both other organisms and the physical surroundings. It involves relationships between individuals within a population and between individuals of different populations. Some definitions stress the point that ecology, as a part of life science, studies living matter at levels above an organism, populations, communities, ecosystems, and biosphere. Microbial ecology is the ecology of microorganisms; their relationship with one another and with their environment. It concerns the three major domains of life - Eukaryota, Archaea and prokaryota such as bacteria - as well as viruses.

2.0 OBJECTIVES

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

- Define and explain the meaning of microbial ecology
- State the scope organisms involved in microbial ecology
- Explain the importance of microbial ecology.

3.1 Definition and Meaning of Microbial Ecology

Microbial ecology is the science that specifically examines the relationship between microorganisms and their biotic and abiotic environment. Like plant, animal, and human ecology, microbial ecology applies the general ecological principles to explain life functions of

microorganisms *in situ*, i.e., directly in their natural environment rather than simulated under artificial laboratory conditions *ex situ* or *in vitro*. Microbial ecology is the study of microbes in the environment and their interactions with each other. Microbes are the tiniest creatures on earth, despite their small size, they have a huge impact on us and our environment.

3.2 Importance of Microbial Ecology

The study of microbial ecology helps us improve our lives via the use of microbes in environmental restoration, food production, bioengineering of useful products such as antibiotics, food supplements and chemicals. The study of these bizarre and diverse creatures that are everywhere, yet nowhere to be seen is fascinating and a pursuit that appeals to the curiosity and playfulness in us. Most types of microbes remain unknown. It is estimated that we know less than 1% of the microbial species on earth. Yet microbes surround us everywhere- air, water, soil. An average gram of soil contains one billion (1,000,000,000) microbes representing probably several thousand species.

4.0 CONCLUSION

Microbial ecology is the ecology of microorganisms; their relationship with one another and with their environment.

5.0 SUMMARY

- Microbial ecology is the science that specifically examines the relationship between microorganisms and their biotic and abiotic environment.
- It applies the general ecological principles to explain life functions of microorganisms *in situ*
- Microbes are the tiniest creatures on earth, despite their small size, they have a huge impact on us and on our environment.
- The study of microbial ecology can help us improve our lives via the use of microbes in environmental restoration, food production, bioengineering and so on.

6.0 TUTOR-MARKED ASSIGNMENT

Explain the meaning, scope and importance of microbial ecology.

7.0 REFERENCES/FURTHER READING

McArthur, J. V. (2006). *Microbial Ecology*. Elsevier.

David, C. C., Grossley, D. A. & Paul, F. H. (1996). *Fundamentals of Soil Ecology*. (2nd ed.). Elsevier Academic Press.

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MODULE 2

Unit 1	Organic Matter Decompositions and Energy.
Unit 2	Role of Different Components of Organic Matter.
Unit 3	The Soil Food web
Unit 4	Biogeochemistry and Nutrient Cycling, C and N Cycling in Soils
Unit 5	Aerobic and Anaerobic Processes.

UNIT 1 ORGANIC MATTER DECOMPOSITIONS AND ENERGY

CONTENTS

1.0	Introduction
2.0	Objectives
3.0	Main Content
	3.1 Role of Microorganisms in Organic Matter Decomposition
	3.2 The Decomposition Process and Formation of Humus
4.0	Conclusion
5.0	Summary
6.0	Tutor-Marked Assignment
7.0	References/Further Reading

1.0 INTRODUCTION

Plant residues and various organic compounds returned to the soil undergo decomposition. This is a biological process that includes the physical breakdown and biochemical transformation of complex organic molecules of dead materials of plant or animal origin into simpler organic and inorganic molecules. The continuous addition of decaying plant residues to the soil surface contributes to the biological activity and the carbon cycling process in the soil. Breakdown of soil organic matter, root growth and decay also contribute to these processes. Carbon cycling is the continuous transformation of organic and inorganic carbon compounds by plants and micro- and macro-organisms between the soil, plants and the atmosphere.

2.0 OBJECTIVES

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

- state the role of microorganisms in organic matter decomposition

- state the products of organic matter decomposition, which includes energy supply to the ecosystem
- describe the process of organic matter decomposition and formation of humus.

3.0 MAIN CONTENT

3.1 Role of Microorganisms in Organic Matter Decomposition

Decomposition of organic matter is largely a biological process that occurs naturally. Its speed is determined by three major factors: soil organisms, the physical environment and quality of the organic matter. Different products are released in the decomposition process, which include carbon dioxide (CO₂), energy, water, plant nutrients and resynthesized organic carbon compounds. Successive decomposition of dead materials and modified organic matter results in the formation of a more complex organic matter called humus. This process is called humification and its product, known as humus positively affects soil properties. As organic matter slowly decomposes, it makes the soil darker, increases soil aggregation and aggregate stability, increases the cation exchange capacity CEC (the ability to attract and retain nutrients) and contributes N, P and other nutrients to the soil.

Soil organisms, including micro-organisms use soil organic matter as food. As they break down the organic matter, any excess nutrients (N, P and S) are released into the soil in forms that plants can use. This release process is called mineralisation. The waste products produced by micro-organisms are also soil organic matter. This waste material is less decomposable than the original plant and animal material, but it can be used by a large number of organisms. Soil biota plays the most important role in nutrient cycling processes by breaking down carbon structures, rebuilding new ones or storing the C into their own biomass, thus, enhancing the ability of a soil to provide the crop with sufficient nutrients to harvest a healthy product. The organic matter content, especially the more stable humus, increases the capacity of the soil to store water and store (sequester) C from the atmosphere.

3.2 The Decomposition Process and Formation of Humus

Fresh residues consist of recently deceased micro-organisms, insects and earthworms, old plant roots, crop residues and recently incorporated manures. Crop residues contain mainly complex carbon compounds originating from cell walls (cellulose, hemicellulose, etc.). Chains of carbon, with each carbon atom linked to other carbons, form the “backbone” of organic molecules. These carbon chains, with varying amounts of attached oxygen, H, N, P and S, are the basis for both simple sugars and amino acids and more complicated molecules of long carbon chains or rings. Depending on their chemical structure, decomposition is rapid (sugars, starches and proteins), slow (cellulose, fats, waxes and resins) or very slow (lignin).

During the decomposition process, microorganisms convert the carbon structures of fresh residues into transformed carbon products in the soil. There are many different types of organic molecules in soil. Some are simple molecules that have been synthesized directly from plants or other living organisms. These relatively simple chemicals, such as sugars, amino acids, and cellulose are readily consumed by many organisms. That is why they do not remain in the soil for a long time. Other chemicals such as resins and waxes also come directly from plants, but are more difficult for soil organisms to break down. Humus is the result of successive steps in the decomposition of organic matter. Humus cannot be used by many micro-organisms as an energy source because of the complex structure of the humic substances; hence it remains in the soil for a relatively long time.

4.0 CONCLUSION

Organic matter decomposition is a biological process that occurs naturally, as determined by the type of soil organisms, physical environment and quality of the organic matter. It yields important products, such as nutrients, energy and humus.

5.0 SUMMARY

- Decomposition of organic matter is largely a biological process that occurs naturally.
- Its controlled by soil organisms, the physical environment and the quality of the organic matter.
- The products are carbon dioxide (CO₂), energy, water, plant nutrients and resynthesized organic carbon compounds.

6.0 TUTOR-MARKED ASSIGNMENT

Without microorganisms there will be no organic matter decomposition. Discuss the assertion, describing clearly, the process and products formed after decomposition.

7.0 REFERENCES/FURTHER READING

Wang, B.Y Ed. (2007). *Environmental Biodegradation*. Nova Science Publishers Inc.

McArthur, J. V. (2006). *Microbial Ecology*. Elsevier.

UNIT 2 ROLE OF DIFFERENT COMPONENTS OF ORGANIC MATTER

CONTENTS

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 decomposition of cellulose
 - 3.2 decomposition of hemicellulose
 - 3.3 decomposition of chitin
 - 3.4 decomposition of lignin
 - 3.5 decomposition of lipids
 - 3.6 decomposition of protein
- 4.0 Conclusion
- 4.0 Summary
- 6.0 Tutor-Marked Assignment
- 7.0 References/Further Reading

1.0 INTRODUCTION

Various organic compounds undergo decomposition when plant residues are returned to the soil. Decomposition is a biological process that includes the physical breakdown and biochemical transformation of complex organic molecules of dead material into simpler organic and inorganic molecules with release of energy to the ecosystem.

2.0 OBJECTIVES

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

- Describe the decomposition of the various components of organic matter.
- State the products of the decomposition of each component.
- Identify the contribution of each component to nutrient and energy supply.

3.0 MAIN CONTENT

3.1 Decomposition of Cellulose

Cellulose is the most abundant carbohydrate present in plant residues/organic matter in nature. When cellulose is associated with pentosans it undergoes rapid decomposition, but when associated with lignin, the rate of decomposition is very slow. The decomposition of cellulose occurs in two stages: (i) in the first stage the long chain of

cellulose is broken down into glucose by the process of hydrolysis in the presence of enzymes cellulase and cellobiase (ii) the glucose is then oxidized into CO₂ and water. Cellulose is a structural polysaccharide that contains glucose. It has to be decomposed by extracellular enzymes to access the glucose for catabolism. The glucose pieces are then transported into the cell for energy generation (catabolism) or production of biomass (anabolism).

3.2 Decomposition of Hemicellulose

Hemicelluloses are water-soluble polysaccharides that consist of hexoses, pentoses, and uronic acids. They are the major plant constituents, only second to cellulose in quantity. Their hydrolysis is brought about by number of hemicellulolytic enzymes known as "hemicellulases" excreted by microorganisms. Hemicellulose is converted into soluble monosaccharide/sugars on hydrolysis (e.g. of such sugars are xylose, arabinose, galactose and mannose). These are further converted to organic acids, alcohols, CO₂ and H₂O. While uronic acids are broken down to pentoses and CO₂.

3.3 Decomposition of Chitin

Chitin is a special compound which can be found in the integument of arthropods and cell wall of fungi. It is polymer that not easily degraded, hence requires a variety of enzymes for its degradation. The dominant chitin degraders are the *Actinobacteria*, *Streptomyces* and *Nocardia*, and (less importantly) fungi such as *Trichoderma* and *Verticillium*.

3.4 Decomposition of Lignin

Lignin is the third most abundant constituent of plant tissues. It accounts for about 10-30% of the dry matter of mature plant materials. It is one of the most resistant organic substances for the microorganisms to degrade however certain *Basidiomycetous* fungi are known to degrade lignin at slow rates. The final cleavages of these aromatic compounds yield organic acids, carbon dioxide, methane and water. Lignin is the main component of wood in trees. Lignin has a varied, unique, and complicated chemical structure which contains many aromatics.

3.5 Decomposition of Lipids

Soil lipids are a complex series of about 500 different types of fatty acids. They are mostly derived from plants and microorganisms. The lipid content of soil organic matter mostly range from 2% to 20%. Phospholipids are the primary lipids composing cellular membranes. Its decomposition releases energy to the ecosystem.

3.6 Decomposition of Proteins

Proteins are complex organic substances containing nitrogen, sulphur, and sometimes phosphorus in addition to carbon, hydrogen and oxygen. During the course of the decomposition of organic matter, proteins are first hydrolyzed to a number of intermediate products e.g. Proteases, peptides and so on. These are collectively known as polypeptides. The intermediate products formed are then hydrolysed and broken down ultimately to individual amino acids, ammonia and amines. Amino acids and amines are further decomposed and converted into ammonia. During the course of ammonification, various organic acids, alcohols, aldehydes and so on, are produced which are further decomposed finally to produce carbon dioxide and water.

4.0 CONCLUSION

Various component of organic matter decomposes differently and yield different products and varying amounts of energy.

5.0 SUMMARY

- Various organic compounds undergo decomposition when plant residues are returned to the soil.
- These release varying products with varying amounts of energy to the ecosystem.
- They include cellulose, hemicellulose, lignin, lipids and proteins.

6.0 TUTOR-MARKED ASSIGNMENT

Discuss the decomposition of the various components of organic matter.

7.0 REFERENCES/FURTHER READING

Bot & Benites, J. (2005). The Importance of Soil Organic Matter. Food And Agriculture Organisation of the United Nations. Rome.

Schnitzer, M. & Khan, S. U. (1978). *Organic Matter*. (Eds). Elsevier Scieintific Publishing Company.

UNIT 3 THE SOIL FOOD WEB

CONTENTS

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 Composition of the Soil Food Web
 - 3.2 Factors Effecting The Composition of the Soil Food Web
 - 3.3 Number and Activities of Organism in the Soil Food Web
- 4.0 Conclusion
- 5.0 Summary
- 5.0 Tutor-Marked Assignment
- 6.0 References/Further Reading

1.0 INTRODUCTION

The soil ecosystem could be described as interdependence life-support system composed of air, water, minerals, organic matter, macro- and micro-organisms, all of which function together and interact closely. The organisms and their interactions enhance many soil ecosystem functions and make up the soil food web. The energy needed for all food webs is generated by primary producers: the plants, lichens, moss, photosynthetic bacteria and algae that use sunlight to transform CO₂ from the atmosphere into carbohydrates. Most other organisms depend on the primary producers for their energy and nutrients, hence they are called consumers.

Soil life plays a major role in many natural processes that determine nutrient and water availability for agricultural productivity. The primary activities of all living organisms are growth and reproduction. Soil organisms live on by-products from growing roots and plant residues. In turn, they support plant health as they decompose organic matter, cycle nutrients, enhance soil structure and control the populations of soil organisms, both beneficial and harmful (pests and pathogens) in terms of crop productivity.

2.0 OBJECTIVES

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

- state the organisms that constitute the soil food web
- state the factors effecting the composition of the soil food web
- describe the number and activities of organisms in the soil food web.

3.0 MAIN CONTENT

3.1 Composition of the Soil Food Web

The living part of soil organic matter includes a wide variety of micro-organisms such as bacteria, viruses, fungi, protozoa and algae (Figure 1). It also includes plant roots, insects, earthworms, and larger animals such as moles, mice and rabbits that spend part of their life in the soil. The living portion represents about 5% of the total soil organic matter. Micro-organisms, earthworms and insects help to break down crop residues and manures by ingesting them and mixing them with the minerals in the soil, and in the process recycling energy and plant nutrients. Sticky substances on the skin of earthworms and those produced by fungi and bacteria help bind particles together. Earthworm casts are also more strongly aggregated (bound together) than the surrounding soil as a result of the mixing of organic matter and soil mineral material, as well as the intestinal mucus of the worm. Thus, the living part of the soil is responsible for keeping air and water available, providing plant nutrients, breaking down pollutants and maintaining the soil structure.

3.2 Factors Effecting the Composition of the Soil Food Web

The composition of soil organisms depends on the food source (which in turn is season dependent). Therefore, the organisms are neither uniformly distributed through the soil nor uniformly present all year. However, in some cases their biogenic structures remain. Each species and group exists where it can find appropriate food supply, space, nutrients and moisture. Organisms occur wherever organic matter occurs by-products from growing roots and plant residues. Therefore, soil organisms are concentrated around roots, in litter, on humus, on the surface of soil aggregates and in spaces between aggregates. Therefore, they are most prevalent in forested areas and cropping systems that leave a lot of biomass on the surface.

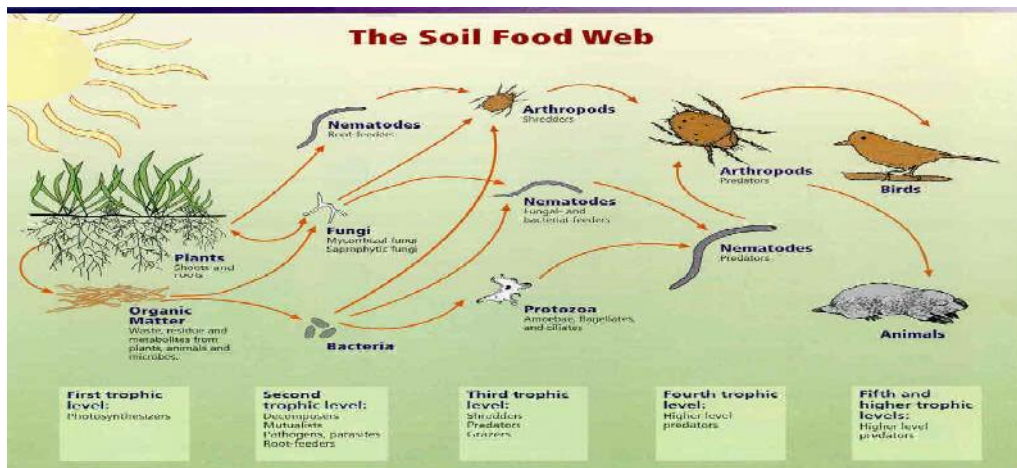


Figure 1. The soil food web

3.3 Number and Activities of Organism in the Soil Food Web

The activity of soil organisms follows seasonal as well as daily patterns. Not all organisms are active at the same time. Most are barely active or even dormant. Availability of food is an important factor that influences the number and level of activity of soil organisms and thus is related to land use and management. Practices that increase numbers and activity of soil organisms include: no tillage or minimal tillage, the maintenance of plant and annual residues that reduce disturbance of soil organisms and their habitat and provide a food supply.

4.0 CONCLUSION

The living part of soil organic matter includes a wide variety of organisms, both macro and microscopic that constitute the soil food web, the composition, number and activities of which depends on food supply, space, nutrients and moisture.

5.0 SUMMARY

- The living part of soil organic matter includes a wide variety of micro-organisms such as bacteria, viruses, fungi, protozoa and algae, plant roots, insects, earthworms, and larger animals such as moles, mice and rabbits that spend part of their life in the soil.
- The living portion represents about 5% of the total soil organic matter.
- Each species and group exists where it can find appropriate food supply, space, nutrients and moisture.
- Practices that increase numbers and activity of soil organisms include: no tillage or minimal tillage, the maintenance of plant and annual residues.

6.0 TUTOR-MARKED ASSIGNMENT

The soil constitutes a variety of organisms forming a food web. State these organisms, factors affecting their composition, number and activities.

7.0 REFERENCES/FURTHER READING

- Wayne, L. & Jeff, L (2010). *Teaming with Microbes* Timber. Press. U. S.
- David, C. C., Grossley, D. A. & Paul, F. H. (1996). *Fundamentals of Soil Ecology*. (2nd ed.). Elsevier Academic Press.

UNIT 4 BIOGEOCHEMISTRY AND NUTRIENT CYCLING WITH REFERENCE TO C AND N

CONTENTS

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 The Carbon Cycling in soils
 - 3.2 The Nitrogen Cycling in Soils
 - 3.2.1 Process of Nitrogen Gain
 - 3.2.1.1 Legumes
 - 3.2.1.2 Organic Matter Decomposition
 - 3.2.1.3 Exchangeable Form of Nitrogen
 - 3.2.2 Processes of Nitrogen Loss
 - 3.2.2.1 Immobilisation
 - 3.2.2.2 Volatilisation
 - 3.2.2.3 Run Off and Leaching
- 4.0 Conclusion
- 5.0 Summary
- 5.0 Tutor-Marked Assignment
- 6.0 References/Further Reading

1.0 INTRODUCTION

Carbohydrates can be produced using the carbon, hydrogen and oxygen in carbon dioxide and water during photosynthesis. However, living organisms need a complex array of molecules to survive. This enables them to synthesize, all the other organic molecules, such as proteins (including enzymes), nucleotides (e.g. ATP), nucleic acids (e.g. DNA and RNA) and phospholipids (found in cell membranes) they use. Plants also need nitrogen, sulfur and phosphorus. Plants also need a supply of inorganic ions dissolved in soil water to be able to carry out the synthetic reactions needed. They are able to remove these from the soil as inorganic ions, such as nitrate, sulfate and phosphate. Since elements used as nutrients are in finite supply, to support life on Earth, they must be constantly recycled.

Nutrients in the soil dissolve in rain water in a process called leaching. Nutrients are washed into rivers and transported to the sea in process called run off. They fall to ocean beds or are taken up by organisms whose dead remains fall to the sea floor. This is called sedimentation. Sediments may form rocks, locking up the nutrients for long periods of time. Eventually, through weathering, erosion and movements of earth's crust, rocks form new soil. All these constitute the biogeochemical cycle.

2.0 OBJECTIVES

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

- explain the basis of biogeochemical cycles.
- describe the carbon cycle in soils.
- explain the nitrogen cycle in soils.
- know the process of gain and losses in the nitrogen cycle.

3.0 MAIN CONTENT

3.1 The Carbon Cycling in soils

Photosynthesis and respiration are opposing processes. Energy from the Sun is used in photosynthesis to synthesize organic compounds which are energy stores. Carbon dioxide is taken up by plants, photosynthesis takes place and one of the products, oxygen, is released into the atmosphere. The other product, glucose, is stored in plant cells.

During aerobic respiration, energy stored in organic compounds is released. Oxygen from the atmosphere is used up and produces carbon dioxide. Around 100 billion tonnes of carbon dioxide is fixed in photosynthesis each year, with about 50 billion tonnes being returned through respiration by plants and animals and the remaining 50 billion tonnes through decomposition of dead organisms remains. These constitute the carbon cycle (Figure 2).

3.2 Nitrogen Cycling in Soils

Nitrogen forms present in soil are constantly undergoing change. Nitrogen cycling is a relationship involving gains, losses and transformations of N among pools in the soil. Seven forms of N are involved in the N cycle: atmospheric N gas (N_2), ammonium (NH_4^+), ammonia (NH_3), nitrate (NO_3^-), nitrite (NO_2^-), nitrogen oxide gases (NO , N_2O) and organic N. Each form of N exists in a pool. For example, organic N is part of the organic pool, NO_3^- exists in the soil solution pool and NH_4^+ can be present in the soil solution or exchangeable pool. Plants can only directly use inorganic N (NH_4^+ and NO_3^-) to meet their N requirements. The continuous changes among the nitrogen form as a result of natural processes constitute the nitrogen cycle (Figure 3).

3.2.1 Process of Nitrogen gain

3.2.1.1 Legumes-rhizobia Relationships

Atmospheric N₂ makes up 78% of the gases in the atmosphere. Hence, thousands of tonnes of nitrogen are present in the atmosphere, while N frequently limits crop production. Crops access this pool of N on conversion to a plant available form. Legumes (e.g., alfalfa, clover, peas, beans) are able to access atmospheric N₂ through a symbiotic relationship with rhizobia such those in the genus *Rhizobium* and *Bradyrhizobium*. Other free living nitrogen fixing bacteria are also involved in this conversion. These convert atmospheric N₂ to plant-available forms in a process called biological nitrogen fixation (BNF).

3.2.1.2 Organic Matter Decomposition

Organic N compounds are also an important source of N for crops. These compounds, which are part of soil organic matter, undergo decomposition to release the N they contain into plant available forms; ammonium (NH₄⁺) and nitrate (NO₃⁻). Soil organisms (e.g., insects, small animals, and microorganisms) gradually break down complex N compounds into simpler forms in a process called mineralization. Organic N compounds are converted to NH₄⁺ in the process, which can be taken up by plants from the soil. However, NH₄⁺ is usually converted quickly to NO₃⁻ by bacteria in the soil through a process called nitrification.

3.2.1.3 Exchangeable Form of Nitrogen

Ammonium has a positive charge and can be temporarily held by negative charges on soil particles. This type of reaction is called cation exchange. Exchange reactions are critical to the nutrient holding capacity of the soil and the ability of the soil to replenish nutrient concentrations in the soil solution. Adsorbed NH₄⁺ makes up a portion of the exchangeable pool of N, but as adsorbed NH₄⁺, it makes up a portion of the exchangeable pool of N, until released into soil solution.

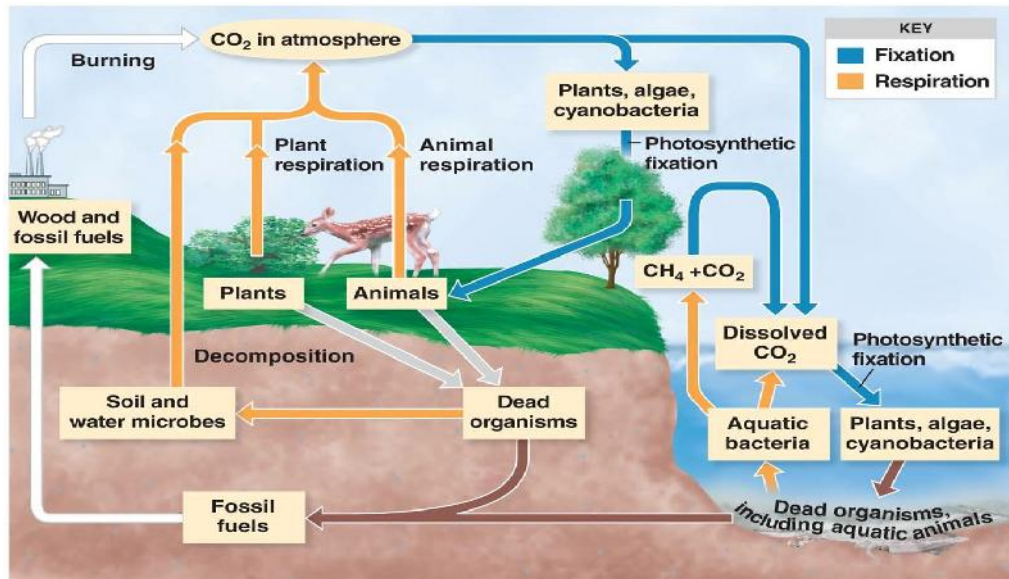


Figure 2. The Carbon cycle

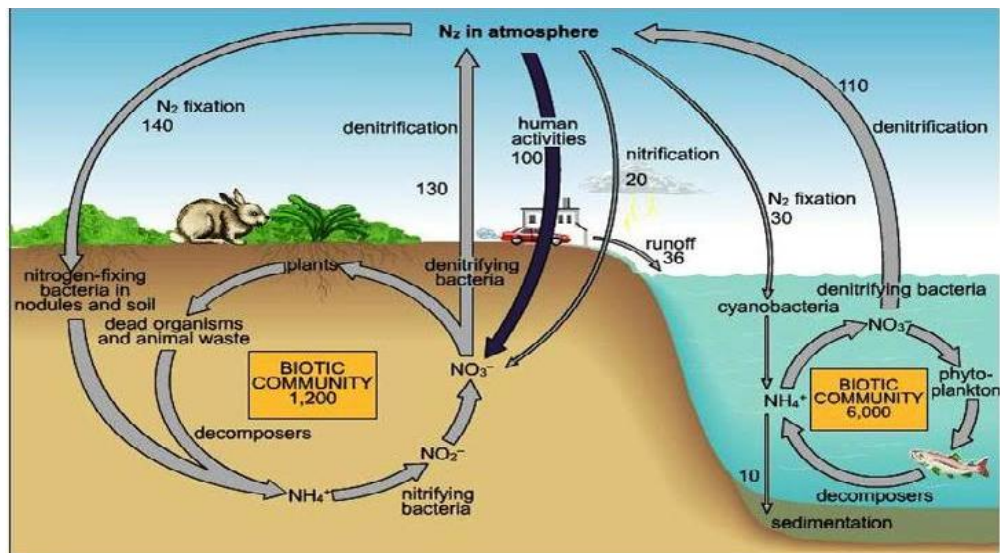


Figure 3. The nitrogen cycle

3.2.2 Process of Nitrogen Loss

3.2.2.1 Immobilisation

Nitrogen in the soil can be temporarily tied up by the microbial biomass, in a process called immobilization. Soil microbes require N to decompose crop residues and can get it either from the organic residues or soil solution. Residues with higher carbon to nitrogen ratios and more lignin, like cereal straw, decompose more slowly, immobilising N for longer periods. Eventually decomposition will be slow and microbial biomass will release the N, increasing plant available N. Organic residues with low carbon-nitrogen ratios, however, easily decompose to

release the nitrogen they contain, thus immobilizing them only for a short period.

3.2.2.2 Volatilisation

Nitrogen can be lost from the soil in four alternative ways depending on the chemical form. NH_4^+ can be converted to ammonia (NH_3) gas and lost to the atmosphere through volatilization. Situations that favour NH_3 volatilization include alkaline soil pH, low buffering capacity (directly related to cation exchange capacity) and warm moist (but drying) soil conditions. NO_3^- can be lost from soil through denitrification - the conversion to N_2O or N_2 gas through microbial activity when soil oxygen levels are low. Soils that experience anaerobic (low oxygen) conditions (e.g., water logging) are more subject to denitrification.

3.2.2.3 Run Off and Leaching

Nitrogen is also lost from soil systems through leaching and runoff. Nitrate is one of the most mobile nutrients in the soil system and readily moves with soil water. Leaching can occur in due to high rainfall, under irrigation and on fallowed fields, especially when these conditions occur on coarse textured soils. Another mode of N loss from soil is through surface runoff, carrying dissolved nutrients or sediments. This can then enter surface water ecosystems, contributing to eutrophication that cause disastrous effect on the aquatic organisms involved. Nitrogen may also be leached into under groundnut water, thus causing contamination through high nitrogen concentrations.

4.0 CONCLUSION

Conversion of nutrients (such as C and N) from one form to another among organisms, the abiotic environment and the atmosphere constitutes the biogeochemical cycles of nutrients in the environment.

5.0 SUMMARY

- The conversion of nutrients from one form to another, biological, chemical in relation to the atmosphere constitutes the biogeochemical cycles.
- The carbon and nitrogen cycles involving various processes of both gain and loss of the nutrients form their cycles.
- Carbon is mainly gained through photosynthesis and loss through respiration of organisms and the abiotic environment.
- The processes of nitrogen gain include conversion by legumes, decomposition of organic matter and exchangeable form of N.

- While the processes of nitrogen loss include immobilization, volatilisation, run off and leaching.

6.0 TUTOR-MARKED ASSIGNMENT

A balance between the processes of loss and gain of nitrogen and makes up the nitrogen cycle, discuss.

7.0 REFERENCES/FURTHER READING

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UNIT 5 AEROBIC AND ANAEROBIC PROCESSES IN THE SOIL

CONTENTS

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 Factors Leading to Aerobic and Anaerobic Conditions in Soils
 - 3.2 Variation among Organisms in their Oxygen Requirement
 - 3.3 Similarities and Differences between Aerobic and Anaerobic Respiration
- 4.0 Conclusion
- 5.0 Summary
- 5.0 Tutor-Marked Assignment
- 6.0 References/Further Reading

1.0 INTRODUCTION

Soil is one of the most complex and highly variable habitats on earth. Organisms that live in the soil have to devise multiple mechanisms to cope with variability in aeration, moisture, temperature and chemical changes for their survival, function and reproduction. Soil conditions can vary from acid to base, wet to dry, aerobic to anaerobic, reduced to oxidized and/or nutrient-rich to nutrient-poor within a distance of 1 mm. Similarly, biological activity generally follows suit with physical and chemical characteristics of a soil. For example, if soil texture and structure allow for a good balance between adequate drainage and moisture retention, with sufficient gas exchange, conditions will generally be conducive for microbial growth and activity. However, if the soil is compacted or water-saturated, it rapidly becomes anaerobic. Under such conditions, fermentative metabolism may predominate, and organic acids and alcohols are produced.

2.0 OBJECTIVES

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

- Explain soil factors leading to aerobic and anaerobic conditions.
- Explain the variation among organisms in their oxygen requirement.
- Compare and contrast between aerobic and anaerobic processes such respiration.

3.0 MAIN CONTENT

3.1 Factors Leading to Aerobic and Anaerobic Conditions in Soils

A typical soil is composed of both a mineral and organic fractions. These two fractions make up the soil solids, with the remaining soil volume composed of pore space, which at any given time is filled with some combination of air and/or water. When the soil is saturated with water, all of the air in its pore spaces will have been displaced; conversely, desiccated soil has only air in the spaces between its soil solids. The soil organic matter content, the nature of the mineral fraction, and the relative proportions of air and water are critical factors affecting microbial activity and function. Soils with their pore space dominated by water are anaerobic. This condition will limit microbial activity to that of anaerobes and facultative anaerobes, i.e., organisms capable of metabolism in the absence of oxygen (O_2).

The anaerobic process of fermentation is energetically less efficient than aerobic metabolism and its end-products are generally organic acid and alcohols, which can be toxic to plants and many microbes. Hence, a soil with much of its pore space occupied by water at most times will be a less productive soil, even though water is one of the most important plants' critical needs. A balanced situation, where about half of the soil's pore space is occupied by air and half by water, is more supportive of both plant growth and microbial metabolism. Roots require O_2 in order to respire, and aerobes (microorganisms capable of aerobic respiration) can derive vastly more energy from this process than can be derived through fermentation or anaerobic respiration.

3.2 Variation among Microorganisms in Their Oxygen Requirement

Microorganisms vary in their need for or tolerance of O_2 . These are referred to two major functional groups in terms of their functional relationship to O_2 : aerobes and anaerobes. Aerobes are species capable of growing at the O_2 concentration found in the atmosphere (21%), and they typically use O_2 as a terminal electron acceptor in the respiratory electron transport chain. There are three main types of aerobes: obligate, facultative, and microaerophilic. Obligate aerobes require the presence of O_2 for their survival; their type of metabolism is aerobic respiration. Even though, facultative aerobes do not require O_2 , they survive better if O_2 is present. These versatile bacteria have the capacity to respire either aerobically or anaerobically. Microaerophiles, however, require O_2 , but they can function at much lower levels than atmospheric concentrations. Their form of metabolism

is aerobic respiration. Anaerobes, on the other hand, do not or cannot use O_2 as a terminal electron acceptor. There are two basic types of anaerobes: aerotolerant anaerobes and obligate anaerobes. The first do not use O_2 for their metabolism, but they are not harmed by its presence. These organisms depend on a fermentative type of metabolism for their energy. Obligate or strict anaerobes, in contrast, are harmed by the presence of O_2 . These organisms metabolize various substrates to derive energy either by fermentation or anaerobic respiration.

Facultative aerobes, microaerophiles, and aerotolerant anaerobes are better able to persist in the soil environment since they have the ability to adapt readily to the often rapid changes in O_2 availability that invariably occur in the soil. The capacity of facultative aerobes to use compounds other than O_2 as terminal electron acceptors in anaerobic respiration, for example, allows them to continue to respire C substrates and to generate the energy-storing molecule ATP via the electron transport chain when O_2 supply is reduced or absent. Under such conditions nitrate (NO_3^-) and sulfate (SO_4^{2-}) are commonly used as alternative electron acceptors in anaerobic respiration.

3.3 Similarities and Differences between Aerobic and Anaerobic Respiration

There similarities and differences (Table 3) between aerobic and anaerobic respiration.

While the similarities is that both:

- (1) Yield adenosine triphosphate (ATP) a source of energy.
- (2) Require complex organic compound as substrates.
- (3) Oxidative processes.
- (4) Have the same initial stage (glycolysis).
- (5) Take place in living cells.

4.0 CONCLUSION

Aerobic and anaerobic conditions in soils are determined by the soil pore spaces, those filled with water are anaerobic, just as organism varies widely on their need for oxygen, which determines their mode of respiration.

Table 3. Differences between aerobic and anaerobic respiration

Serial No.	Item	Aerobic	Anaerobic
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1	oxygen requirement	Yes	No
2	oxidation of substrate	complete oxidation	incomplete oxidation
3	end products	carbon dioxide and water	plant cell: CO ₂ and alcohol, Animal cell: lactic acid
4	energy released per glucose	more (38 ATPs)	less (2 ATPs)
5	occurrence	in most organisms	in lower organisms, e.g. yeast, bacteria and muscle cells after prolonged contraction

5.0 SUMMARY

- Soil texture and structure with a good balance between adequate drainage and moisture retention with sufficient gas exchange is generally conducive for microbial growth and activity.
- However, compacted or water-saturated, rapidly becomes anaerobic.
- There are two major functional groups in terms of their functional relationship to O₂: aerobes and anaerobes
- Aerobes are species capable of growing at the O₂ concentration found in the atmosphere and they typically use O₂ as a terminal electron acceptor in the respiratory electron transport chain.
- Anaerobes, on the other hand, do not or cannot use O₂ as a terminal electron acceptor.
- This is the basis for variation among the organisms in the process the involve in, even though they also share some characteristics and vary in their tolerance to the presence or absence of oxygen.

6.0 TUTOR-MARKED ASSIGNMENT

Describe how soils become aerobic or otherwise, differentiate between aerobic and anaerobic soil organisms.

7.0 REFERENCES/FURTHER READING

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MODULE 3

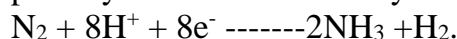
Unit 1	Contributions of Rhizobia to Nutrient Cycling and Energy Flow.
Unit 2	Contributions of Mycorrhizae to Nutrient Cycling and Energy Flow.
Unit 3	Inter Relationship Between Soil and Vegetation.
Unit 4	The Role of Plant Roots
Unit 5	The Concept of Rhizosphere.

**UNIT 1 CONTRIBUTIONS OF RHIZOBIA TO
NUTRIENT CYCLING AND ENERGY FLOW****CONTENTS**

1.0	Introduction
2.0	Objectives
3.0	Main Content
3.1	The Nitrogen Fixing Bacteria and Their Activities in the Soil.
3.2	Nature of the Symbiosis Between Rhizobia and Legumes and its Contribution to Nutrient Cycling.
3.3	Diversity of Organisms Involved in Nitrogen Fixation.
4.0	Conclusion
5.0	Summary
5.0	Tutor-Marked Assignment
6.0	References/Further Reading

1.0 INTRODUCTION

Nitrogen gas (N₂) makes up nearly 80% of the earth's atmosphere, yet nitrogen is often the nutrient that limits primary production in many ecosystems. This is because plants and animals are not able to use of nitrogen gas in the inert form. For nitrogen to be available to synthesize proteins, DNA, and other biologically important compounds, it must first be converted into a different chemical form. The process of converting N₂ into biologically available nitrogen is called nitrogen fixation. N₂ gas is a very stable compound due to the strength of the triple bond between the nitrogen atoms, which requires a large amount of energy to break. The whole process requires eight electrons and at least sixteen ATP molecules. As a result, only a selected group of prokaryotes are able to carry out this energetically demanding process.



2.0 OBJECTIVES

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

- explain the role of nitrogen fixing bacteria in the ecosystem
- explain the nature of the symbiosis between rhizobia and legumes
- describe the diversity of organisms involved in nitrogen fixation.

3.0 MAIN CONTENT

3.1 The Nitrogen Fixing Bacteria and Their Activities in the Soil

Some nitrogen-fixing organisms are free-living such as azotobacter, while others are symbiotic. The symbiotic organisms require close association with a host to carry out the process. These are called root nodule bacteria or rhizobia. Most of the symbiotic associations are very specific and have complex mechanisms that help to maintain the symbiosis. For example, root exudates (such as flavonoids) from legume plants serve as a signal to certain species of root nodule bacteria (rhizobia). This signal attracts the bacteria to the roots (triggering the expression of its Nod factors), and a very complex series of events then occurs to initiate uptake of the bacteria into the root and trigger the process of nodule formation on the root and eventually nitrogen fixation in the nodules. Other free living bacteria such as those in the genus *Frankia* are involved in nitrogen fixation.

3.2 Nature of the Symbiosis between Rhizobia and Legumes and Its Contribution to Nutrient Cycling

The symbiosis involves the supply of photosynthetic products and provision of shelter by the legume. In return, the rhizobia, using nitrogenase enzyme in the presence of leghaemoglobin and absence of oxygen, converts the inert N₂ in the soil atmosphere into forms (such as ammonia and nitrates) usable by the legume *in situ* for its growth and development. The N₂ fixed is readily converted by the legumes into organic N forms, such as amino acids and nucleotides. This spares the companion cereal crop in a mixed cropping with applied mineral N or the N is released into the soil on decomposition of the whole or part of the legume residues for subsequent crops in rotation and contributing soil N fertility and the general nitrogen cycle.

3.3 Diversity of Organisms Involved in Nitrogen Fixation

Although there is great physiological and phylogenetic diversity among the organisms that carry out nitrogen fixation, they all have a similar enzyme complex called nitrogenase that catalyses the reduction of N_2 to NH_3 (ammonia). This can be used as a genetic marker to identify the potential for nitrogen fixation. One of the characteristics of nitrogenase is that the enzyme complex is very sensitive to oxygen and is deactivated in its presence. Genes encoding nitrogenase are globally distributed and have been found in both aerobic and anaerobic habitats. Broad distribution of N_2 - fixing genes suggests wide distribution of N_2 fixing organisms in terms of environmental conditions for their survival. This is expected of a process that critical to the survival of all life on earth, described by some scientists as only second to photosynthesis.

Table 4: Representative prokaryotes known to carry out nitrogen fixation

Genus	Phylogenetic Affiliation	Lifestyle
<i>Nostoc, Anabaena</i>	Bacteria (Cyanobacteria)	free-living, aerobic, phototrophic
<i>Pseudomonas, Azotobacter, Methylomonas</i>	Bacteria	free-living, aerobic, chemoorganotrophic
<i>Alcaligenes, Thiobacillus</i>	Bacteria	free-living, aerobic, chemolithotrophic
<i>Methanosarcina, Methanococcus</i>	Archaea	free-living, anaerobic, chemolithotrophic
<i>Chromatium, Chlorobium</i>	Bacteria	free-living, anaerobic, phototrophic
<i>Desulfovibrio, Clostridium</i>	Bacteria	free-living, anaerobic, chemoorganotrophic
<i>Rhizobium, Frankia</i>	Bacteria	symbiotic, aerobic, chemoorganotrophic

Source: Bernhard, 2010

4.0 CONCLUSION

Nitrogen fixing bacteria range from a symbiotic to symbiotic, both involved in the conversation of the vast atmospheric nitrogen into form that the plants could take, and later release into the soil on decomposition and subsequently the nitrogen cycle.

5.0 SUMMARY

- Some nitrogen-fixing organisms are free-living such as a zotobacter, while others are symbiotic.
- The symbiotic organisms require a close association with a host (legumes) to carry out the process; these are called root nodule bacteria or rhizobia.

- The symbiosis involves the supply of photosynthetic products and provision of shelter by the legume, while in return, the rhizobia converts inert N₂ in atmosphere into forms usable by the legume for its growth and development.
- The nitrogen rich legume residues release the nitrogen for subsequent crops in rotation, thus contributing soil N fertility and the nitrogen cycle.
- There are diverse population of nitrogen fixing organism in varying environments globally.

6.0 TUTOR-MARKED ASSIGNMENT

Discuss the nature and activities of nitrogen fixing bacteria and with reference to their role in the nitrogen cycle.

7.0 REFERENCES/FURTHER READING

Isirimah, N. O., Dickson, A. A. & Igwe, C. (2003). *Introductory Soil Chemistry and Biology for Agriculture and Biotechnology*. OSIA International Publishers Ltd.

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UNIT 2 CONTRIBUTIONS OF MYCORRHIZAE TO NUTRIENT CYCLING AND ENERGY FLOW

CONTENTS

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 Types of Mycorrhiza Associations and the Nature of Their Symbiosis with Plants.
 - 3.2 Contribution of Mycorrhiza to Nutrient Cycling.
- 4.0 Conclusion
- 5.0 Summary
- 6.0 Tutor-Marked Assignment
- 7.0 References/Further Reading

1.0 INTRODUCTION

Mycorrhizal fungi are perhaps the best known of fungal mutualists. Mycorrhiza means fungus growing inside plant roots. Up to 5 m of living hyphae of mycorrhizal fungi can be extracted from 1g of soil. There are four groups of mycorrhizal fungi; arbuscular, ectomycorrhizal, ericoid and orchid. Arbuscular Mycorrhiza (VAM) are the most common form of mycorrhiza, especially in agricultural plant associations. These fungi have arbuscles which are growths formed inside the plant root that have many small projections going into the cells. About 150 arbuscular mycorrhizal species are known. Most plants (about 90%) have some sort of association with these fungi except for groups such as the *Cruciferae* family (eg mustard, canola, broccoli), *Chenopodiaceae* (eg spinach, beets, saltbush) and *Proteaceae* (banksia, macadamia).

2.0 OBJECTIVES

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

- Explain the different types of mycorrhiza association with plants.
- Describe the contribution of mycorrhiza to nutrient cycling in soils.

3.0 MAIN CONTENT

3.1 Types of Mycorrhiza Associations and the Nature of Their Symbiosis with Plants

A group of fungi form symbiotic relationships with plants by attaching themselves to the roots, either inter-cellularly, without penetrating the roots (ectomycorrhiza) or by penetrating the root cells (endomycorrhiza), referred to as arbuscular mycorrhiza (AM). Sometimes they have other structures called vesicles and referred to as vesicular-arbuscular mycorrhiza (VAM). The plants supply the fungi with photosynthetic products (carbohydrates), while the fungi hyphae act as an extension of the plant roots, enhancing uptake of moisture and soil nutrients, primarily phosphorus. The mycorrhizal-plant symbiosis is much more unspecific and common than other interactions between micro-organisms, such as N₂ fixation by rhizobia in association with legumes.

3.2 Contribution of Mycorrhiza to Nutrient Cycling

Mycorrhizal fungi are well known for their role in assisting plants in the uptake of phosphorus. Mycorrhizal fungi can benefit plants by promoting root branching and increasing nitrogen, phosphorus and water uptake from the soil and organic matter due to their large surface area and internal cellular mechanisms. The nutrients are subsequently released to their various cycles on the decomposition of the phosphorus rich organic materials. The organic P pool comes from microbial, plant and animal residues deposited on or in the soil. Most of the organic pool is found in the top layers of soil and nearly half of this is in the form of phytic acid. Each molecule of phytic acid has the potential to release six molecules of orthophosphate (H_2PO_4^- or HPO_4^{2-}) to the soil solution. This subsequently joins the phosphorus cycle.

4.0 CONCLUSION

Mycorrhizae are symbiotic association between fungi and plants by attaching themselves to the roots, either inter-cellular or by penetrating root cells.

5.0 SUMMARY

- Mycorrhizal fungi are perhaps the best known mutualists, which mean fungi growing inside plant roots.
- They associate with plants either inter-cellularly (ectomycorrhiza) or by penetrating root cells (endomycorrhiza).

- Mycorrhizal fungi can benefit plants by promoting root branching and increasing nitrogen, phosphorus and water uptake due to their large surface area and internal cellular mechanisms.
- The nutrients are subsequently released to their various cycles on decomposition of the nutrient rich organic residues.

6.0 TUTOR-MARKED ASSIGNMENT

Discuss the role of mycorrhizal fungi in plant development and nutrient soil in the soil ecosystem.

7.0 REFERENCES/FURTHER READING

Isirimah, N. O., Dickson, A. A. & Igwe, C. (2003). *Introductory Soil Chemistry and Biology for Agriculture and Biotechnology*. OSIA International Publishers Ltd.

UNIT 3 INTER RELATIONSHIP BETWEEN SOIL AND VEGETATION ON THE LAND SCAPE

CONTENTS

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 Direct Relationship Between The Soil and Plants as Mediated By Soil Organisms.
 - 3.2 Dead Plants as Source of Energy and Nutrients in Natural and Agricultural Systems.
 - 3.3 Relationship between Plants and Soil Microorganisms.
- 4.0 Conclusion
- 5.0 Summary
- 5.0 Tutor-Marked Assignment
- 6.0 References/Further Reading

1.0 INTRODUCTION

Plants are primary producers that capture energy by their aerial leaf systems, and much of the energy is transferred to the plant system up to the roots and shoot tips, or apical meristems through the phloem, part of the plant's vascular system specialized for the purpose. Plant roots provide a special, highly energized habitat for microorganisms living next to them in the surrounding soil, referred to as the rhizosphere. Some microorganisms are endophytic, inhabiting the interior tissues of roots as mutualists rather than as parasites. Hence, it is sometimes difficult to delineate where the realm of the plant root ends and that of soil organisms begins. The relationship between the soil, the plants inseparable entities, with their roots directly anchored by the plants. Associated soil organisms also play as significant role in the relationship.

2.0 OBJECTIVES

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

- explain how plants are the main sources of carbon and energy for the soil ecosystem
- the contribution of dead plant energy and nutrients in agricultural systems
- describe the relationship between plants and soil microorganisms.

3.0 MAIN CONTENT

3.1 Direct Relationship between the Soil and Plants

Carbon compounds released by plant roots serve as the primary source of energy for most heterotrophic or saprophytic soil organisms. Herbivores below the ground, plant-parasitic nematodes and pathogenic fungi feed directly on living root tissues, thus reducing plant productivity. However, the vast majority of organisms in the rhizosphere that feed on root-derived compounds are decomposers. Their presence around the roots is highly beneficial to plant growth, particularly when their activities release mineral nutrients that plants can subsequently acquire, thus creating a positive feedback between the plants and the rhizosphere microbial community.

3.2 Dead Plants as Source of Energy and Nutrients in Natural and Agricultural Systems

A major source of energy for soil heterotrophs or saprophytes is dead plant materials (litter) and animal residues. This is primarily in the form of leaf fall and tissues of dead plants, in addition to animal excrement and carcasses in natural vegetation. Most of the plant material is however, removed during harvests and not returned to the soil in agricultural systems. This is an undesirable management practice, since it runs down the energy status of the soil, depleting the energy needed by microorganisms to perform their many beneficial functions.

3.3 Relationship Between Plants and Soil Microorganisms

In addition to vascular plants, other primary producers that may be present in surface soil are photosynthetic bacteria, cyanobacteria, and algae. However, their energy contribution to soil is comparatively small. The soil biota are limited mainly by the amount of energy that can be produced and stored by the plants that is ultimately transferred below ground. Gross and net rates of primary production vary greatly from one plant species to another, mainly due to the photosynthetic pathway used (C3, C4, and CAM) and abiotic factors such as variations in light, soil moisture, temperature, and nutrient availability. The highest capacities for photosynthesis are seen in plants possessing the C4 photosynthetic pathway such as maize, sorghum, and sugarcane; the lowest capacity is found in plants relying on crassulacean acid metabolism (CAM), such as desert succulents. Variations in photosynthetic capacity have a direct impact on the amount of fixed C that reaches the soil and becomes available for use by heterotrophic soil organisms. Of the total C fixed by photo or chemosynthetic organisms (gross primary production [GPP]), some portion is used to fuel their own cellular respiration. GPP minus

respiration is called net primary production (NPP), or the accumulation of standing plant biomass (and that of other autotrophs). NPP is what fuels the soil subsystem, largely in the form of detritus and root exudates.

4.0 CONCLUSION

Plants are primary producers of energy through carbon compounds that benefits the whole system with little contribution from dead plant materials and soil microorganisms, which all depend on the nature of plant and abiotic soil environment.

5.0 SUMMARY

- Plants are the major primary producers that capture energy by their aerial leaf systems.
- Carbon compounds released by roots serve as the primary source of energy for most heterotrophic soil organisms
- Majority of organisms in the rhizosphere that feed on root-derived release mineral nutrients as positive feedback between to the plants
- Dead plant materials (litter) and animal residues other major sources of energy for soil heterotrophs that decompose them to release nutrients to the living plants
- Other primary producers that may be present in surface soil are photosynthetic bacteria, cyanobacteria, and algae, even though their energy contribution to soil is comparatively small.
- Gross and net rates of primary production vary greatly from one plant species to the next, mainly due to their photosynthetic pathway and abiotic factors such as light, soil, moisture, temperature, and nutrient availability.

6.0 TUTOR MARKED ASSIGNMENT

Plants are the primary energy producers in the soil ecosystem, but they could not survive without the soil discuss.

7.0 REFERENCES/FURTHER READING

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UNIT 4 THE ROLE OF PLANT ROOTS

CONTENTS

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 Nature and Function of The Plant Root System in Relation to The Soil Biota
 - 3.2 Development of Plant Roots Relative to Their Role in the Soil.
- 4.0 Conclusion
- 5.0 Summary
- 5.0 Tutor-Marked Assignment
- 6.0 References/Further Reading

1.0 INTRODUCTION

Processes that occur at or near the soil - root interface control the productivity of both plants and soil organisms. The roots also offer habitat for microorganisms such as bacteria and fungi, living within and around the roots, performing mutualistic services. Microbial population associated with roots differ in size and age. They need to be taken into account for understanding root-soil dynamics. They immensely contribute to soil development and plant productivity.

2.0 OBJECTIVES

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

- state the importance of the plant roots in soil-plant relationship
- explain the nature and function of the plant roots in relation to the soil biota
- describe the parts of the plant roots and their contribution to soil development.

3.0 MAIN CONTENT

3.1 Nature and Function of the Plant Root System in Relation to the Soil Biota

Root systems are composed of long thick roots that provide structural support and shorter, fine roots that are important in the uptake of nutrients and water. Soil biota that exist around the root system are not evenly distributed. Various root types within a single root system

support very distinct distributions of both bacterial and fungal species. Fine roots and root hairs (specialised epidermal cells) are very important in soil ecology studies. This is because microbial population associated with these roots greatly influences the root - soil dynamics. Plants acquire the water and nutrients that they need for survival through the roots. Plant roots are not passive absorbers of nutrients and water, but active regulators maintaining complex signaling relationships between roots and shoots. Root hairs and the root cap are very influential in controlling rhizosphere microbial populations. Root hairs greatly increase the amount of soil that plants can explore and from which they can extract nutrients and water. Root hairs extend into the soil environment usually less than 10 mm and range from 20 -70 mm in diameter. They form on both the structural roots, as well as on the finer lateral roots. Root hairs initially grow straight, but when they encounter soil particles they curl, bend, and often develop branches, creating microhabitats in which microbes can reside. Root hairs are often the cells in which mutualistic relationships with mycorrhizal fungi and nitrogen-fixing rhizobia bacteria are initiated.

3.2 Development of Plant Roots Relative to Their Role in the Soil

A growing plant root has three distinct zones: 1. the meristem, or zone of cell division, where new root cells are formed; 2. the zone of elongation where these cells expand and lengthen and 3. the zone of maturation, or root hair zone, where these cells mature and root hairs originate. As roots grow, root cap cells are continuously sloughed off into the soil, being replaced by the dividing meristem cells of the elongating root. Root cap cells secrete a dense mucilage of polysaccharides that serve several significant purposes, including providing a lubricant for the root to grow through the soil and for retaining moisture, thereby guarding root tissues against desiccation. Mucilage that undergoes continuous wetting and drying. Thus contributing to the formation of soil aggregates, which give the soil better structure and tilth.

4.0 CONCLUSION

Plant roots play significant roles in the soil and plant relationship through processes that occur at or near the soil - root interface, effecting the plants, soil and soil organisms.

5.0 SUMMARY

- Processes that occur at or near the soil - root interface control the productivity of both plants and soil organisms.

- Root systems are composed of long thick roots that provide structural support and shorter, fine roots that are important in the uptake of nutrients and water from the soil.
- Root hairs greatly increase the amount of soil that plants can explore and from which they can extract nutrients and water.
- Roots contribute to the formation of soil aggregates, which give the soil better structure and tilth.

6.0 TUTOR-MARKED ASSIGNMENT

Discuss the nature and role of the plant root system in the uptake of water and nutrients from the soil in relation to their role in soil formation.

7.0 REFERENCES/FURTHER READING

Thies J. E. & Grossman J. M. (2006). *The Soil Habitat and Soil Ecology*. DOI: 10.1201/9781420017113.ch5

UNIT 5 THE ROLE OF THE RHIZOSPHERE

CONTENTS

- 1.0 Introduction
- 2.0 Objectives
- 3.0 Main Content
 - 3.1 Extent of the Rhizosphere
 - 3.2 Activities of Microorganisms in the Rhizosphere
 - 3.3 Manipulation of Rhizosphere Microorganism for Increased Crop Productivity
- 4.0 Conclusion
- 5.0 Summary
- 5.0 Tutor-Marked Assignment
- 6.0 References/Further Reading

1.0 INTRODUCTION

The root surface is referred to as the rhizoplane, while biologically active area of soil that surrounds the root and is chemically, energetically and biologically different from the surrounding bulk soil is called the rhizosphere. It is the zone where plants have the highest direct influence on the soil environment. This occur through root metabolic activities, such as respiring and excreting C-rich compounds. It also occurs through non metabolically mediated processes that cause cell contents to be released into the surrounding soil, such as cell abrasion or sloughing. It is therefore, an important component of soil ecological studies.

2.0 OBJECTIVES

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

- understand that Rhizosphere is the biologically, chemically and energetically active area of soil.

3.0 MAIN CONTENT

3.1 Extent of the Rhizosphere

The rhizosphere extends outward up to 1 cm or more from the root surface depending on the plant type, soil moisture and texture. The rhizosphere and the rhizoplane provide diverse habitats for a wide assortment of microorganisms. Habitats on root surfaces are affected by differences in moisture, temperature, light exposure, plant age, root architecture, and root longevity. However, the primary way in which

plants influence the communities of microorganisms that inhabit the rhizosphere is through their deposition of root-derived compounds. These are classified as root exudates (passive process), secretions (active process), mucigel (root/microbial byproduct mixtures) and lysates (contents of ruptured cells). The accumulation of these substances in the soil is called rhizodeposition and represents the key process by which C is transferred from living plants into the soil subsystem of the larger ecosystem. Rhizodeposition increases the energy status of the surrounding soil and consequently, the mass and activity of soil microbes and fauna that are found in the rhizosphere. This is reflected in the R/S ratio, i.e., the biomass of microbes in the rhizosphere (R) in relation to that in the bulk soil (S). This ratio is generally greater than one.

3.2 Activities of Microorganisms in the Rhizosphere

Microorganisms engage in a variety of activities in the rhizosphere. Beneficial interactions include fixing N₂, solubilizing or enhancing uptake of less mobile nutrients, promoting plant growth, mutualistic symbioses, biocontrol, antibiosis, aggregating and stabilizing soil and improving water retention. Neutral or variable interactions include free enzyme release, bacterial attachment, competition for nutrients, and nutrient flux. Harmful activities include allelopathy, phytotoxicity and infection or pathogenesis. Complementing these positive, neutral or negative functions are ones that occur within roots and associated with endophytic organisms. Many activities of microbes in the rhizosphere are of benefit to plants. Indeed, some research findings have indicated that plants may select for i.e. support, certain taxonomic or functional groups of organisms present in their rhizospheres.

3.3 Manipulation of Rhizosphere Microorganism for Increased Crop Productivity

Enhancing or manipulating microbial populations found in the rhizosphere, including abundance and differential distribution of species is of central interest in soil ecology. Many inoculation programs are aimed at changing species distributions in the rhizosphere, either to enhance a particular process or to suppress plant pathogens. Inoculating legumes with specific strains of rhizobia aims to increase biological nitrogen fixation, or provide other benefits, while inoculating with mycorrhizae is intended to increase plant uptake of poorly mobile nutrients, especially phosphorus. Inoculating with *Trichoderma*, plant growth-promoting rhizobacteria or applying compost aid in suppressing plant pathogens in many systems.

4.0 CONCLUSION

Rhizosphere is the biologically, chemically and energetically active area of soil that surrounds the root in which various microorganisms engage activities benefiting the plant growth that could be manipulated for improvement in plant productivity.

5.0 SUMMARY

- Rhizosphere is the biologically active area of soil that surrounds the root and is chemically, energetically and biologically different from the surrounding bulk soil.
- Microorganisms in the rhizosphere engage activities benefiting the plants
- These activities include fixing N₂, solubilizing or enhancing uptake of less mobile nutrients, promoting plant growth, mutualistic symbioses, biocontrol, antibiosis, aggregating and stabilizing soil and improving water retention.
- Modification of the rhizosphere is the target of inoculation programs, usually aimed at changing species distributions in the rhizosphere either to enhance a particular process or to suppress plant pathogens.

6.0 TUTOR-MARKED ASSIGNMENT

Describe the role of the rhizosphere, its role in improving plant growth and how it could be manipulated for improving plant productivity.

7.0 REFERENCES/FURTHER READING

Thies, J. E. & Grossman, J. M. (2006). *The Soil Habitat and Soil Ecology*. DOI: 10.1201/9781420017113.ch5

David, C. C., Grossley, D. A. & Paul, F. H. (1996). *Fundamentals of Soil Ecology*. (2nd ed.) Elsevier Academic Press.