COURSE CODE:	FWM 303
COURSE TITLE:	NATURAL ECOSYSTEMS
NUMBER OF UNITS:	2 UNITS
COURSE DURATION:	Two hours per week

COURSE DETAILS:

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COURSE CONTENT:

THE ECOSYSTEM CONCEPT, THE MAJOR ATTRIBUTES OF ECOSYSTEMS, THE MAJOR OF ECOSYSTEMS, ECOLOGICAL ENERGETICS, ENERGY FLOW IN ECOSYSTEMS**,** BASIC LAWS OF ENERGY FLOW, TROPHIC STRUCTURE OF ECOSYSTEMS, ECOLOGICAL PYRAMIDS, PYRAMIDS OF BIOMASS, PYRAMIDS OF ENERGY, CYCLING OF NUTRIENTS IN ECOSYSTEMS**,** PATHWAYS IN TYPICAL BIOGEOCHEMICAL CYCLES IN NATURAL FOREST ECOSYSTEMS

COURSE REQUIREMENTS:

. This is compulsory course for all students in the Department of Forestry and Wildlife Management. In view of this, students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination

READING LIST:

LECTURE NOTES

THE ECOSYSTEM CONCEPT

The term “eco” implies environment; while the term “system” implies an interacting, interdependent complex.

The word ecosystem was proposed by an English ecologist, Arthur George Tansley in 1935. It is the central concept of ecology and the biologically rational management of forest resources. The ecosystem as a concept is often described as the basic unit of ecology and it embraces every level of organization.

An ecosystem (i.e. the contraction of the phrase ‘ecological system’) is a discrete structural-functional life sustaining system. It is a network of interactions between living organisms and physical, chemical, biological and social environments.

There are two basic components of the ecosystem: first, the biotic part, which is living, and second, the abiotic part, which is non-living. Both of these components are equally important to the ecosystem because without one of them the system would not function. The biotic and abiotic components in a habitat constitute an interacting environmental system in which inorganic constituents are synthesized into organic structure and through energy exchange processes, life of various forms exists in the system. Such a dynamic environmental system is known as ECOSYSTEM. i. e a contraction of the phrase ‘ecological system’.

A system implies coordinated functioning of different components. Ecosystems are the subject matter of ecology, and an understanding of their structure and function is the concern of the ecologist.

Simply defined, an ecosystem is a natural system consisting of living communities and their environment interacting to form a stable unit.

In an ecosystem the abiotic components which include all the factors of the non-living environment such as light, air, water, minerals provide the matrix for the synthesis and perpetuation of organic component (protoplasm).

The synthesis and perpetuation processes involve energy exchange and this energy comes from the sun in the form of light. Thus, in any ecosystem there must be:

1. Inorganic constituents. i. e. the abiotic component (air, water, mineral salts – nutrient elements).
2. Organisms (plants and animals) i.e. the biotic component, and
3. Energy input.

These three interact and form an environmental system. Based on their functions, organisms . i. e. the biotic component can be divided into three parts:

a) Producers
b) Consumers
c) Decomposers

The inorganic constituents are synthesized into organic structures by the green plants (primary producers) through photosynthesis and solar energy is utilized in the process. The green plants become the source of energy for the animals (herbivores – primary consumers), these animals become source of energy for the flesh eating animals (carnivores – secondary consumers). Animals of all types grow and add organic matter to their body weight and their source of energy is the complex organic compounds taken as food, are known as secondary producers. All these living organisms whether plants or animals have definite life span and die. The dead organic structures provide food for the bacteria, fungi and lots of microbes which ultimately decompose the organic structure and break the complex molecules and liberate the inorganic components into the environment. These organisms are known as **decomposers**. During the process of decomposition of the organic molecules the energy which kept the inorganic components bound together in the form of organic molecules gets liberated and dissipated in the environment as heat energy. Thus, in an ecosystem the inorganic materials (air, water, mineral salts) keep on circulating from the abiotic environment to the biotic components and back to the abiotic state. This circulatory cycle is known as BIOGEOCHEMICAL CYCLE. The energy, unlike abiotic components, has a unidirectional and non-cyclic passage in the ecosystem. It enters into the ecosystem in the form of light (solar energy), flows through the ecosystem and ultimately passes out in the form of heat.

THE MAJOR ATTRIBUTES OF ECOSYSTEMS

The term ecosystem is a concept with six major attributes:

1. The attribute of **STRUCTURE.** Ecosystems are made up of biotic and abiotic sub-components. At the very least, a terrestrial ecosystem must have green plants, a substrate, and an atmosphere, and in most ecosystems there must be an appropriatemixture of plants, animals and microbes if the ecosystem is to function. Terrestrial ecosystems normally of a complex biotic community together with soil and atmosphere, a source of energy (generally the sun), and a supply of water.
2. The attribute of **FUNCTION.** The constant exchange of matter and energy between the physical environment and the living community. Because living and non-living things are both composed of energy and matter, and because it is often difficult to define when organic material is alive and when it is dead, there are*considerable* advantages in looking at an

ecosystem in terms of physical-chemical entity. Within this entity there is a constant exchange of matter and energy between different components, some of which have the characteristics of life and some of which do not. This way of looking at ecosystems in no way denies the importance of the more traditional genetic view of life; it is complementary to it.

3. The attribute of **COMPLEXITY.** This results from high level of biological integration that is inherent in an ecosystem. All events and conditions in ecosystems are multiply determined. They are therefore difficult to predict without a considerable knowledge of the structure and functional processes of the system.
4. The attribute of **INTERACTION AND INTERDEPENDENCY**. So complete is the interconnectedness of the various living and non-living components of the ecosystem that a change in any one will result in a subsequent change in almost all the others.
5. **NO INHERENT DEFINITION OF SPATIAL DIMENSIONS.** The term ecosystem focuses on the structure, the complexity of organization, the interaction and interdependency, and the functioning of the system, and not on the geographical boundaries of the system.
6. **TEMPORAL CHANGE.** Ecosystems are not static, unchanging systems. In addition to the continuous exchanges of matter and energy, the entire structure and function of an ecosystem undergoes change over time.

THE MAJOR ECOSYSTEMS

In the broadest sense, there are **three** major types of ecosystems; namely,

1. Terrestrial Ecosystems,
2. Aquatic Ecosystems,
3. Underground Ecosystems.

In turn, in each type; subdivisions can be recognized. For example, there are freshwater, estuarine and marine aquatic ecosystems and several major types of terrestrial ecosystems, such as grassland, forest and tundra. The aquatic ecosystems are distinguished on the basis of a major chemical difference (i. e. salt content), the terrestrial ones on the other hand; are generally distinguished on the basis of the predominant type of vegetation (grass, trees etc.).

I. TERRESTRIAL ECOSYSTEMS

A) Natural Terrestrial Ecosystems

1. Wet Coastal Ecosystems,
2. Dry Coastal Ecosystems,
3. Polar and Alpine Tundra,
4. Mires: Swamp, Bog, Fen and Moor,
5. Temperate Deserts and Semi-Deserts,
6. Coniferous Forest,
7. Temperate Deciduous Forests,
8. Natural Grasslands,
9. Heathlands and related shrublands,
10. Temperate Broadleaved Evergreen Forests,
11. Mediterranean –Type Shrublands,
12. Hot Deserts and Arid Shrublands,
13. Tropical Savannas,
14. Tropical Rain Forest Ecosystems,
15. Forested Wetlands,
16. Ecosystems of disturbed Ground.

B) Managed Terrestrial Ecosystems

1. Managed Grasslands,
2. Field crops Ecosystems,
3. Tree crop Ecosystems,
4. Greenhouse Ecosystems,
5. Bioindustrial Ecosystems.

II. AQUATIC ECOSYSTEMS

A) Inland Aquatic Ecosystems

1. River and Stream Ecosystems,
2. Lakes and reservoirs

B) Marine Ecosystems

1. Intertidal and littoral Ecosystems,
2. Coral Reefs,
3. Estuaries and enclosed seas,
4. Continental Shelves,
5. Ecosystems of the Deep Oceans.

C) Managed aquatic Ecosystems

1. Managed Aquatic Ecosystems

III UNDERGROUND ECOSYSTEMS

1. Subterranean Biota

ECOLOGICAL ENERGETICS

The study of the energy relationships (inputs, storage, transfer and outputs) of ecosystems is called **ECOLOGICAL ENERGETICS.** Energy is the driving force of ecosystems. Organisms are accumulations of energy. Energy itself can take several forms or states. Four of these are most important:

1. **Radiant energy** – This is the energy of light and is composed of a broad spectrum of electromagnetic waves radiating from the sun.
2. **Chemical energy** – This is the energy stored in chemical compounds.
3. **Heat energy** – Heat energy results from the conversion of non-random to random molecular movements. This sort of energy is released whenever work is done. All types of work are included here, not only muscular contractions but also the complicated growth of organisms.
4. **Kinetic energy** (energy in motion) – This is energy which an organism possesses from its movement. The potential energy of chemical substances

is converted to kinetic energy by means of movement when it is released to do work.

ENERGY FLOW IN ECOSYSTEMS

Energy flow in ecosystems obeys the two laws of thermodynamics. **The first law of thermodynamics** which is also called **the principle of conservation of energy** states that energy may be transformed from one type into another, but it can never be created or destroyed. For example, light energy can be transformed into heat energy or into plant-food energy (chemical energy). In the process of transformation of light energy into plant-food energy, no energy is lost or destroyed, only its form is changed.

The second law of thermodynamicswhich is called **the principle of degradation of energy** states that no transformation of energy will occur unless energy is degraded from a concentrated form to a more dispersed form, and further that no transformation is 100% efficient.

Energy is quite different from matter in that it has unidirectional, non-cyclic passage through an ecosystem. During such a single cycle of energy flow in an ecosystem, the second law of thermodynamics shows that it is degraded as it progresses, so that it is gradually dispersed and lost to the surroundings in a non-usable form (entropy). The function of all biological systems, including crops, follows the second law of thermodynamics when solar energy (a high-energy form) is converted into chemical energy. Plants utilize this chemical energy in the process of building their own tissue. Some of the energy being changed from light to chemical energy is lost as heat that dissipates into the surrounding environment.

BASIC LAWS OF ENERGY FLOW

The biotic (living) component of an ecosystem carries out two basic tasks:

1) Fixing and utilizing solar energy.
2) Conserving and recycling of mineral resources.

Energy from the sun is the ultimate driving force of all ecosystems. The collection of solar energy needed to power the entire ecosystem depends directly on the plant population. Plants themselves depend on solar energy to meet their own energy needs. Of the total collected about 25% is used for respiration, 35% for building and maintaining structure, and 35% for reproduction (seeds). Plants also produce a surplus used by the consumers and reducers/decomposers. Some animal consumers feed directly upon the plant population but others obtain their energy by feeding on the first- order consumers. In general, the amount of energy removed from the plant population by animals feeding on living plants is small, estimated at about 5%. The green plants do work with the energy of sunlight to collect nutrients from the soil and gases from the air to produce food. The food energy is passed through the system in the food chains and webs from one trophic level to the next. In this way, energy flows through the system. Ecologists have traditionally looked at this energy flow in ecosystems in the same way as other scientists have examined energy flow in other physical systems.

As the heterotrophs are unable to fix the solar energy, energy fixed by the autotrophs is made available to the heterotrophs through their food. As stated in the second law of thermodynamics, when the plants are eaten by the animals; the food is assimilated and transformed into animal tissues. This transformation is not 100% efficient and approximately 90% of the energy trapped in the plant tissues is lost from the animal body through excreta and metabolic activities and only 10% of the energy is stored in the herbivore tissue. When the herbivore is eaten by a carnivore; a third step of energy transformation takes place in the body of the carnivore and during metabolic activities and through excreta the carnivore looses a major part of the energy and approximately 30 to 50% is transformed as its body tissue.

The flow of energy through food chain from the autotrophs through herbivores and ultimately through the decomposers is a continuous process in any ecosystem. Energy input into the biota is through sunlight and the exit is in the form of heat which dissipates into the space. Within the ecosystem the energy is stored in living or dead organic parts which form food of the consumers and decomposers.

TROPHIC STRUCTURE OF ECOSYSTEMS

All organisms with similar feeding habits are grouped together and known as **TROPHIC LEVEL.**

Food Chains- The transfer of food energy from the source in the plants through a series of organisms with repeated stages of eating and being eaten is known as the FOOD CHAIN. Food chain can be a simple form as in:

Plants herbivores carnivores decomposers. e.g. in a marine ecosystem a food chain could be :

Phytoplankton zooplankton whales bacteria.

Often there are more than four steps in a food chain. For example, an ecosystem could contain a sequence of three types of carnivores feeding on each other.

Plants herbivores carnivores carnivores carnivores decomposers.

However, it is rare to find more than six steps in a food chain.

There are two basic types of food chains:

1) Grazing food chain; and
2) Detritus food chain.

GRAZING FOOD CHAIN- In grazing food chain; the **plants** are **eatenlive**by the herbivores. This involves a fairly rapid and direct transfer of food energy from the living plants to grazing animals and carnivores.

DETRITUS FOOD CHAIN – In detritus food chain; **dead plants materials** (detritus), such as dead leaves, **is eaten** by a group of animals known as DETRITIVORES.

In terrestrial ecosystems; detritivores include soil mites, earthworms and millipedes, and in the aquatic ecosystems they include various worms and mollusks. The detritus food chain transmit energy to other ecosystem components more slowly than the grazing food chain chain does. Dead plant material (detritus) may remain in the system for a long time before it is consumed, although the action of the detritivores is often aided by the decomposers. Detritus food chains are generally more complicated than then grazing food chains. The two types of food chain may exist separately or they may operate in conjuction with each other.

FOOD WEB – Although simple linear food chains can be found in many types of ecosystems, feeding relationships are frequently more complicated than this because the majority of animals consume a wide variety of food. Most herbivores eat many types of plant, while most carnivores eat several types of herbivores and other carnivores.

Consequently, the linear food chains interconnect to form FOOD WEBS.

The grazing and detritus food chains often link up in food webs at the carnivore level.

The patterns of feeding relationships in food chains and webs can be determined by several techniques such as:

1) by analyzing the gut contents of animals
2) by introducing radioactive tracers to plants and monitoring their progress through the system.

ECOLOGICAL PYRAMIDS

In a grazing food chain the trophic structure can be

Green plants ------- Herbivore----Carnivore--- Top carnivore------ Decomposers

T_1 T_2 T_3 T_4 T_5

Elton, a biologist, observed that the number of organisms at T_1 is always higher than that of T_2 and at T_4; it is least.

Trophic structure of an ecosystem could be indicated by means of ecological pyramids in which T1(green plants) form the base and successive levels (consumers- T2, T3 and T4) form the tiers which make up the apex.

These pyramids are three types:

1. Pyramid of numbers;
2. Pyramid of biomass;
3. Pyramid of energy.

The first TWO types of pyramids give us information about standing crop (i.e. the amount of biomass at any time) of the ecosystem; while the third type (i.e. pyramid of energy) is indicative of the productivity of the system; and each bar represents the total amount of energy utilized at each trophic level.

1. **PYRAMID OF NUMBER**

In Africa, it has been estimated that the support of a single lion necessitates the slaughter of around 50 Zebras or their equivalent a year. The need to quantify the relationship between predators and their prey led Elton to coin the phrase, pyramid of numbers. In an ecosystem; if we count the number of individuals belonging to each of the trophic levels and represent them in successive levels in tiers, we shall get the following types of pyramids A and B.

A – When the primary producers are small as in grassland or aquatic habita

B – When the primary producers are large as tree.

The pyramid of numbers enables us to ascertain the numerical relationships between producers and consumers within a particular ecosystem. Its principal limitation is that it provides no basis for a comparison of different ecosystems.e.g. a pond and a stream, where the situations are quite different. The problem can be overcome to some extent if we use as our parameter the dry mass (biomass) of organisms rather than their numbers.

BIOMASS – is the weight of an organism after all the water has been removed.

2. **PYRAMID OF BIOMASS**

This is also usefulfor visualizing an ecosystem. In such a pyramid, the biomass of all the individuals of a trophic level are added together. The pyramid of biomass shows how, in general, biomass tends to decrease along with energy transfer.

Pyramid of biomass differ for terrestrial and aquatic ecosystems. In terrestrial ecosystems the biomass of all the primary producers is always maximum at any time and the top carnivores have minimum biomass.In ocean (aquatic) system, however, the situation is different and the biomass of the consumers is always higher than that of the primary producers which are diatoms etc; and have a shorter life-span. Pyramid of Biomass could be represented as shown below:

Terrestrial Ecosystem   Aquatic Ecosystem

The pyramid is upright in the case of terrestrial ecosystem and inverted in that of aquatic ecosystem.

3. **PYRAMID OF ENERGY**

   The pyramids of number and biomass do not give an estimate of production rate of the ecosystem and in order to know the ecological efficiency (the efficiency of energy transfer from one trophic level to the next) or productivity of the ecosystem, we base the pyramid on energy accumulation pattern at different trophic levels.

The energy available for use by organisms at each trophic level averages only approximately 10% of the preceding level. This means that as much as 90% of the energy is used up or lost during metabolism. In a pond ecosystem, for example, for every 1,000 kilocalories of energy taken in as light by the algae, which are the producers, almost 900 Kcal.are available to the minnows that eat the algae.

Bass, the secondary consumers that eat minnows, receive only 10% Kcal. or only 0.01 of the original energy input. If a human catches and eat the bass, the energy he/she receives is only 1 kilocalorie, or 0.001 of the energy initially stored by the algae.

To visualize this decrease in available energy in an ecosystem, ecologists create diagrams called Ecological pyramids and an energy pyramid shows the amount of energy, measured in calories, contained in the bodies of organisms at each trophic level. Notice that at each level. Less energy is available .i.e. such a pyramid for all ecosystems is always an upright one.

CYCLING OF NUTRIENTS IN ECOSYSTEMS

Movement and storage of energy in ecosystems are inseparable from the accumulation, storage, transfer and recycling of the chemical elements associated with this energy. Understanding one requires knowledge of the other. The study of the dynamics of these chemical elements is the focus of the ecological discipline known as BIOGEOCHEMISTRY. Energy enters, flows through, and is ultimately lost from an ecosystem. It does not cycle because it is not reused once it has been converted to heat. The chemical elements involved in this energy flow behave differently. Once they are released from their association with energy in an organic molecule, they are returned to the non living part of the ecosystem, where they may again become available for uptake by plants. Once in plants, they are reunited with solar energy in the form of a new organic molecule.

Alternatively, they may be moved to another ecosystem or may go into long-term storage. Chemicals associated with energy flow. i.e. nutrients, are therefore cycled: they are reused within the ecosystem indefinitely unless they are transferred to the cycle of another ecosystem or are converted to along-term immobile form. The cycling of nutrients in ecosystems is complex. Two simultaneous processes, MINERALIZATION and IMMOBILIZATION, are involved in nutrient cycling.

IMMOBILIZATION is the uptake of inorganic elements (nutrients) from the soil by organisms and conversion of the elements into microbial and plant tissues. These nutrients are used for growth and are incorporated into organic matter.

MINERALIZATION is the conversion of the elements in organic matter into mineral or ionic forms such as NH_3, Ca^2, H_2PO_4, SO_4^2 and K^+. These ions then exist in the soil solution and are available for another cycle of immobilization and mineralization.

The forest nutrient cycle has THREE major segments; viz:

i) the nutrient uptake;
ii) nutrient accumulation in the biomass (roots, stem, branches, leaves and other vegetation) and
iii) nutrient return.

Below is a diagram showing the pathways in typical biogeochemical cycles in natural forest ecosystems.:

PATHWAYS IN TYPICAL BIOGEOCHEMICAL CYCLES IN NATURAL FOREST ECOSYSTEMS

The nutrient storage pattern in soil, wood, litter and leaf differs in tropical and temperate forest ecosystems. In temperate regions more than 50% of the nutrients is always present in the soil, while in the tropics about 80% of the nutrients are locked up in the biomass as organic matter and only 20% is present in the soil. This situation may be due to slow decomposition rate in the cold temperate soils. Removal of temperate forest does not deplete mineral contents of the soil, while in tropical regions forest removal depletes soil of its mineral wealth by 80%. For this reason agriculture in ‘forest clearings’ in tropical countries fails after a couple of years as much of the minerals are removed along with the wood and the remaining portion is washed or leached away when the soil is exposed to heavy rains.