

S.6 TOPIC 9: ECOLOGY NOTES

BY

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Competency: The learner evaluates the interactions within ecosystems by analyzing data and personal experiences to develop strategies for enhancing food security and promoting sustainable management of natural resources.

Learning outcomes	Content break down
(a) Analyse population dynamics and the factors affecting them in different ecosystems.	• Introduction to population ecology • Population dynamics in different ecosystems. (i).Population characteristics. (ii).Population growth. (iii).Interpretation of population growth curves (iv).Factors affecting population density. (v).Estimation of population density using quadrats and capture-recapture techniques in different ecosystems. (vi).Precautions and assumptions to obtain accurate results.
(b) Analyse the processes of ecological succession and strategies for effective ecological restoration practices in diverse environments.	• Introduction to ecological succession(definition and types) • The role of primary and secondary succession in preserving diversity. • Mechanisms/processes involved in ecological succession • Concept of degraded ecosystem. • Techniques and benefits for restoring degraded ecosystems(ecological restoration techniques) • Project activity: Designing a small-scale restoration project on a degraded area within or around the school.

(c)Examine the concept of energy flow through ecosystems, its role in maintaining ecosystem stability, and its impact of human activities on energy flow (u,s)	The concept about: • Components of the ecosystem. • Energy flow in the ecosystem. • Illustrations of energy flow in the ecosystem(food chains, food webs, energy flow diagrams) • Effects of human activities on energy flow. • Bio-accumulation, bio-magnification and their importance and relationships to energy transfer/flow. • Significance of bio-accumulation and bio- magnification to the health of organisms and the environment in an ecosystem. • Analysis of bioaccumulation data. • Feed conversion Ratio(FCR) • Application of feed conversion ratios(Animal feeding efficiency) • Practical activity for learners. • Carry out a scientific investigation on feed conversion ratio in a small mammal (rat or rabbit) using different diets.
(d)Explain the concept of carbon foot print in relation to climate change, including its measurement, as well as the role of carbon sequestration in mitigating climate change(u,gs,v/a)	The concept about: • Carbon foot print and its measurement. • Activities that contribute to carbon output/key sources of greenhouse gas emissions. • How carbon sequestration in forests reduce the impact of climate change. How carbon sequestration mitigates climate change.
(e) Examine the impact of invasive species on native,biodiversity,ecosystem,and economies as well as strategies for their management and control.(u,s,gs,v/a)	The concept about; • Characteristics of invasive species. • Their impacts/effects on the native biodiversity, ecosystem, and economies.

	• Management strategies such as biological, chemical and cultural methods. • Pest control management strategies/measures such as biological, chemical and cultural methods. • Benefits of biological control over pesticide control.
(f) Analyse the concept of food security, focusing on its components and sustainable agricultural practices to address its challenges.(u,s,gs,v/a)	The concept about; • Components of food security; availability, access, utilization, and stability. • Their roles in maintaining a stable food supply. • Threats and solutions to food security. • Sustainable agricultural practices and how they support food security.

Introduction.

Ecology is the study of the relationships between organisms and with their environment that determine their distribution and abundance. An environment refers to all the conditions in which an organism for example include, temperature, light, water and other organisms.

Branches or types of ecological studies.

There are two types of ecological studies namely,

- a) Autecology** is the study of relationship between an organism and its environment. For example studying a single oak tree.
- b) Synecology** is the study of the communities and their environment, this involves the study of more than one species and their interactions in an area.
- c) Population ecology:** This branch ecology focuses on dynamics of population.

Self-check. How is the study of ecology important to a biologist?

Importance of Ecology

1. It gives us an understanding of the composition of our environment and interactions therein. This is important in biological control and maximum utilization of the environment.
2. It enables us to relate structures of organisms to their functions.
3. It accounts for the evolutionary adaptations of organisms like; through the study of giraffe's ecology we can account for the presence of the long neck.
4. It facilitates us to monitor the state of our environment such as levels of pollution.
5. It enables us to make predictions of the future trend of our environment such as predicting the population change or a dying lake.

6. It assists in designing biological control strategies such as cats control the population of rats.
7. It facilitates designing conservation strategies after registering likely trends of extinction.
8. It is vital in identifying factors responsible for environmental change. This is registered during the study of interactions.

Inter-relationship in an ecosystem means there is a close association between the living and non-living components of an ecosystem. Both affect each other and are equally important for the maintenance of the ecosystem

COMMON TERMS USED IN ECOLOGY

Interactions in the environment above be studied at various levels which include; Species; Community; Population; Ecosystem; Biosphere; Biome; Habitat and Niche.

1.Organisms. An **organism** is a living thing

2.Species. This refers to group of organisms with similar characteristics and are capable of interbreeding to produce fertile offspring. For example all human being belong to the same species called sapiens.

3.Population. This refers to the number of organisms of the same species living in an area at a given period of time. For example a population of human beings, a population of monkeys, a population of tomatoes.

4.Community. This refers to a group of organisms of different species living together and interacting in an area. It includes organisms of different species for example a farmer looking after his cattle.

5.Biosphere (Ecosphere). This includes all living organisms and the physical environment with which they interact. All parts of the earth occupied by different living organisms form the biosphere.

5.Biome is a region within the Biosphere with a unique set of environmental conditions where specific type of animal species (fauna) and plant species (flora) are adapted to live or supported. Biomes of the world include tropical rain forests, tropical savannah, grass lands, deserts, tundra of arctic and Antarctic regions, temperate regions, oceans, etc. Biomes are divided into smaller units called zones. For example tropical rain forest is divided into ground zones and canopy zones. Within each biome are habitats.

6.Habitat is a specific locality with a particular set of climatic conditions to which communities of organisms get adapted. For example, fresh water ponds, streams etc. Habitat is further divided into micro-habitats, each with its own particular conditions called microclimate.

7.Ecological niche is a spatial habitat (an area where an organism lives) and the entire ways of life and roles played in the community. A niche of an organism in absence of predators are called **fundamental niche** and its niche in presence of predators and other competitors is known as **realized niche**.

POPULATION ECOLOGY

Population ecology is the branch of ecology that deals with studies of the number of organisms and what determines their abundance and distribution. This deals with the study of the structure, size, growth, and dynamics of populations and factors influencing them.

The term population ecology is derived from the Latin word **populus** which means people. Originally, it was referred to as a group of people occupying a particular area. Like so many others, the term population has come to many things.

Ecologically, a population is a group of organisms of the same species or other groups within which individuals may change genetic information, occupying a particular space. According to Wynne Edsards (1965), a population is an automated system.

The study of how and why population size changes over time is called **population dynamics**.

i) POPULATION CHARACTERISTICS

Refers to the measurable features or attributes or parameters that describes and define a population.

A population is a group of individuals of a single species living in the same general area. Members of a population rely on the same resources, are influenced by similar environmental factors, and are likely to interact and breed with one another.

Populations are often described by their boundaries and size (the number of individuals living within those boundaries). Ecologists usually begin investigating a population by defining boundaries appropriate to the organism under study and to the questions being asked. A population's boundaries may be natural ones, as in the case of an island or a lake, or they may be arbitrarily defined by an investigator.

Characteristics of populations

Population dynamics are described in terms of the following:

1. The **population size** is the number of individuals of the same one species occupying a particular area.
2. The **population density** is the number of individuals of the same one species per unit area or volume. If the total number of individuals is reported by N and the number of units of space (area for land organisms and volume for water organisms) by S , the population density D is obtained as, $= N/S$

Space is indicated in two dimensions (m^2) for land organisms and in 3D (m^3) for aquatic organisms. Density is affected by several environmental factors such as natality, mortality, emigration, and immigration.

3. **Population growth** is the change in the number of individuals of the same species with time in a particular area.
4. The **population growth rate** is the change in the number of individuals of the same one species per unit time. Population growth is **positive** when the numbers of individuals increases with time; and **negative** when the number of individuals decreases with time.

5. **Birth rate (Natality) (BR)**; This refers to the number of new individuals produced by one organism per unit time.

6. **Death rate (Mortality) (DR)**; This refers to number of individuals dying per unit time per unit population.

7. **Carrying Capacity**. The maximum number of organisms of a given species that can be sustained in a given area by the available resources.

8. **Age Structure/distribution**. The population of individuals of each age in a population. ie the young (group before reproduction/pre-reproductive), middle age(reproduction), and old age (after reproductive stage)

9. **Sex Ratio**; This refers to the relative number of males to females in a population. It affects the reproduction potential/biotic potential. Balanced Ratios often favour population stability. The term biotic potential refers to the maximum rate at which the members of a given population can reproduce given unlimited resources and favorable environmental conditions.

10. Migration; This refers to movement of individuals into and out of the population, affecting its size and density.

There are two types;

Immigration. Which is the movement of individual into the population from another area. This increases the population size. In favourable conditions the population grows if,

Number of number of births + immigrants is greater than number of deaths + number of emigrants.

$$BR + I > DR + E$$

In unfavorable conditions, the population will decrease if,

Number of births + number of immigrants is less than number of deaths + number of emigrants.

$$BR + I < DR + E$$

Emigration. Which is the movement of individuals out of the population to another area. This decreases the population size.

11. Population distribution/Dispersion .Refers to the way how organisms are distributed/arranged in a given area or habitat. There are three types of dispersion patterns in a population.

i. Uniform/regular: The organisms are regularly or uniformly spaced in the whole habitat or area. It occurs where the competition is severe throughout the habitat.

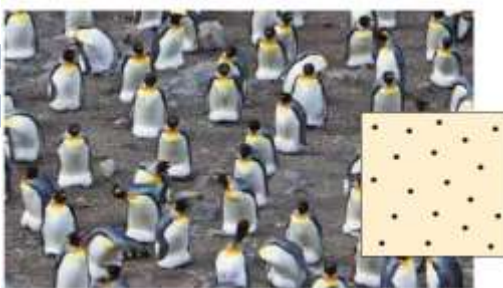
ii. Random: The tendency to aggregate is absent in random dispersion. The environment is uniform throughout the habitat and competition is also absent. This allows the organisms to be anywhere in the habitat creating a random pattern. Such dispersion occurs through seed dispersal by air.

iii. Clumped: Here, the organisms grow in clumps or groups. This pattern can further be divided into uniform, random, and aggregated.

Clumped



Regular



random



Importance of population growth and population size of different organisms in ecosystem.

- Enables monitoring of population growth
- To determine habitat requirements of species.
- To construct food webs, food chains, pyramid of numbers, pyramid of Biomass and energy,
- To be able to understand the existing food relationships within the habitats.
- The predator and prey organisms are easily identified,

- *To realize population changes overtime or seasons, so as to understand the way populations are affected by various environmental factors,*
- *It determines the population of the pests, to help in designation of control methods and rapid prevention of its spread.*
- *To determine the carrying capacity of a habitat of different populations so as to maintain ecologically balanced habitats,*
- *For management of national parks, game parks, game reserves and forest reserves to enable plans for cropping programmes.*
- *To be able to value wild life reserves (national parks) and design or alter boundaries of various conservation areas.*

POPULATION GROWTH AND POPULATION GROWTH CURVES.

Population growth is the change in population size over time. The population of a given species grows when two conditions;

- *Natality is greater than mortality*
- *Immigration is greater than emigration.*

Population growth curves are graphs which show the trends of population growth over a period of time.

There are two types of growth curves,

a) Exponential population growth (J-shaped growth curve).

b) Logistic population growth curve sigmoid (S-shaped or Sigmoid growth curve).

a) Exponential population growth (J-shaped growth curve.)

It describes a situation where organisms better adapt in the initial lag phase, then the population size increase rapidly during the exponential phase that it exceeds the carrying capacity then population growth suddenly stops and declines, population crash occurs. The populations that show this type of growth curve is referred as boom and bust populations. Its growth is regulated by density independent factors. Overpopulation can damage the environment leading to a new lower carrying capacity. After the crash the population fluctuates around the new carrying capacity. The abrupt stop (population crash) may be caused by,

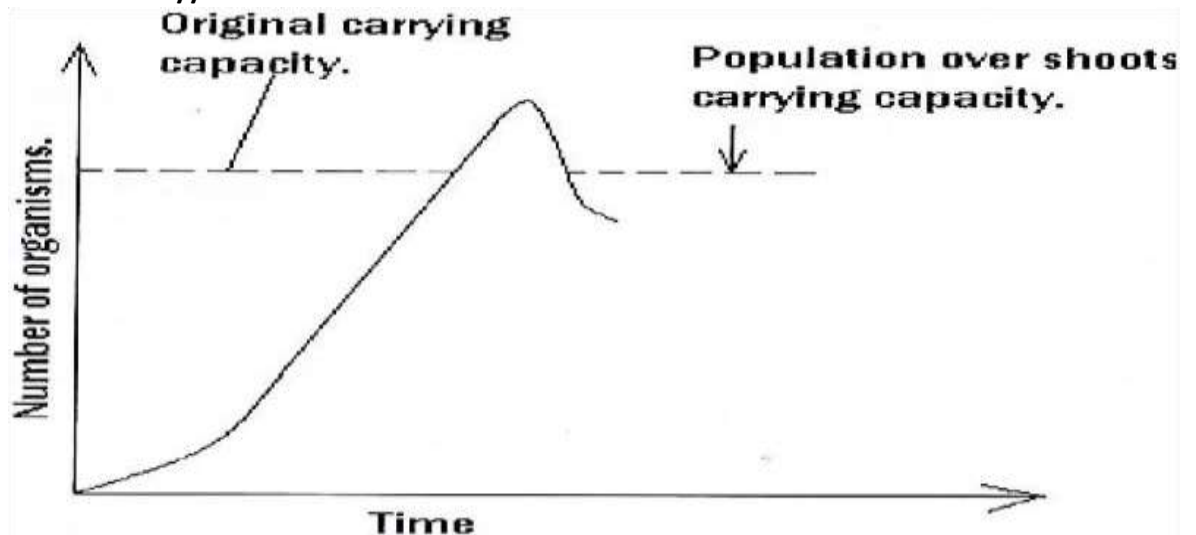
Application of pesticides or insecticides to control an insect pest.

Harsh environmental conditions.

End of breeding season.

End of particular stage in the life cycle of some organisms.

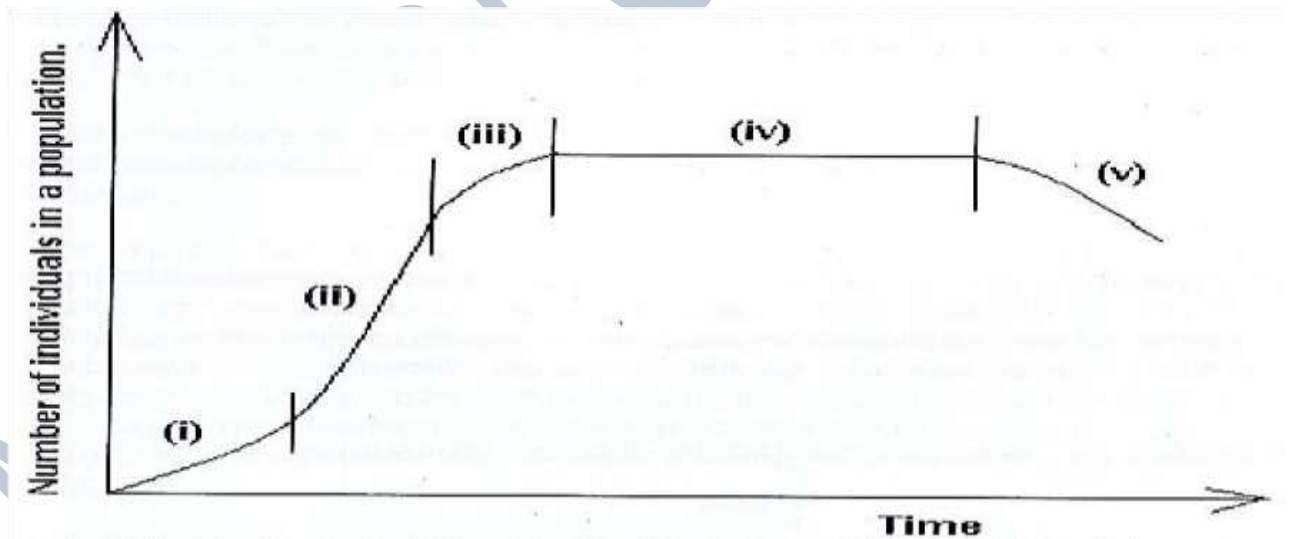
J-shaped growth curve.



b) The sigmoid growth curve (S-shaped sigmoid growth curve).

The type of population that exhibits the sigmoid growth curve has population growth controlled by the density dependent factors. It is associated with a population living in an area with limited resources.

S-shaped sigmoid growth curve.



- (i) Lag phase.
- (ii) Exponential phase,
- (iii) Decelerating phase,
- (iv) Stable phase,
- (v) Decline phase.

Description of the shape of the graph.

Description: The population size increases rapidly.

Explanation: The log phase is due to:

1. High number of reproducing individuals
2. Most organisms have reached reproductive age
3. Organisms have adapted themselves to the environmental conditions
4. The increased ease of locating mates due to increased population size and clumped distribution.
5. The low concentration of metabolic wastes
6. The high availability of resources
7. The low levels of competition
8. In microorganisms, they have synthesized enzymes required for nutrient utilization.
9. So the birth rate exceeds death rate.

Phase III: Deceleration phase

Description: The population size increases gradually.

Explanation: There is a decrease in the rate of growth of the population size due to:

1. The rapid population growth causes a **population explosion/overpopulation** which results in **overcrowding**, which leads to:
2. Accumulation of toxic wastes produced by organisms causing pollution.

Explain for phase (iv) and phase (v)

Real-world examples

1. Forest Ecosystems

In forests, competition among trees for sunlight, nutrients, and water intensifies as tree density increases. Larger, established trees often outcompete younger saplings, limiting forest growth.

2. Aquatic Systems

In a pond, dense populations of algae may deplete nutrients and oxygen, causing die-offs. This phenomenon, known as eutrophication, showcases how density dependent factors regulate aquatic ecosystems.

3. Wildlife Populations

In the Serengeti, wildebeest populations experience density-dependent regulation through predation and resource competition. As the population grows, predation by lions and food scarcity prevent unchecked growth.

Applications in conservation and management

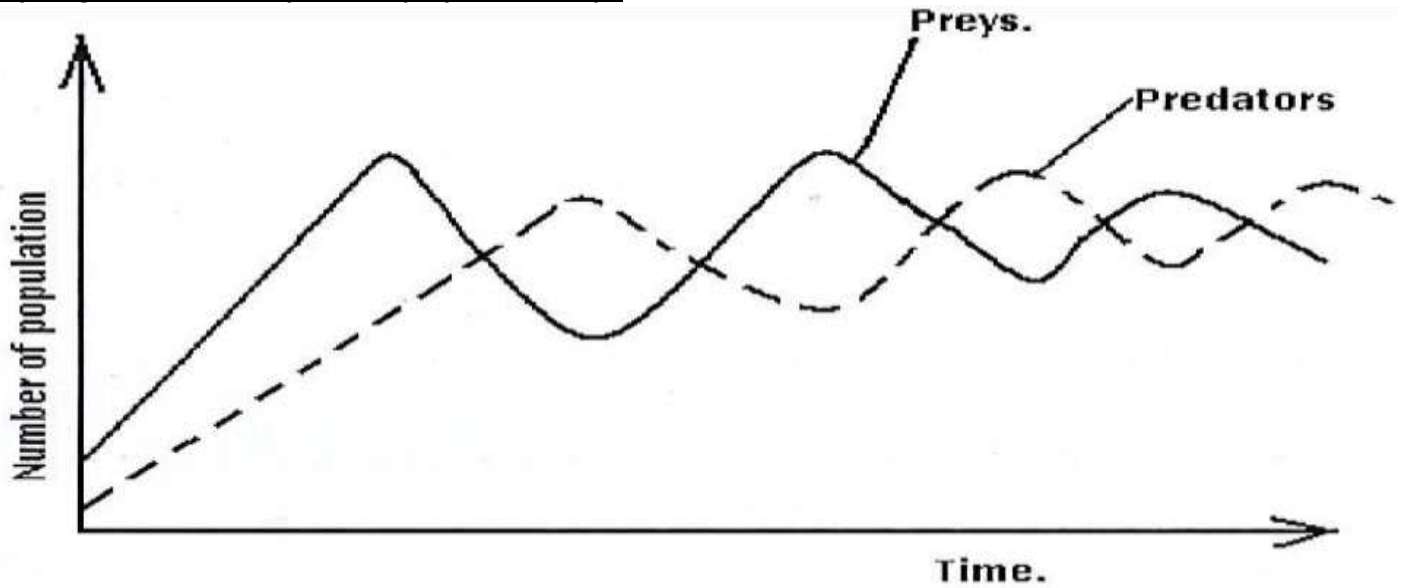
Understanding density-dependent factors is vital for ecological conservation and population management:

Wildlife Management: Controlling overpopulation through culling or reintroducing predators helps maintain balance.

Agriculture: Recognizing pest outbreaks driven by density-dependent factors aids in sustainable farming practices.

Ecosystem Restoration: Restoring habitats can mitigate density-dependent pressures, promoting species recovery.

c) The cyclic growth curves in predator-prey relationships



There are three important features of predator-prey relationship graphs:

1. The prey population size peaks earlier than the predator population size Reason:

The predator depends on the prey population for its food; and thus the predator population size takes time to respond to changes in the prey population size, because the predator population has a lower reproductive rate, a slower growth rate, a longer gestation period and longer life cycle than the prey population.

Thus the predator population size increases at a lower rate than the prey population size, allowing the prey population size to peak earlier than the predator population size

2. The predator and prey population sizes show cyclic slightly out-of-phase fluctuations. Reason:

Increase in the prey population size causes increase in the predator population size, due to increased food availability in form of the prey.

Increase in the predator population size causes decrease in the prey population size, due to increased predation.

Decrease in the prey population size causes decrease in the predator population size, due to decreased food availability in the form of prey, which results in increased competition, increased aggression, reduced natality and increased mortality due to starvation.

Decrease in the predator population size causes increase in the prey population size, due to reduced predation; and the cycle is repeated.

3. The prey population size is generally much higher than the predator population size. Reason:

In order for the predator population not to eat all the prey population; because the prey population has a higher reproductive rate, faster growth rate, a shorter gestation period and a shorter life cycle than the predator population

Thus the prey population size increases faster and to a higher value than the predator population size, to avoid the prey population from being preyed upon by the predator population to extinction, as this would also starve the predator population to extinction.

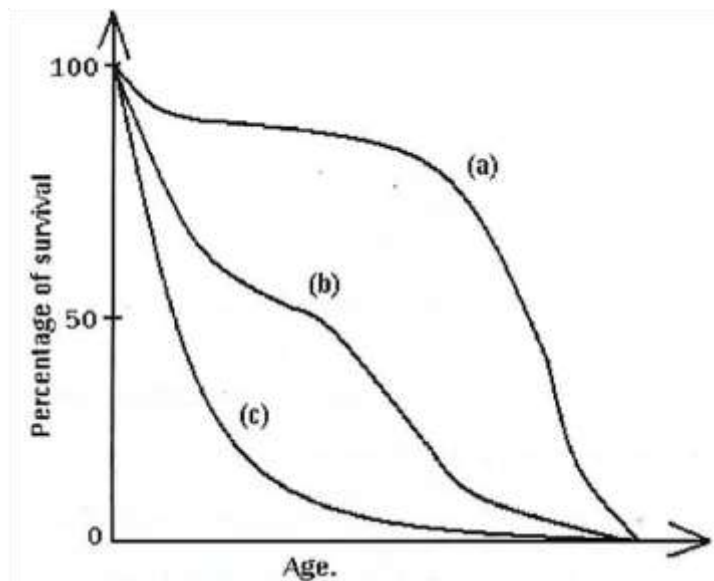
d) Survivorship curves.

It indicates the relationship of the new born individuals and the decrease in numbers of survivors with time. When number of survivors is plotted against time, a survivorship curve is obtained. On the vertical axis, actual numbers of survivors may be plotted or percentage survival.

The percentage of individuals which die before reaching reproductive age (pre-reproductive mortality) is one of the major factors affecting population size. Different organisms have characteristic survivorship curves, some examples are shown in the graph below.

$$\text{Percentage survival} = \frac{\text{Numbers of survivors}}{\text{Number in original population}} \times 100$$

A GRAPH SHOWING SURVIVORSHIP CURVES.



EXPLANATION OF THE CURVES. Curve (a).

Shows ideal curve for a population in which senescence is the major factor affecting mortality. An example is a human population in modern industrialized country in which the standards of medicine and nutrition are maintained and so most people live to old age. But the life expectancy cannot be prolonged beyond 75 years of age. The initial gradual decrease of the curve is due to the infant mortality. The drastic decrease of the curve can be due to the following,

Accidental deaths i.e deaths through car accidents, etc.

Senescence (ageing). Is the general decline in the normal physiological functions of the body systems (declining vigor) with increasing age beyond maturity, resulting eventually into death of the organisms.

The immediate cause of the senescence are, reduced resistance to external factors such as diseases, others causes include, mistakes in protein synthesis, degeneration of cells, inefficient homeostasis, auto immunity. Auto-immunity is where old people produce antibodies against their own antigens.

In curve (a) the population would combine its high survival rate with low reproductive rate to maintain a stable population.

Curve (b).

Is for a population with a high mortality rate early in life like for humans in a country in which starvation and diseases are prevalent.

In this case, the population would need a higher reproductive rate to maintain a stable population since high percentage of individuals would die before reproductive age is reached.

Curve (c)

It indicates a smooth curve that would be obtained if there was a constant mortality throughout life. In this case, chance is the major factor influencing mortality and organisms die before senescence with high juvenile mortality, examples is in the hydra where there is no special risks attached to being young, most non-vertebrates and plants.

NOTE: Minor variations in survivorship curves may occur within species due to sexual differences, for example in humans female life expectancy is slightly greater than for males.

Carrying capacity

Carrying capacity is the maximum number of individuals that can be supported or sustained using the available natural resource in an environment.

Factors that determine carrying capacity of the environment.

- Food shortage.
- Increased predation.
- Overcrowding.
- Competition.

Conditions that may cause carrying capacity to be exceeded.

Removal, death or absence of predators in an area.

Abundant food supply.

Favourable climatic or weather conditions.

Adequate space/shelter/breeding sites.

High Biotic potential.

Low mortality rate.

Environmental indicators for a population that has exceeded its carrying capacity.

Destruction of vegetation, rapid environmental degradation.

Extinction of some species of organisms.

Accumulation of wastes.

Increased rate of emigration. Rate of emigration exceeds immigration.

Death rate exceeds birth rate.

REGULATION OF POPULATION GROWTH/SIZES

The size of the natural population doesn't keep increasing indefinitely. Starting with a small number of organisms, the population size increases at a rate lower than the theoretical growth rate and then levels off.

A number of factors are responsible for slowing down the growth and eventually bringing it to halt.

*These are collectively called **environmental resistance**.*

Environmental resistance refers total of limiting factors both biotic and abiotic factors which affect together to prevent the biotic potential from being obtained.

Factors that affect or influence size of populations in an ecosystem.

These factors are divided into two broad categories,

- a) Density dependent and*
- b) Density independent factors.*

a) Density dependent factors that influence size of population.

Density dependent factors are those factors whose effectiveness in controlling the size of population depends on the number of individuals or organisms per unit area. These factors are usually biotic and they include the following;

- **Availability of food/water/nutrients.**

Plenty of food favours reproduction and increase in population size and lack of food and water leads to reproductive failures and death. This causes declines in the size of the population.

- **Diseases and pests.**

Where there is a large number of individuals crowded together diseases spread rapidly and cause deaths, reducing the population and where there is overcrowding of individuals, diseases are rare and population grows.

- **Accumulation of toxic wastes.**

Toxic wastes can cause death of some organisms and reduce their population size. Non-toxic environment provides favourable condition for growth of organism and the size of population increase.

- **Predation.**

Predators feed on other organisms called the preys. Where the number of predators are few or individuals have the ability to avoid predators, the population size increase. While a decline in the size of population is caused by large population size of predators or individuals lack ability to avoid predators.

- **Availability of space/shelter.**

This includes breeding sites. It determines protection of organisms from hostile environmental conditions, determining their survival. Plenty of suitable space increases population size. While, lack of suitable space or in adequate space decreases population size.

- **Reproductive or Biotic potential.**

High biotic potential increases size population of organisms, while low Biotic potential decreases the population size of organisms in an ecosystem. Large size of reproducing individuals in a population will increase size of population; few reproducing individuals in a population will maintain low population size.

- **Stress factors /psychological factors.**

These include stress factors arising from overcrowding. It leads to abnormal behaviours that may lead to reproductive failures, low food intake, decreasing population size. Absence of stress conditions increase size of population.

- **Territorial behaviour/territoriality.** It occurs among wide range of animals such as certain fish, reptiles, birds, mammals and social insects where a male or both male and female animals demarcate an area which they defend against members of the same species. Territoriality limit size of a population within the territory more than outside it.

- **Emigration.** Refers to departure of animals from their mother population to a new habitat. This can be due to competition, seeking for resources limiting the growth of their mother population.

b) Density independent factors that influence size of population.

Density independent factors are those factors whose effectiveness in controlling size of population does not depend on the number of individuals or organisms per unit area. These factors are usually abiotic and they include,

1. Availability of light.

Sufficient light intensity provides light energy for photosynthesis and favours the growth of plant population. This causes increase in the population size of the plants (primary producers). The animals feed on these plants, they reproduce rapidly and their population size too increases. In- adequacy of light or its absence limit plant population.

2. Availability of oxygen.

Oxygen is utilized by aerobic organisms for respiration, its presence in sufficient amounts favours growth of aerobic organisms, hence growth of population size of these aerobic organisms and its absence or insufficient amounts limits size of populations, especially in aquatic organisms.

3. Climatic conditions such as

- a) **Temperature:** Temperature affects enzyme activity and thus affects rates of metabolic reactions in organisms. Temperature also affects germination of seeds, rate of growth, stomata opening and closure, rate of photosynthesis, distribution of organisms, and behavior of organisms.

- b) **Humidity:** Humidity affects rates of transpiration from plants and evaporation from animals. Higher humidity reduces transpiration and evaporation, while lower humidity encourages transpiration and evaporation causing water loss.
- c) **Water:** Water is precipitated from the atmosphere as rain, snow, sleet, hail, dew, frost, mist, fog. Terrestrial plants absorb water from the soil. Water is a component of the bodies of living organisms, a raw material for photosynthesis, aids dispersal of seeds, is an agent of pollination, is a habitat for some organisms, is a condition for germination, and serves as a heat sink, a medium for recycling of nutrients, a spawning medium
- d) **Wind and air currents:** Wind causes dispersal of light pores, seeds, fruits and other plant propagules, influences movement, dispersal and migration of flying animals, such as the wandering albatross Wind movements affect globe climatic patterns, influence surface temperatures, humidity and causes pollination in wind-pollinated plants

4. Catastrophies such as fire, storms, and floods may lead to sudden mass deaths of organisms, reducing size of population. In absence of such Catastrophies population size remain increasing.

5. Edaphic factors, these are soil factors such as soil temperature, pH, air, water content, mineral and organic matter when favourable favour plants growth and activities of microorganisms, increasing the size of population and when unfavourable decrease the size of population.

6. Pollution, high levels of any kind of pollution will limit the population size of organisms compared to low level or no pollution of the ecosystem.

7. Topography. It influences local climate and "soil factors. The main topographic factor is altitude. Higher altitudes are associated with lower average temperatures, higher precipitation, increased wind speed, lower atmospheric pressures, more intense radiations, these lower growth rate and support smaller size of population than lower altitudes.

Mountains are climatic barriers to dispersal and migration, limiting increase in population size. Population grows and declines in characteristic ways. The size of population increase is determined generally by the reproductive potential (Biotic potential and environmental resistance).

8. Maximum Biotic potential (Reproductive potential) of an organism is the rate of reproduction given unlimited environmental resources.

9. Environmental resistance is both biotic and abiotic factors that together prevent the maximum reproductive potential to be achieved and as such limit growth of a population. They include external factors such as shortage

of food, water or oxygen, lack of light, presence of predators and parasites, lack of shelter (space), excessive heat, intraspecific competition and behavioral adaptations.

THE ROLE OF NEGATIVE FEED BACK MECHANISM IN CONTROL OF POPULATION SIZE OF ORGANISMS.

Feedback mechanisms. *Are systems that detect a change in the level or amounts of a particular parameter from the norm or normal levels, then the system is stimulated or triggered to bring into action corrective processes or regulatory processes.*

In negative feedback mechanisms, a change in the amounts of the parameter about the norm or set point, triggers processes that will bring the amounts or the levels of the parameter back to norm.

Regulation of population size of most organisms in an ecosystem is by negative feedback mechanism, which maintains size of population at the carrying capacity (the Norm) with minimum oscillations or deviations. When the population size increases far beyond or above the carrying capacity, environmental resistance or environmental stress factors set in, like competition for scarce natural resources such as food, space, mates. Other stress factors such as accumulation of own toxic wastes, starvations also occur, resulting into death of some organisms. The population size declines back to normal. And when the population size decreases below the normal, the environmental stress factors are removed, encouraging population growth and the size of the population increases back to norm.

However, human population cannot be regulated by negative feedback mechanisms. This is due the following reasons,

Modern methods of food production have led to production of plenty of food hence deaths due to hunger have been minimized.

Manufacture of drugs has minimized deaths due to diseases and other pathogenic infections.

Improved standards of living such as good hygiene, people tend to live longer.

Use of contraceptives or birth control methods has controlled abnormal rise in human population.

Factors to be considered before determining population size of organisms.

- (i) *Size of the area,*
- (ii) *Nature of vegetation,*
- (iii) *Topography or terrain,*
- (iv) *Size of organisms to be counted.*
- (v) *Behaviour of the organism or its social structure and activities,*
- (vi) *Nature of the habitat whether terrestrial or aquatic, concealed or non-concealed habitat.*
- (vii) *Resources available for example, apparatus, money etc.*

Methods/techniques for estimating the size of population in an ecosystem.

The methods used to estimate the size of a population is divided into two categories, Total count methods. Sampling methods.

1. Total count methods.

This method involves physical count of all the organisms in an area under study. In this method, the whole area is searched, all organisms are counted and it should give absolute number of organisms in the whole area. These methods include the following,

a) Direct observation.

This involves direct counting of all the animals in the whole area of study. The total number of the animals observed and counted is recorded. It is applied to sessile, slow moving animals and also applied to many larger mobile organisms that do not live in concealed areas such as deer, lions, wood pigeons and bats as they leave their roost. Direct observation methods is further divided into,

• **Direct counting method.**

This method can be carried out from ground or using a low flying aircraft. This is mainly used to determine populations of large animals. The number of animals under study is obtained by directly counting and recorded. This is done for several times and the average population density is calculated.

Advantages

- i) Quick estimate of the population sizes.
- ii) Other studies on the population such as feeding habits, reproductive behaviour, and predation can be carried simultaneously
- iii) Reduces the risks of attacks from aggressive animals like lions, buffalos, etc.

Disadvantages

- i) Expensive since it requires sophisticated aircraft and skilled man power.
- ii) Sound made by aircraft may scare some animals which may hide in concealed area e.g. under trees.
- iii) Greatly hampered by some weather conditions eg fog, misty or cloudy weather.
- iv) Can be used on large animals and only in grassland.
- v) Not effective in very hilly areas
- vi) Calculations involved may cause inaccuracy.

• **Drive and count methods.**

Here the animals are driven by number of people to a particular spot and they are counted. It applies to large animals which live in non-concealed areas and less hostile.

Advantages.

- (i) Quick and more accurate especially for slow moving animals.
- (ii) It reduces the chances of counting the same animals more than once.
- (iii) It is a fairly quick and easy method for animals which live in herds.

Disadvantages.

- (i) It involves disturbance of the animals which may make them aggressive.
- (ii) It can be applied on aggressive animals.

(iii) *it is difficult to apply on animals which live in herds.*

• **Strip census.**

In this method, animals are counted along paths while walking or in vehicles. Population density is determined as number of individuals per unit area of the strips. It is applied to large animals which live in non-concealed areas.

Advantages.

- (i) *It is fairly quick.*
- (ii) *It is comparatively cheaper than aerial photography.*

Disadvantages.

- (i) *The animals may be scared by the passing vehicles or even by the presence of the human beings and scared away, such animals may not be counted at all.*
- (ii) *Some animals avoid paths and therefore may not be counted.*
- (iii) *Very many counts must be conducted in order to get reliable information.*
- (iv) *Some of the animals are too mobile and are likely to be counted twice.*

• **direct counting using a low flying air crafts.**

This method involves physical counting of all the animals within the study area. It is applied to large animals living in non-concealed habitats for example, lions, buffaloes, rhinos, giraffes and elephants.

In this method, the study area within the park is surveyed using a low flying light air crafts, then a low flying light air craft is flown along a transect and animals along the transect are counted. The air craft then flies back along another adjacent transect and counting continues until the whole area sampled is covered. Several such counting are carried out and an average is determined, the product of the average count and the total square per unit area of the study area gives the estimated size of population of the organisms.

Advantages.

- (i) *Is a very quick method of estimating population.*
- (ii) *It can be done concurrently with other studies for example studying feeding habits.*
- (iii) *It can be applied in some aggressive animals like lions since it has minimum risks of the researcher being attacked.*
- (iv) *It is less tiresome and not laborious.*
- (v) *It reduces the chances of counting the same animals more than once since it very organized.*

Disadvantages

- (i) *It is very expensive since it involves expensive equipment like air-crafts.*
- (ii) *The air craft may scare.*
- (iii) *It is difficult to apply on animals that live in concealed habitats.*
- (iv) *it can be applied to very small animals since they may not be seen from a distance,*
- (v) *Its operation can be affected by bad weather or poor climatic conditions for example when the weather is misty or foggy.*

b) Aerial photography.

This method is also applied to larger animals which live in non-concealed habitats.

Procedure.

Survey the area of the park with low flying light air craft, photograph the animals in places within the study area where they are present in groups or herds, count their number from the developed photographs, repeat the process of photography and counting animals from the developed photographs at regular intervals of time over a given period of time, the average number of animals counted from photographs is obtained, then the product of the average count and the total area gives the number of the individuals per unit area.

Note: The advantages and the disadvantages of this method are the same as those for direct counting.

Advantages.

- (i) It's a very quick method of estimating Population.
- (ii) It can be done concurrently with other studies for example studying feeding habits.
- (iii) It can be applied in some aggressive animals like lions since it has minimum risks of the researcher being attacked,
- (iv) It is less tiresome and not laborious,
- (v) It reduces the chances of counting the same animals more than once since it very organized.

Disadvantages.

- (i) It is very expensive since it involves expensive equipment like air-crafts,
- (ii) The air craft may scare away the animals which may go into hiding and end up not being counted.
- (iii) It is difficult to apply on animals that live in concealed habitats,
- (iv) It can be applied to very small animals since they may not be seen from a distance.

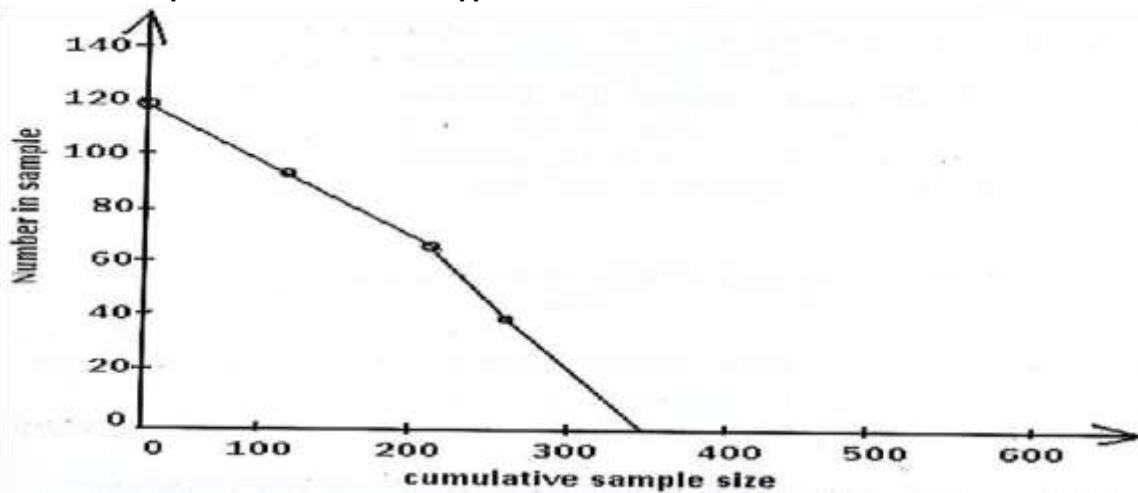
Its operation can be affected by bad weather or poor climatic conditions for example when the weather is misty or foggy.

c) Removal method.

It suitable to estimate numbers of small organisms, particularly insects within a known area of grass land or volume of water. Using a sweep net, the number of animals captured is recorded and the animals kept. This procedure is repeated three times and the gradually reducing numbers recorded. A graph is plotted of number of animals captured per sample against the previous cumulative number of animals captured. By extrapolating the line of the graph to the point at which no further animals would be captured i.e. number in the sample = 0, the example of how the population will be estimated is shown below,

Sample	Number in sample	Cumulative sample size
1.	120	0
2.	93	120
3.	60	213
4.	35	273

A graph showing variation of number in samples with cumulative sample size



The estimated population size is equal to the cumulative sample size when the number in sample is zero (0), according to the graph = 350 individuals.

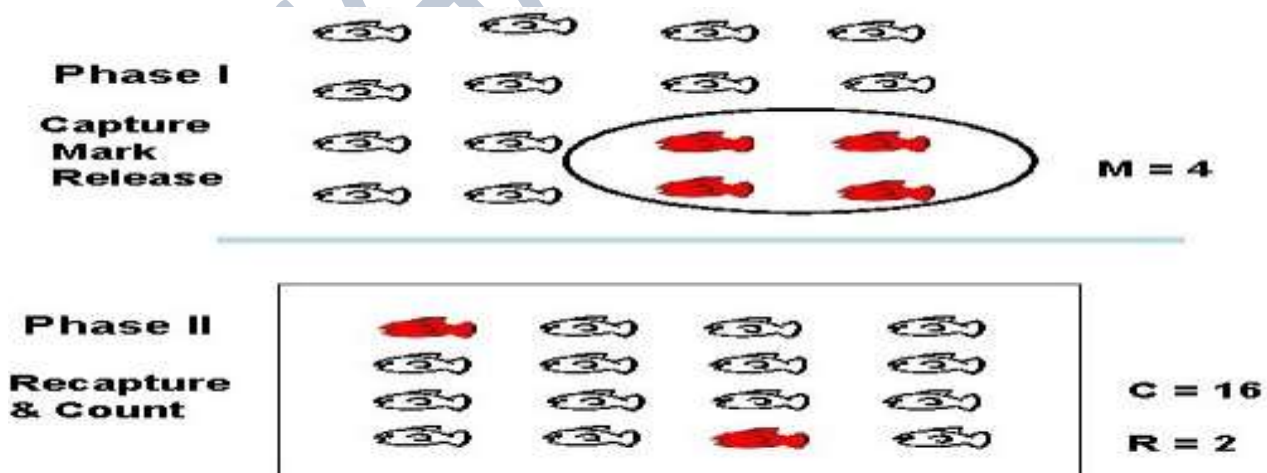
2. Sampling methods of estimating size of a population.

Is the random determination of the number or distribution of organisms within a population. In this method, only part of the area is surveyed, only a few organisms within the study area are counted but bias should be avoided and every organism must have equal chances of being chosen in the sample, which must be large and the total number of organisms in the whole area is calculated or estimated from the sampled plots. These methods include, Capture-mark release recapture method.

- i. Quadrat method.
- ii. Use of line transect/Belt transect.

(i) Capture - mark release recapture method. (Lincoln index)

This method is suitable to determining population of animals which are small, mobile, fast moving, live in concealed habitats and they can easily be tagged or marked, examples include, arthropods, fish, small mammals and birds.



M, C, & R are used to estimate N (number of fish in lake)

In this method, a number of animals are captured using traps which are set up randomly within an area. The animals are marked for instance arthropods may be marked on their back with non-toxic dabs of paint, fish can have tags attached to their opercula, mammals may have tags clipped to their ears and birds can have their legs ringed. The number of the marked animals recorded is **labeled N** and then they are all released back into the population and given sufficient time to mix freely in the population. After a period of time, the traps are set up again randomly in the area and the animals are captured for the second time and the number of the animals captured for the second time is **labeled as M**, at the same time the number of the animals captured and marked (recaptured animals) is **labeled R**.

The size of the population size is estimated is determined using Lincoln index as,

Estimated population size =

$$\frac{\text{Total No. of Individuals in the First samples (N)} \times \text{Total number of individuals in the second sample (M)}}{\text{Number of marked individuals recaptured (R)}} = \frac{N \times M}{R}$$

Examples

1. In an attempt to estimate the number of tilapia in a small lake, 625 tilapias were netted, marked and released. One week later, 873 were netted of which 129 tilapias had been marked. What is the estimated population size of tilapia?

$$P = \frac{N \times M}{R}$$
$$P = \frac{625 \times 873}{129}$$

P= 4230 tilapia Trial examples

2. Students at St. Mary's Secondary School want to estimate the number of tilapia in the school fish pond. On Day 1, they catch 20 tilapias, mark them with a harmless dye, and release them back into the pond. On Day 3, they catch another 25 tilapias, of which 5 are found to be marked. Use the capture–recapture formula to estimate the total number of tilapia in the pond.

A biology class is studying insect populations in their compound. On Monday, they capture 40 grasshoppers, mark them with a dot of non-toxic paint, and release them. On Wednesday, they capture 50 grasshoppers, of which 10 are already marked.

- Calculate the estimated population of grasshoppers in the garden.
- Explain why it is important to allow time to pass between the first and second capture.
- Give one reason why grasshoppers may not be suitable for long-term capture–recapture studies.

Assumption of the capture mark release recapture method.

- Organisms mix randomly within the population.
- Sufficient time must elapse between capture and recapture to allow random mixing.
- The less mobile the species of animals the longer the time lapse must be.
- It is only applicable to populations whose movement is restricted geographically.

- *Organisms disperse evenly within the geographical area of the population.*
- *Changes in population size as a result of immigration, emigration, births and deaths are negligible.*
- *Marking does not hinder the movements of the organisms or make them conspicuous to predators or death of the animals.*
- *The population of the marked to unmarked individuals in the second sample is the same as the proportion of marked to unmarked individuals in the whole population.*
- *Every marked animal has the same probability of surviving the sampling period.*
- *Every animal captured, marked and released have the same or equal probability of being recaptured.*

Precautions to be taken.

- *The marks should not be harmful to the animals.*
- *The marks or the tags used should not be conspicuous to the predators.*
- *Sufficient time should elapse between the first and second capture.*

Disadvantages /limitations

- *It's only reliable when the organism's range of movement is relatively restricted and defined.*
- *Animals often move in groups whose members recognize one another and avoid mixing with those marked.*
- *Loss of marked reduces numbers to be recaptured, causing inaccuracy.*
- *The label may physically disturb organisms.*

(ii) Quadrat method.

A quadrat is a metal or wooden frame with one metre sides. It encloses an area of 1m^2 , however, larger quadrats marked on ground by either ropes or suitable materials may also be used. The quadrat method provides means of studying three aspects of species,

(i) Species density.

This is the number of individuals of a given species in a given area. It is obtained by counting the number of organisms in randomly thrown quadrats.

(ii) Species frequency.

This is a measure of the probability or chance of finding a given species within any one throw of a quadrat in a given area. This is obtained by recording the presence or absence of the species in a randomly thrown quadrat.

(iii) Species cover.

This is the measure of the proportion of the ground occupied by the species. It gives the estimate of the percentage of the area covered by the species. It is obtained by observing the species covering the ground at a number of random points.

It is a random sampling method. This method is suitable to estimate population size of plant species and sessile organisms or very slow moving organisms. In this method, survey the area under study and establish its size in square metres, then a quadrat of known square meters i.e. 1m^2 is thrown at random on an area marked randomly and the number of enclosed organisms are counted, such of these of throws are carried out several times. An average of these counts is taken and the population size is estimated by determining the product of the average count taken and total square meter of the area under study.

Size of population = Average number of animals in 1m^2 Quadrat $\times$ Total square metre of area under study

Example:

If 5 quadrats of 1m^2 show number of certain plant species as 1st quadrat = 3, 2nd quadrat = 7 3rd = 2. 4th = 4, 5th = 4 respectively, if the total area under study = 500m^2 .

The size of population can be estimated as follows, 5 quadrats = 20 plant species.

1 quadrat of $1\text{m}^2 = \frac{20}{4} = 4$ plant species.

Therefore 1m^2 quadrats = 4 plant species.

$500\text{m}^2 = 4 \times 500 = 2000$ plant species.

Advantages of using quadrat methods.

- *It is cheap method to carry out since it does not require many expensive types of equipment to use.*
- *The aspect of species density makes this method accurate enabling different areas and different species to be compared,*
- *Species density provides an absolute measure of abundance of species in an area.*
- *The aspect of Species frequency is easy and quick to conduct,*
- *It can be applied in large ecosystem such as wood land.*

Disadvantages.

- *It is time consuming like in determination of species density.*
- *In determining species frequency, the quadrat size, plant size and spatial distribution affect the results.*
- *It is slow and tedious like in determining species cover.*
- *It can only be efficiently applied in estimating population size of plants species.*

(iii) Line transect/belt transect.

This consists of record of plants occurring along a line taken by stretching a string in a study area. Survey the area under study to establish its size in square metres. Then a tape or string is stretched along the transect line and only plants touching or beneath the tape or string are counted or the plant species touching or beneath the tape or string are recorded. This method is useful to study changes in plant species in an area (Qualitative data) however, to establish size of population of plant species using this method (Quantitative data), several counts are made, and an average of such counts is taken, the population size is a product of average count and total size of the area under study in square metres.

- **Belt transect**

It's where parallel strings called twines are tied across a habitat by help of pegs. The areas between the strings are belts which can be divided into small squares. Organisms within the belts are recorded. This method can be applied for both plants and animals in larger area of study. In belt transect method, both a quadrat and a line transect can be used. The type of a transect to use depends on the following factors,

Qualitative or quantitative nature of the investigation.

Degree of accuracy required.

Nature of organisms present.

Size of the area to be investigated.

Time available.

Over a short distance a line transects is used and over a longer distance the species present every metre or any other suitable distance is recorded. Height variations recorded along line or belt transects produce a profile of transect known as profile transect.

NOTE: State advantages and disadvantages of using line transects.

Methods used to collect organisms.

There are several methods which include, trapping, trapping is a method of collecting moving organisms using a trap.

(i) Pit fall trap.

It is inform of a hole dug in a path where the animals pass and when they reach it they fall into it.

(ii) Sticky trap.

is made of wooden sheet onto which a sticky substance is applied when an animal comes into a contact with the sticky substance, it gets trapped and cannot move away.

(iii) Light trap.

It is made up of a mercury vapour light trap that attracts flying organisms which hit baffles and fall down into the base and become trapped in cardboard egg boxes or crumbled up paper. It traps night flying insects like the moths.

(iv) Footer.

This is where a collecting tube is directed to slow moving insects or other arthropods like, aphids, small insects and spiders. Air from the bottle is sucked from the sucking end. This results in reduction of pressure within the bottle, this draws the insect into the bottle. A mosquito netting is placed at one end to prevent the insects from being sucked out of the bottle.

(v) Using strainer or sieve.

This is for collecting soil arthropods. Sample of soil is collected and placed on a strainer. It is then heated from above using moderate heat source. As the soil dries from the trap, the trapped organisms move to the lower layer and finally fall into collecting container below the strainer

(vi) Tullgren funnel.

This method is useful to trap many soil and leaf litter-dwelling organisms that move from source of heat and towards moisture conditions. A soil sample or litter sample is placed in the sieve about 25cm below a bulb in a metal reflector. Every two hours the bulb is moved closer and nearer to the soil sample. The apparatus is left for a total of 24 hours.

All small arthropods move down wards and drop through the metal gauze into the alcohol.

(vii) Sweep net and plankton net.

A sweep net is a nylon attached to a steel handle and swept through grass, bushes, ponds or streams. It used for collection of insects and crustaceans.

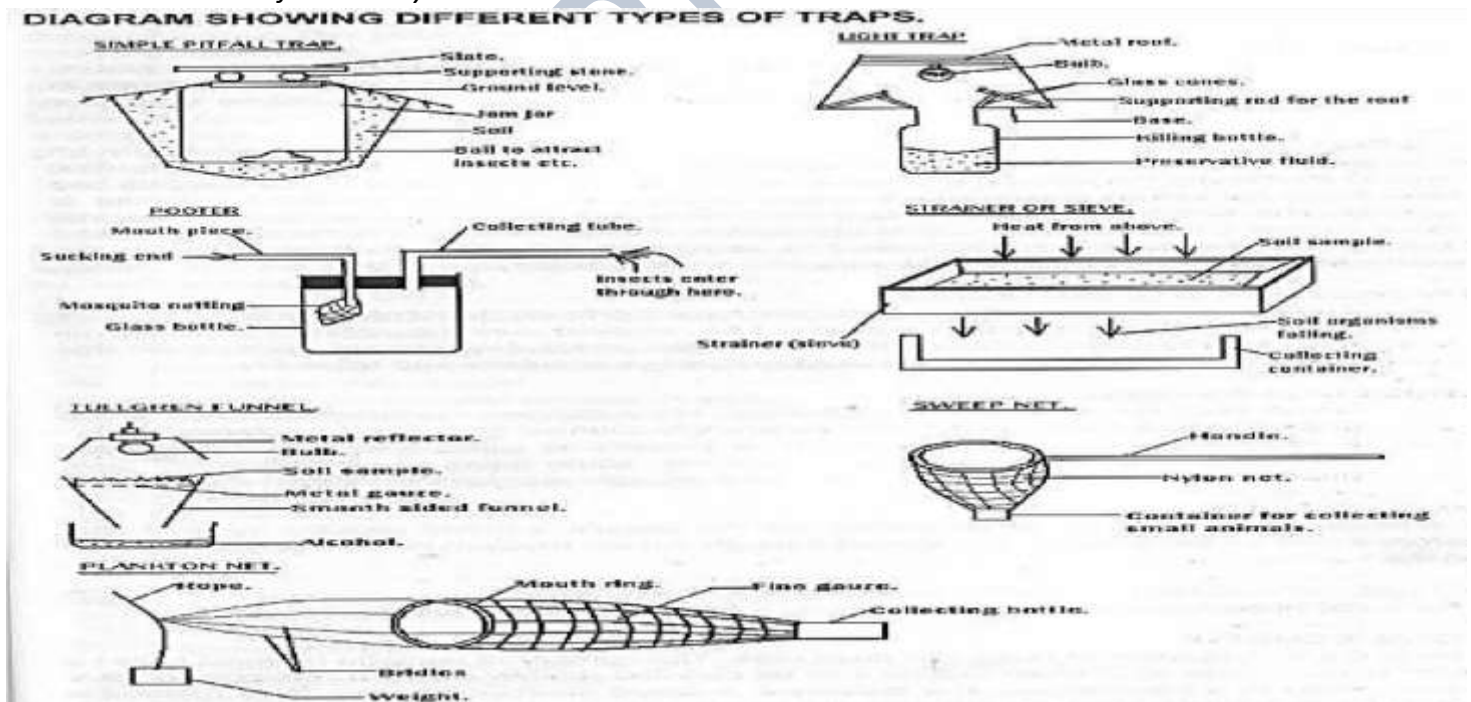
Plankton net is a bolting silk net attached to a metal hoop and rope harness and towed through the water. A small jar is attached to the rear of the net to collect specimens. It is used to collect planktons (zooplankton and phytoplankton) in water.

(viii) Hand-sorting.

Samples of soil or vegetation. For example grass, leaf litter, pond and seaweed, are placed at one end of a tray and small amounts of materials are systematically examined between the fingers, specimens are removed to a collecting jar and sorted material passed to the other end of the tray. The sample is then examined as it is moved back to the original end of the tray. This method is applied for collection of mites, insect larvae and pupal stages.

(ix) Extractions.

Small quantities of 5% formaldehyde are added to 50cm³ of water and the solution is sprayed to square metres of lawn or grassland. Earth worms are driven out of their burrows and collected and immediately washed in water to remove the formaldehyde.



Research work:

Discuss the methods of controlling population.

REGULATION OF POPULATION SIZE

Population size is naturally maintained at their normal carrying capacity depending on the resources in a given habitat. These populations are

controlled by homeostatic means depending on the density controlled factors e.g. food, pests, diseases, predators etc.

The population itself initiates the control measure i.e an increase in population stimulates environmental resistance which brings the

population back to normal, and a decrease in population below carrying capacity, environmental resistance decreases, thus causing an increase in the number of organisms e.g. predator –prey relationship.

Methods of population control

(a) Biological control method

This is the eating or weakening of a pest species or weeds using other organisms called control agents e.g. natural predator, parasite or

pathogen .E.g.. (i) Using cats to eat rats, (ii) using beetles to feed on the water hyacinth on Lake Victoria, (iii) placing fish in ponds to eat mosquito larvae.

Biological control aims at bringing the pest population to a level where they are economically un harmful.

Biological control method can be used to; (i) control of vector population (ii) control of parasites (iii) control of pathogens (bacteria& virus)

(iv)control of some plants e.g. weeds (v) control of pests.

Steps involved in biological pest control:

- ❖ Identifying the pest and tracing its origins, i.e. where it came from.
- ❖ Investigating the original site of the pest and identifying natural predators, parasites or pathogens of the pest.
- ❖ Testing the potential control agent under careful quarantine to ensure its specificity.
- ❖ Mass culturing of the control agent.
- ❖ Development of the most effective distribution / release method for the control agent. NB. Biological control of population is very specific, thus useful organisms are not affected.

(b) Chemical method.

Involves use of chemicals by humans to eradicate harmful organisms

Are named according to the target organisms e.g. herbicides kill weeds, insecticides kill insects, fungicides kill fungi.

Properties of an ideal pesticide:

- ❖ Should be biodegradable / non-persistent so that toxic products are not left in or on crop plants.
- ❖ Should be specific so that only pest species is killed
- ❖ Should not accumulate either in specific parts of an organism or as it passes along food chains.
- ❖ Should effectively control the pest under field growing conditions

- ❖ Should be easy to apply at the correct dosage.

Problems of using insecticides:

- ❖ Accidental misuse of toxic chemicals results in death of humans and domestic animal.
- ❖ Many are non-specific, killing non-target species, particularly natural predators of the pest species.
- ❖ Pest resistance occurs i.e. genetic variation enables a few individuals in the pest population to survive and may quickly reproduce.
- ❖ There is pest replacement i.e. since most crop are susceptible to attack by more than one pest species, and the pesticide may be more deadly to one species than another, elimination of one species may simply allow another species to assume major pest proportions.
- ❖ Pest resurgence may occur i.e. non-specific pesticides may kill natural predators as well as pests, and so a small residual pest population may multiply quickly without being checked.
- ❖ **Bioaccumulation** (some molecules of the pesticide may be stored in specific organs or tissues at levels higher than would be expected) and **biological magnification** (the pesticide may get more concentrated as it passes along the food chains and webs) may occur. E.g. If Dichlorodiphenyl trichloroethane, DDT is sprayed on plants, to kill green flies, some survive, and absorb the chemical into their bodies. When eaten by small birds, DDT accumulates and when birds are eaten by other predators, e.g birds of prey, the accumulation of DDT reaches a level which burns up and kills the final consumer.

Research work

1tem 1. The table shows the amount of DDT in plants per million found in a variety of organisms associated with fresh water lake.

Site of DDT measurement	Amount of DDT in parts per million
water	0.0003
phytoplankton	0.002
zooplankton	0.004
Herbivorous fish	0.39
Carnivorous fish	0.89
Fish eating birds	14.2

- (a) (i). Calculate how many times DDT is more concentrated in carnivorous fish compared with its concentration in water
(ii) What do the results in a (i) show?
(b) Explain why the concentration of DDT changes from water to carnivorous fish.
c) Explain how a pest sprayed with a pesticide may flourish afterwards.

3. In an aquatic ecosystem which was affected by an insecticide, analysis of energy flow and concentration of the insecticide in each trophic level in a food chain was made. The results were shown in the table below.

Energy flow	pesticide
Producers	0.04
Herbivores	10
Carnivore 1	50
Carnivore 2	75

- (a) Explain why from producers to consumers, (i) level of insecticide increases (ii) the flow of energy decreases.
 (b) Give three ecological problems that may arise from the use of pesticides.

b) Analyze the processes of ecological succession and strategies for effective ecological restoration practices in diverse environments (LO.2)

- i) The role of primary and secondary succession in preserving biodiversity and restoration of degraded ecosystems.
 ii) Change in community structure in the serial stages.
 iii) Techniques and benefits for restoring degraded ecosystems.

The role of primary and secondary succession in preserving biodiversity

ECOLOGICAL SUCCESSION / COMMUNITY CHANGES.

Succession is the sequence of change from the initial colonization of a new area to establishing a relatively stable community.

The main features of ecological succession include, they are of two forms, occur gradually and in stages called **seres or seral stages**, there is pioneer community gradually replaced by other communities until a relatively stable community which is in equilibrium with its environment called climax community is reached

Ecosystems are dynamic. They are constantly changing in response to both physical factors such as climate and biological factors resulting from the activities of organisms within the communities. Communities change gradually from one type to another.

A succession principle is applied to land restoration. Rapid colonization by vegetation of waste mine lands, reclaimed lands, construction sites, etc. is important means of stabilizing them.

Types of ecological succession.

There are two types of succession. These are. **a) Primary succession. b) Secondary succession.**

The process of succession continues through stages known as seral stages and there are a number of seres dependent on the environment being colonized.

Hydrosere: succession in an aquatic environment.

Halosere: succession in a salty environment

Xersosere: succession in a dry environment

Lithosere: succession on a rocky surface.

*Each sere has its own community of organisms until the terminal relatively stable and final stage community called **climax community** is established.*

The climax community comprises of dominant or several co-dominant species which refers to species with the greatest collective biomass/productivity and physical size of individuals in a given area after some time (years).

At climax community the net productivity/biomass tends to remain constant but dependent on species number and population size.

a) i) Primary succession in terrestrial ecosystem.

Is the sequence of change from the initial colonization of a new area which has never been inhabited before like bare rocks, sand or cooled lava flow, etc to establishing a relatively stable community (climax community).

Primary succession occurs in three stages, pioneer stage, spruce stage and climax community. The process proceeds quite slowly. It begins when the propagation structures like seeds, buds, rhizomes, stolons and bulbs are not readily available.

- **Pioneer stage.**

During this stage, bare rock breaks down physically and chemically during the process of weathering. The acidic rains in tropics dissolve more minerals which cause further disintegration of the rocks. The existing conditions do not favour growth of most plant species but lichen which is an association between algae and fungi are the first to inhabit the rock. They are referred to as the pioneer organisms. Algae are a drought resistant and photosynthetic, providing food for the fungi. Some invertebrates exist and feed on the algae. Then the hyphae of the fungus penetrate tiny cracks, absorbing minerals and widening the cracks further, the hyphae also provide support. Some lichen die, decay and add onto the organic matter.

After the activity of the lichen has enlarged the cracks in the rocks and filled them with decomposing dead lichens, the conditions within the rock become favourable for the growth drought resistant and sun tolerant mosses as well as insects that feed on them. Mosses form a dense mat like network which traps tiny particles of rocks, some organic debris and water, some thin soil layer begin to form and lichens gradually replaced by the mosses and liverworts.

- **Spruce stage.**

Death and decay of the moss plants adds nutrients to the rock particles. Thickness of soil increase and this favours the growth of herbs like the ferns, grasses and other angiosperms. Animals like amphibians, reptiles and birds also come in. Some herbs die off and add on the organic matter. The soil layer become thick enough.

- **Climax stage.**

Soon large woody shrubs begin to grow in the newly formed soil. The mosses and the lichens may be shaded or covered by decaying leaves and other vegetation.

Eventually as a thicker layer of soil develops, trees are able to take root in deeper rock crevices and the shrubs disappear. Larger animals may also come in. After a very long period of time, a mature forest community grows. This is the climax community.

Climax community is defined as the relatively stable community which is in equilibrium with its environment. A single type of climax community is known as climatic climax. A community where human interventions have led to a relatively stable community very different from the original climax is termed as a plagioclimax. The succession is said to have been deflected. A climax community can have one dominant or several co-dominant species. Dominance in this case, refers to the species with the greatest collective biomass or productivity. Species with larger size can be referred to as being dominant.

DIAGRAM OF SUMMERY OF PRIMARY SUCCESSION.

Bare rock. → Lichens → Herbs → Shrubs → Young Wood → Climax community
(Algae and fungi) Land (Large trees)



a) ii) Primary succession in aquatic ecosystem.

In ponds and lakes, organic matter builds up from dead remains of plants and animals and sediments brought by the water run offs from the land. This causes the water in these water bodies to become shallower and richer in nutrients, allowing rooted plants to grow and crowd along the shores of the ponds, rivers and lakes.

The growth of these plants extends further into the pond, river and lake. More sediment is trapped in the process and the water become even shallower. The ponds, rivers and lakes develop into marshes, then into swamps which support growth of many herbs and shrubs.

Given good climatic and ecological conditions, after a long time a wood land develops and eventually large trees forming climax community.

b) Secondary succession.

Is the sequence of change from the initial colonization of an area which has previously been inhabited by a particular community like cleared forest, abandoned field, burnt area to establishing a **relatively stable community (climax community)**.

In secondary succession, the pioneer organisms are fast growing annual plants like *Bidens pilosa*, *commelina* species, they grow in an area which was previously inhabited by well-established communities. The animals which become available at this stage include insects, detritivores such as earth worms and their predators.

When some of the organisms die, they decompose and add organic matter into the soil. After a few years, herbs such as *Lantana camara* begin to establish themselves in the area.

After many years, the shrubs like *Acacia* and other small trees come in place, these shrubs gradually replace the herb community in the area. At this stage birds come in place.

Due to favourable climatic conditions, accumulation of sufficient nutrients in the soil, a climax community comprising of large trees and larger animals develop. The animal communities keep changing with changing plant communities.

Driving forces of succession (initiations of the succession process).

(i) Nudation.

This is exposure of a given locality to succession stages. For example clearing a given plant community to have an open land.

(ii) Arrival of propergules.

In this case, the propagation structures such as seeds, stolons, rhizomes and corms etc are dispersed to the locality or the already existing propergules begin to establish.

(iii) Germination (Easis).

The established propergules together with the newly introduced ones germinate.

(iv) Competition.

The germinated propergules begin to exhibit both interspecific and intraspecific competitions.

(v) Reaction.

A better adapted and well established individuals out compete those which are less adapted to the environment.

(vi) Establishment .A better competitor establish a climax community.

Examples of secondary succession

• **Fire**

Fire is one of the most common causes of secondary succession and is an important component for the renewal and vitality of many types of ecosystem. Fires may either take place naturally, for example when lightning strikes a dry habitat, or may involve controlled, systematic burning of a landscape by humans.

Both the abiotic and biotic components of an ecosystem can be drastically altered by the presence of fire. The most notable abiotic feature that is affected by fire is the soil; CO₂, CO and CH₄ stored within the organic material is released into the atmosphere during the combustion process; however, this initial loss of nutrients is often counterbalanced and then increased by the decomposition of leftover plant material which leaches N, P and K back in to the soil. The moisture retention of the soil also increases due to the reduction of transpiration by plants, and because more water is allowed to reach the soil surface where interception of rain by leaves is greatly reduced or non-existent. Soil pH often rises (more alkaline) after a fire due to the combustion of acids.

- **Renewal after disease**

If a disease affects all of a certain species within an area, the species is likely to experience a rapid die-off. Although the onset of disease can be a catastrophic event for a particular species, once the living crop has entirely died off and the disease therefore eradicated, if the roots or seeds remain in the soil, the crop can repopulate. Alternatively, the disease can kill enough of a species to allow for invasion by species which may have been previously unable to colonize, which in turn enables a more diverse range of species to inhabit an area.

- **Gap dynamics**

Although secondary succession can happen on a large scale and have an intense effect on a habitat or ecosystem, it is most common on a small scale. The disturbance and subsequent secondary succession that occurs after a gap is created in a forest canopy, following the death and collapse of a single tree or the loss of a large branch, is known as gap dynamics; the effect is often most prevalent

Changes that take place in a community during the succession process.

- (i) Species composition changes and its more rapid in the pioneer or early stages.
- (ii) Biomass and non-living organic matter increases,
- (iii) There is increased specialization in the trophic levels which become longer with upto five levels. Food webs become established from food chains.
- (iv) Primary productivity in the community reduce because of increased specialization.
- (v) Total number of species represented in a community becomes fairly stable,
- (vi) Species diversity becomes high,
- (vii) The structure of the community change from simple to complex with many microhabitats and stratification.
- (viii) Niche specialization become narrow from being broad.
- (ix) The size of organisms become large.

r-SPECIES AND k- SPECIES.

The first species to colonise an area are known as **r-species (opportunists)** and the last species to colonise the land are known as the **k-species (equilibrium species)**.

Examples of r-species. Annual plants like the herbs, bacteria, paramecium, aphids, beetles etc.

Examples of the k-species; Perennial plants, large birds, tropical butterflies, humans etc.

DIFFERENCES BETWEEN r-SPECIES AND k-SPECIES.

r-SPECIES.	k- SPECIES
Reproduce rapidly. Reproductive rate not sensitive to population density to population density (i.e they do not stop producing when the number is large). Show significant population fluctuations. Are not very persistent in the environment. Are small in size, Disperse widely. Occupy short lived habitats eg. Bacteria on rotting. Have shorter life cycle. Are poor competitors. Do not become dominant in an area.	Reproduce slowly. Reproductive rate is sensitive to population density (they stop producing when the number is large) Population size is close to equilibrium. Are very persistent in the Environment. Larger in size. Do not disperse widely in an area. Occupy long lived habitats eg. Trees in a forest. Have a longer life span. Are good competitors. They become dominant in an area.

Techniques and benefits for restoring degraded ecosystems.

Ecosystem restoration involves methods and techniques aimed at bringing back the health of damaged environments. This process can vary in complexity. It might include practices like reforestation, where trees are replanted, or soil health improvement to make land productive again.

Numerous factors contribute to ecosystem Degradation, such as urban expansion and pollution. Each of these issues can disrupt the balance of nature. Those involved often face challenges like invasive species, which can outcompete native plants and animals. Effective land management strategies are essential to combat these threats.

Restoring degraded areas is crucial for multiple reasons.

- Healthy ecosystems provide vital services, such as clean water, fertile soil, and a stable climate. They have a direct impact on our lives and the future of our planet.
- Benefits extend beyond nature alone; they reach our communities and economies.
- Increased biodiversity enhances resilience, allowing environments to withstand changes like climate change.
- Furthermore, successful projects often require active community involvement. Local people play a key role in maintaining and supporting restoration efforts. Without their participation, success is unlikely.

Ecosystem assessment and damage quantification techniques**Techniques to restore the eco system Passive restoration strategies****a. Natural regeneration processes**

Passive restoration relies on the inherent ability of ecosystems to recover naturally once stressors are removed.



b. Soil seed bank activation and seedling recruitment

The soil seed bank is a natural repository of dormant seeds that can remain viable for years or even decades. By creating favorable conditions for germination, there can be activation of their hidden potential. This might involve reducing competition from invasive species, improving soil moisture retention, or altering light conditions to break seed dormancy.

Seedling recruitment is the next crucial step in this process. Once seeds germinate, young plants need to establish themselves successfully. This can be done by protecting seedlings from herbivores, reducing competition from faster growing species, and ensuring adequate water and nutrient availability during the critical early growth stages.



An example of a constructed wetland

c. Monitoring and adaptive management in restoration projects

Ecosystem restoration is not a one-time intervention but an ongoing process that requires careful monitoring and adaptive management. There is need to track progress towards restoration goals, identify emerging challenges, and adjust strategies as needed. Effective monitoring programs typically include:

- ✓ Regular surveys of plant and animal communities
 - ✓ Assessments of soil and water quality
 - ✓ Monitoring of key ecosystem processes such as nutrient cycling
 - ✓ Evaluation of ecosystem services provision
 - ✓ Documentation of human interactions with the restored ecosystem
- Data collected through monitoring is then used to inform adaptive management decisions. This might involve adjusting planting strategies, modifying water management practices, or implementing additional interventions to address unexpected challenges.

d. Policy frameworks and socioeconomic aspects of ecosystem restoration

Successful ecosystem restoration requires more than just ecological expertise it also depends on supportive policy frameworks and consideration of socioeconomic factors. There is need to engage with a wide range of stakeholders, including local communities, policymakers, and industries that may be impacted by restoration activities.

- ✓ Policy support for ecosystem restoration can take many forms, including:
- ✓ Legal protection for restored areas
- ✓ Financial incentives for landowners to undertake restoration
- ✓ Integration of restoration goals into land-use planning and development policies
- ✓ Support for research and capacity building in restoration science
- ✓ Mechanisms to value and compensate for ecosystem services

C) Examine the concept of energy flow through ecosystems, its role in maintaining ecosystem stability, and the impact of human activities on energy flow. (10.3)

- the concept of energy flow in the ecosystem.
- Effect of human activities on energy flow
- Bio-accumulation, bio magnification, and feed conversion ratio, their importance and relationship to energy transfer/flow.
- Significance of bioaccumulation and bio magnification to the health of organisms and the environment in an ecosystem.
- Applications of feed conversion ratios.

THE CONCEPT OF ENERGY FLOW IN THE ECOSYSTEM.



Describe the functioning of ecosystem.

An ecosystem functions through the **flow of energy** and the **cycling of matter**

A.Explain the process of Energy flow in an ecosystem.

The energy flow in an ecosystem is basically non-cyclic. It is passed along a feeding hierarchy in a chain called **food chain**. Each feeding stage (feeding level) in a food chain is called **trophic level**.

The source of energy in an ecosystem is the sun. Sun energy is received in form of electromagnetic radiations. About 40% of the sun's radiation is reflected or absorbed immediately from the clouds, dust, soil, water or vegetation in the atmosphere and the earth's surface. Only 1% of the sun's radiation is trapped by the green plants which are the primary producers (autotrophic organism) and converted into chemical energy in a process of **photosynthesis**. The rate at which this chemical energy is formed and stored by the primary producers (Green plants) per unit area per unit time is known as gross primary productivity (GPP).

Some of this chemical energy is utilized by green plants and in the process lost as heat through respiration and photorespiration. The remaining energy stored in form of carbohydrates per unit area per unit time after respiration and photorespiration is known as **Net Primary productivity (NPP)**. The NPP becomes available to the primary producers which are the herbivores at the next trophic level. The herbivores feed on the primary producers to acquire this chemical energy. The rate at which **primary consumers** (the herbivores) accumulate and store this chemical energy per unit area per unit time is called **Secondary productivity (SPP)**.

Some energy is lost in the primary consumers as heat through respiration, excretion, growth, repair, reproduction, uneaten plant parts, egestion, etc. The remaining energy is passed into the secondary and tertiary consumers in the next trophic levels when they feed on the herbivores. In the process energy is again lost as heat through the same processes. Decomposers which include bacteria and fungi utilize energy from every trophic level when the organisms in each stage of the feeding relations die and begin to decompose.

Energy flows out of the trophic levels in the following ways,

- Lost as heat.
- In structures synthesized by the plant but not contributing to increase in biomass. For example shedding leaves, bark, flowers and production of seeds for dispersal.
- Death of plants and animals.
- Plants eaten by herbivores

Causes of the limited number of trophic levels in ecosystems and food chains

1. Some energy is used up during respiration.
2. Some energy is lost in inedible and indigestible parts of organisms.
3. Some organisms die before they are eaten.
4. Some of the chemical energy is converted into other forms such as sound, light energy, heat energy, which easily escapes from the organisms.
5. Food preferences limit the available energy in ecosystems 6. Territorial behaviour limits available food sources

Feeding inter-relationships in an ecosystem.

This is biotic factor which influence an environment, they include, Food chains. Food webs. And ecological pyramids.

The feeding inter-relationships arise due to grazing, predator-prey relationship, parasitism, mutualism, symbiosis, etc.

a) Food chains.

Food chain is a linear sequence or series of organisms existing in an ecosystem through which chemical energy formed and stored (Carbon compounds produced) by the green plants and other photosynthetic organisms are systematically transferred.

Each organisms in the series feeds on and derives energy from preceding one, it is also consumed by another organisms following it and provides energy for that organism. The energy in the food chain is passed along the hierarchy in a chain called food chain. Each feeding level in a food chain is called trophic level. Some energy is lost when it passed from one level to another; this is why food chains are short.

Types of food chains.

There are two types of food chains,

- (i) Grazing food chains.
- (ii) Detritus food chains.

Grazing food chains

Is the linear nutritional sequence of organisms in an ecosystem where the chemical energy is passed in which the first trophic level is occupied a green plant or green algae and the second trophic level is a grazing animal (Herbivore) and the subsequent levels by the carnivores.

Examples.

- (i) **Grass** ⇒ Grass hopper ⇒ **Frog** ⇒ **Snake** ⇒ Eagle.
(Primary producer) (Primary consumer) (Secondary Consumer) (Tertiary consumer) (Quaternary consumer)
- (ii) **Plant** ⇒ Fly ⇒ Spider ⇒ **Shrew** ⇒ Owl
- (iii) Grass ⇒ Deer ⇒ Jaguar

Detritus food chains

Is the linear nutritional sequence of organisms in an ecosystem through which a chemical energy is passed and in this case the first trophic level is occupied by the detritus, second by detritivores and the subsequent levels by the carnivores.

Examples.

- (i) **Leaf litter** ⇒ **earthworm.** ⇒ **Black bird** ⇒ **Sparrow snake.**
- (ii) **Dead animal** ⇒ **Blowfly maggots** ⇒ **Common frog** ⇒ **Grass snake.**

Research on these questions.

1. Fragments of decomposing materials are called detritus and many small animals feed on them, contributing to the process of breakdown (decomposition), these animals are called detritivores. Examples of detritivores include,

(i) Wood land detritivores. Earth worms, wood lice, blow fly maggot,

(ii) Sea shore detritivores.

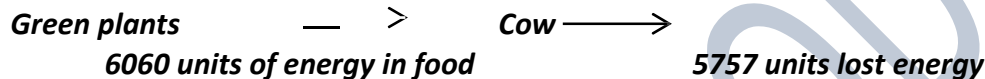
Rag worm, dog whelk, sea cucumber.

(iii) Terrestrial detritivores.

Earth worms, wood lice, millipedes, mites, nematodes, termites, springtails etc.

2. Rats are herbivores that usually live in human dwellings which are filthy. Bacteria of the species *Pasteur Ella pestis*, live in and feed on the blood of the them to humans when the fleas bite humans. The bacteria feed on human blood too; and this sometimes results into humans developing bubonic plague. In the space below, draw a food web to show the feeding relationships described

3. In a food chain, when energy is transferred from one trophic level to another some of it is lost. The figure below shows such a transfer of energy in an out of a cow in a year. Eaten



(a) Name the trophic levels shown in the figure.

(b) State two ways in which energy is lost from the cow

(c) Calculate the percentage of energy taken in during the year, which is retained by the cow.

(d) In proportion to its body, a calf uses more energy to maintain its body temperature than a Cow. Explain why this is so

How some detritivores influence the components of terrestrial ecosystem

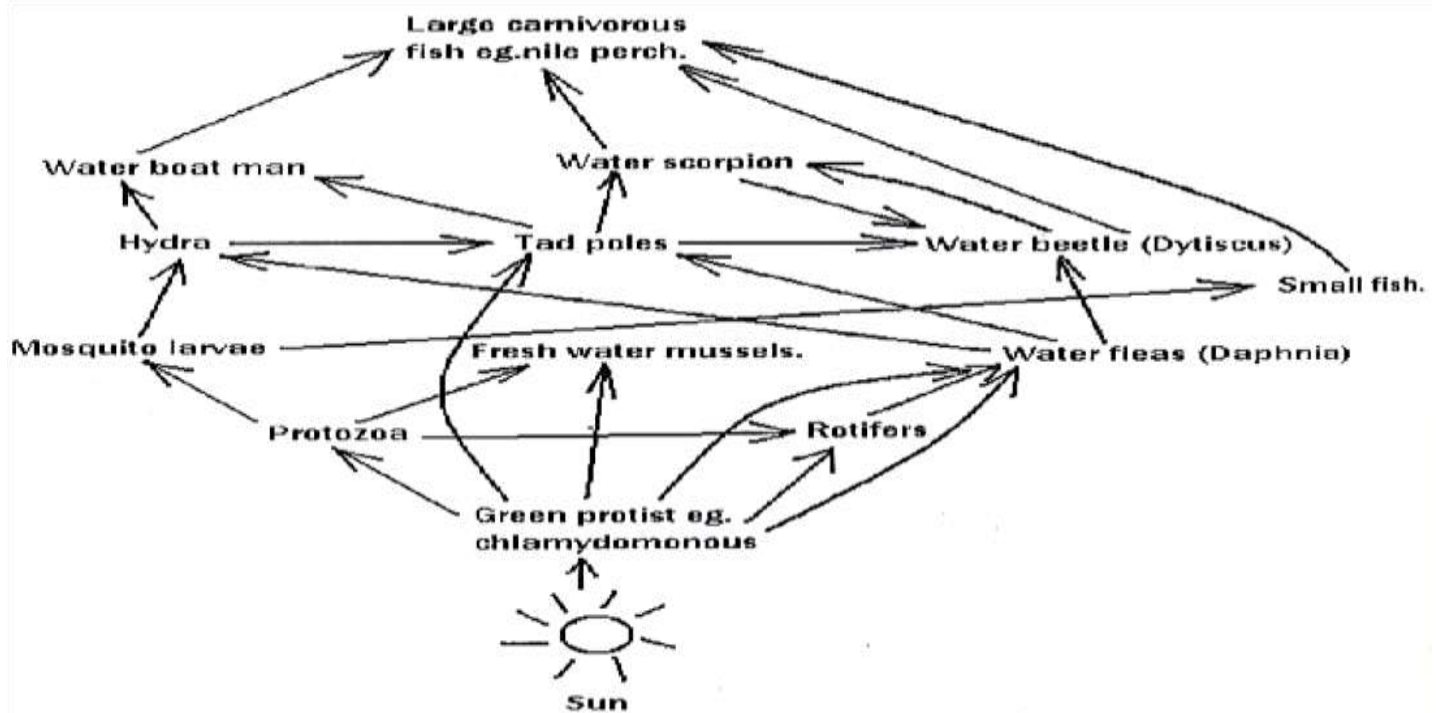
Termites live in nests called termitaria, they build galleries below the soil surface with cemented walls, and this prevents free aeration in the soil and reduces proper drainage of the soil. Termites also carry plant materials into the soil and break them into smaller fragments, increasing their surface area for the process of decomposition by aerobic bacteria. This releases nutrients to the soil. Termites eat other organisms, lowering organic matter content of the soil. Their faecal materials contain uric acid which is incorporated into the termitarion but also adds into the humus content of the soil.

Earth worms burrow into the soil, burrowing promotes and improves aeration of the soil, oxygen is available for activities of aerobic bacteria which increases the rate of decomposition of organic matter, more nutrients are released into the soil. The nitrogenous wastes of the earth worms add more ammonia and nitrates in the soil. Dead individuals are decomposed to add humus into the soil. Earth worms ingest the soil particles and mix the plant materials within the soil. Earth worms contain mucus and bacterial polysaccharides which hold together the fine particles, improving the crumb structure of the soil. The crumbs are not easily dispersed by water and promote the granular texture of the soil.

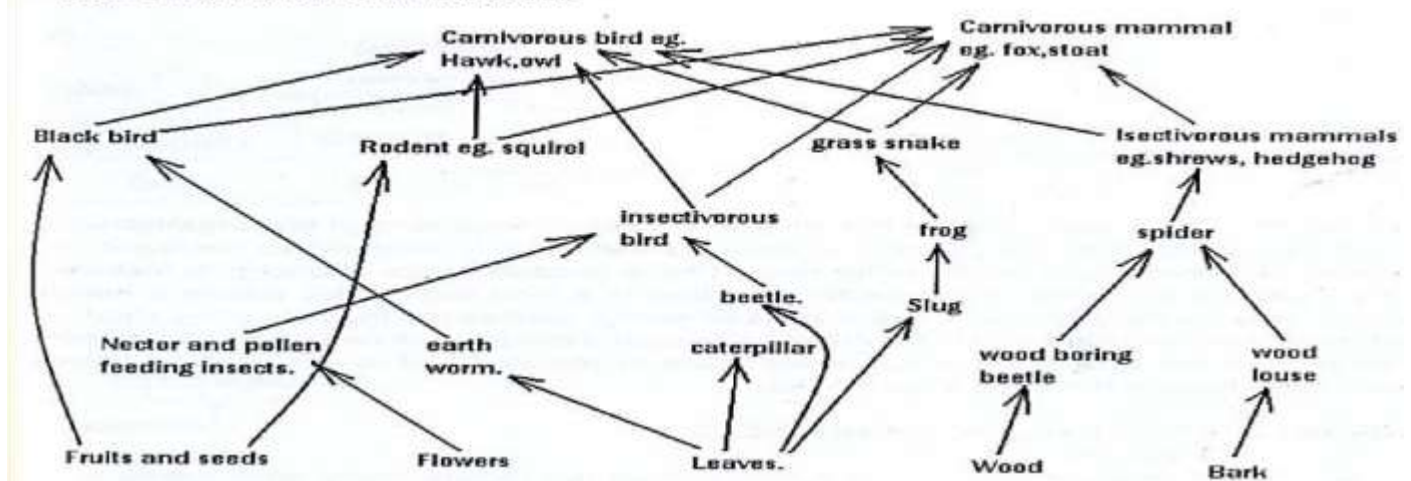
b) Food web.

Is an interconnected food chains in which an animal or organism at one trophic level has several alternative animals that it can feed on at different trophic levels, and also has many other animals that can feed on it at different trophic levels.

Example of a food web in a typical fresh water pond.



EXAMPLE OF FOOD WEB IN WOODLAND.



ECOLOGICAL PYRAMIDS.

Feeding relationships and energy transfers through the biotic component can be quantified and shown diagrammatically as ecological pyramids. Ecological pyramids provides basis for comparing, different ecosystems, seasonal variation within an ecosystem, changes in an ecosystem. There three types of ecological pyramids, these include the following,

- Pyramid of numbers.
- Pyramid of Biomass.

- Pyramid of Energy.

Shortcomings of the Ecological pyramids include the following,

- It is quite not easy to identify the trophic levels of an organism as many organisms feed at several trophic levels.
- It omits the detritivores organic matter content, yet much of the energy fixed may be passed into the detritivores.
- It only considers energy stored by the green parts of the plant and consumed by the herbivores, yet some herbivores cannot digest chlorophyll, others eat only seeds or fruits or nectar.

Types of ecological pyramids.

a. Pyramid of numbers.

Is a bar diagram indicating the relative numbers of individuals at each trophic levels in a food chain. Example.



The length of each bar indicates the relative number of organisms at each trophic level.

It can be noticed from the pyramid of numbers that there is progressive decline in the number of individuals at each trophic level. This is because, a lot of energy is lost each time it passed from one trophic level to another in a food chain. This places a natural limit or reduces the biomass and this loss of energy causes the food chain to be short, i.e. not more than six levels exist. Therefore to support individuals at one trophic level more energy from the individuals at the levels below is required and is achieved by having more individuals at the lower trophic levels.

Advantages of pyramid of numbers.

- It is easy to carry out.
- It is relatively cheaper to conduct, does not require many equipments to do measurements.

Disadvantages of pyramid of numbers.

(i) All individuals are counted as the same, yet not all individuals have the same sizes.

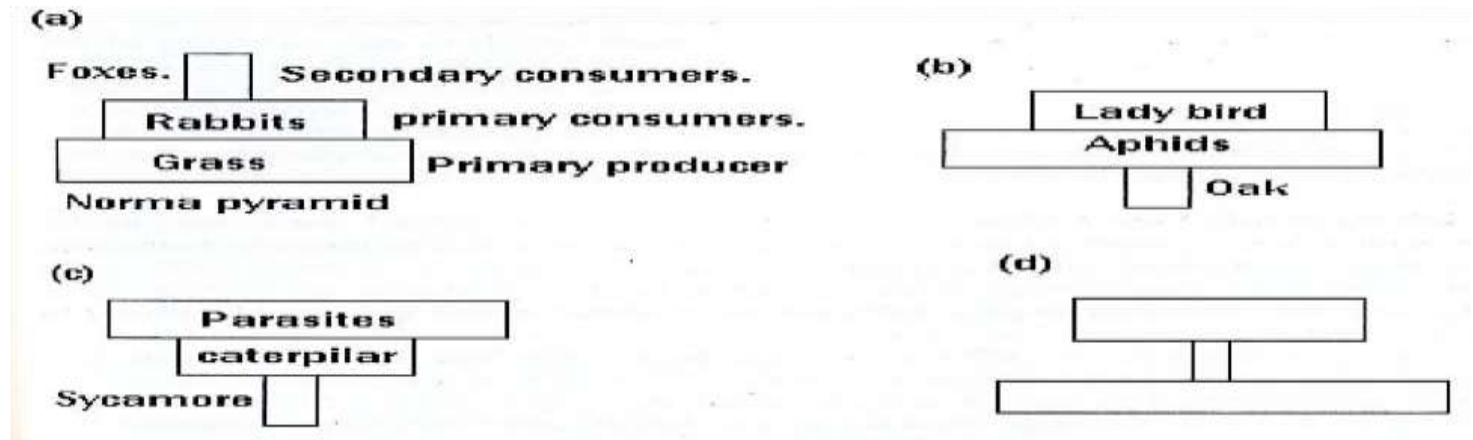
For example an oak tree is counted as one individual in the same way as an aphid. (ii) No account is made for juveniles and other immature forms of species whose diet and energy requirements may differ from that of the adults.

(iii) The numbers of some individuals is so large that it is difficult to represent them accurately on the same scales other species in food chain with considerable numbers. For example, Millions of black flies may feed on a

single rose-bush and this relationship cannot be effectively drawn to scale on a pyramid of numbers. Such conditions give rise to unusual pyramids of numbers.

(iv) Does not indicate the source of energy in an ecosystem.

Examples of unusual pyramids of numbers



(a) In a normal pyramid of numbers for comparison.

(b) The producer is a single plant such as a single tree.

(c) Producer is a single plant, infested with parasites (primary consumers) and the later are parasitized by further parasites.

(d) A large number of producers are eaten by a single primary consumer which is infested with parasites {Secondary consumers}

Some of the disadvantages are overcome by use of a pyramid of Biomass.

B. Pyramid of biomass.

Is a bar diagram of proportionate length indicating dry mass of all organisms at each trophic level. Biomass is the weight of living material per unit volume or area.

Advantages of pyramid of biomass.

- (i) Biomass provides a relatively accurate measure of the amount of energy in each trophic level,
- (ii) It gives the measure of total productivity in each trophic level.

Disadvantages of the pyramid of biomass.

- (i) It is impossible to measure exactly the biomass of all individuals in a population. A sample is usually taken and measured and this sample may not be a representative of all organisms at a particular trophic level.
- (ii) The biomass of individuals varies from one season to another. For example Biomass of deciduous tree in summer may be different from those in winter, so, the sample only measures the amount material present at a particular time. This is called standing crop and gives no indication of total productivity.
- (iii) It involves destroying or killing of the living organisms in order to obtain the dry weight.
- (iv) No source of energy is indicated.
- (v) It is more laborious and expensive to conduct,
- (vi) It is very much time consuming because it involves many steps,

(vii) *The standing biomass or standing crop biomass which is the biomass at the time of sampling does not indicate exactly the productivity.*

c. Pyramid of energy.

Is a bar diagram in proportion to indicate the total energy utilized at each trophic level. The total productivity of primary producers of a given area can be measured for a given period. But obtaining the necessary data can be a complex and difficult affairs.

Advantages of pyramid of energy.

- (i) It represents the amount of energy per unit area or volume passed from one trophic level to another. So, it is more accurate.*
- (ii) It represents total productivity at each trophic level.*
- (iii) It takes into account the energy from the sun which is the source of energy in an ecosystem.*
- (iv) It enables comparison of different ecosystems, so, the importance of one ecosystem to another can be determined.*
- (v) Unusual and inverted pyramids are not obtained.*
- (vi) The energy content of each individual is determined independently of the others; it shows that no two individual species can have the same energy content.*

Disadvantages.

- (i) It is most difficult to obtain data for pyramid of energy since it requires a lot of technical knowhow.*
- (ii) It is expensive to carry out because it requires some sophisticated equipments to do measurements.*

Productivity in an ecosystem.

Productivity refers to the rate at which energy and Biomass or organic matter is produced per unit time in a unit area by organisms in an ecosystem. Productivity are of two types,

- Primary productivity.*
- Secondary productivity.*

Primary productivity.

This is the rate at which certain amount of energy and Biomass is, produced and stored by primary producers per unit time in a unit area. It is further divided into,

- **Gross primary productivity (GPP).**

This is the rate at which certain amount of energy and Biomass is produced and stored by primary producers per unit time in a unit area before any loss of energy due to respiration and photo respiration.

- **Net primary productivity (NPP).**

This is the amount energy and biomass available per unit time in a unit area after loss of some energy from the Gross primary productivity due to respiration and photorespiration.

i.e

$NPP = GPP - \text{Respiration.}$

$\text{In } C_3 \text{ plants, } NPP = GPP - \text{Respiration} + \text{Photorespiration.}$

Note: C_3 plants have a lower NPP than C_4 plants.

GROSS SECONDARY PRODUCTIVITY (GSP).

Is the rate at which certain amount of energy and Biomass is produced and stored by primary consumers per unit time in a unit area.

*The amount of the energy and biomass that remains in primary consumer per unit time in a unit area after some energy have been lost from the GSP due to excretion, egestion and respiration is referred to as the **Net Secondary Productivity (NSP).***

Carnivores have higher Net secondary productivity (NSP) than herbivores because of the following reasons,

-The diet of carnivores is rich in proteins which is easily digested and soluble products efficiently absorbed. In this case, very little energy is lost, while herbivores feed on diet rich in carbohydrate cellulose (plant material) which is not easily digested or only partially digested, a lot of energy is lost in the undigested parts and hence herbivores have lower NSP.

-Carnivores do not have symbiotic microbes to consume part of the energy from their diet, while herbivores have Cellulose secreting bacteria in their guts, these bacteria utilize some of the energy from the cellulose.

Factors that influence productivity of an ecosystem.

(i) Level of nutrients especially phosphate and nitrates. The higher the level the greater the productivity as they are used in protein synthesis hence more dry matter is formed.

(ii) Temperature. The higher the temperature the higher the productivity since temperature activate enzymes involved in photosynthesis.

(iii) Carbon dioxide concentration. The higher its concentration in air, the greater the productivity since carbon dioxide is a raw material for photosynthesis. The lower the concentration of carbon dioxide the, the lower the productivity.

(iv) Amount of light available. The higher the light intensity, the more energy fixed and the greater the productivity. Lower light intensity results into decreased productivity.

(v) Availability of water. Plenty of water increases rate of photosynthesis since water is a raw material for photosynthesis, hence more energy is fixed raising the productivity.

(vi) Length of growing season. The greater the length, the higher the productivity. The shorter the length, the lower the productivity.

(vii) *Relative population size of primary producers. The greater size of green plants, the more energy fixed and the higher the productivity.*

(ix) *Nature and type of tree species. Certain tree species tend to be more productive than others, therefore the more abundant these tree species are, the greater the productivity. The fewer such tree species, the lower the productivity.*

(x) *Concentration of pollutants in air. The higher the concentration, the lower the amount of photosynthesis and less energy fixation, hence the lower productivity.*

(xi) *Chlorophyll concentration in case of aquatic ecosystem, upper zones of lake have higher chlorophyll content than deeper zones, hence the greater the concentration of chlorophyll, the higher the productivity.*

(xii) *Soil fertility, humus, mineral content. Productivity increases with increase in Soil fertility, humus, mineral content. They are utilized in protein synthesis and formation of new organic matter. Decrease in Soil fertility, humus, mineral content, decreases productivity.*

(xiii) *Abundance of decomposers which enable nutrient recycling making the nutrients available for synthesis of new organic matter. This will increase productivity. Few decomposers reduce productivity.*

ECOLOGICAL TECHNIQUES OF STUDYING FEEDING RELATIONS OF ORGANISMS.

(i) Direct observations of what the organism eats. *This method has some disadvantages,*

- *It cannot be applied to aggressive animals.*
- *It cannot be applied to organisms living in concealed and hidden habitat.*
- *It cannot be applied on organisms which refuse to eat under observation. For example Rodents and some birds.*

(ii) Faecal analysis.

This involves studying the content of faeces of a given animal.

This method has some disadvantages that include,

- *Some food cannot be seen in the faeces because they are already digested and absorbed.*
- *It cannot be applied on animals which eat their faeces like Rabbits a practice known as coprophagy. The faeces are eaten because they still contain more nutrients following little digestion and absorption which occurred within the gut.*

(iii) Examination of the stomach content.

This is to find out what they feed on and it requires identification skills after enzyme action and mastification.

(iv) Use of radio-active tracers.

It involves labeling available foods using radio-active substances and their trace their presence or absence in the animals gut. It can be used in all animals no matter their nature.

NOTE: To come up with more reliable information, more than one method is used.

B.CYCLING OF MATTER (BIOCHEMICAL CYCLES).

This is another feature or characteristic of an ecosystem. It is the means by which essential nutrients in nature like nitrogen, carbon, hydrogen and water are maintained

Constant. The Bio-chemical cycles existing in an ecosystem include,

Nitrogen cycle.

Carbon cycle.

Hydrological or water cycle.

i) Nitrogen cycle.

Nitrogen comprises about 78% of all atmospheric converted into nitrates by the following processes, gases.

Atmospheric nitrogen is

- **Lightening.**

Lightening combines nitrogen and oxygen to form nitrates. Nitrates formed dissolve in rain water and fall down and enter the soil. The nitrates are absorbed by the plant roots and converted into nitrogen compounds in plants such as amino acids and proteins.

- **Fixation of nitrogen/Nitrogen fixation.**

*The aerobic nitrogen fixing bacteria such as Rhizobium and Azotobacter live in the root nodules of leguminous plants like peas, beans and clover. These aerobic nitrogen fixing bacteria in the root nodules fix or convert atmospheric nitrogen into nitrates which are then built up into amino acids and proteins in the plants. Therefore **nitrogen fixation** is the process by which atmospheric nitrogen is converted into nitrogen compounds such as amino acids and nitrates.*

The plant materials are consumed by the herbivores and other animals. In this way the nitrogen compounds become available in the herbivores. The herbivores are equally eaten by other animals called the heterotrophic organisms.

When the plants and animals become old, they die and their remains mix with the soil. In the soil, saprophytic organisms like putrefying bacteria and fungi cause the breakdown of proteins in dead decaying organisms to form ammonium compounds. Other ammonium compounds can be derived from any of the following sources,

- *Animals excrete urine containing high concentration of the nitrogenous waste urea. Putrefying bacteria convert nitrogen compounds in the urea to ammonia.*
- *Industrial Haber process produce ammonia that is released into the soil.*
- *Human activity which involves application of organic farm fertilizers like CAN, NPK releasing nitrogen compounds and urea into the soil. Putrefying activities cause release of ammonia.*
- *Sewage discharge on the land. Sewage contains ammonium compounds in the soil, ammonia is converted into the ammonium compounds by chemical combinations. The ammonium compounds are converted into nitrites and nitrates in a process called Nitrification. Nitrification is the process by which ammonium compounds are converted to nitrites and nitrates in the soil by the activities of nitrifying bacteria.*

In this process, aerobic nitrifying bacteria like Nitrosomonas and Nitrococcus oxidize ammonium compounds to nitrites. Then the Nitrobacter bacteria further oxidizes nitrites into nitrates. Nitrates are absorbed by the plants.

Some of the nitrates in the soil can be converted back into atmospheric nitrogen in a process called **Denitrification**.

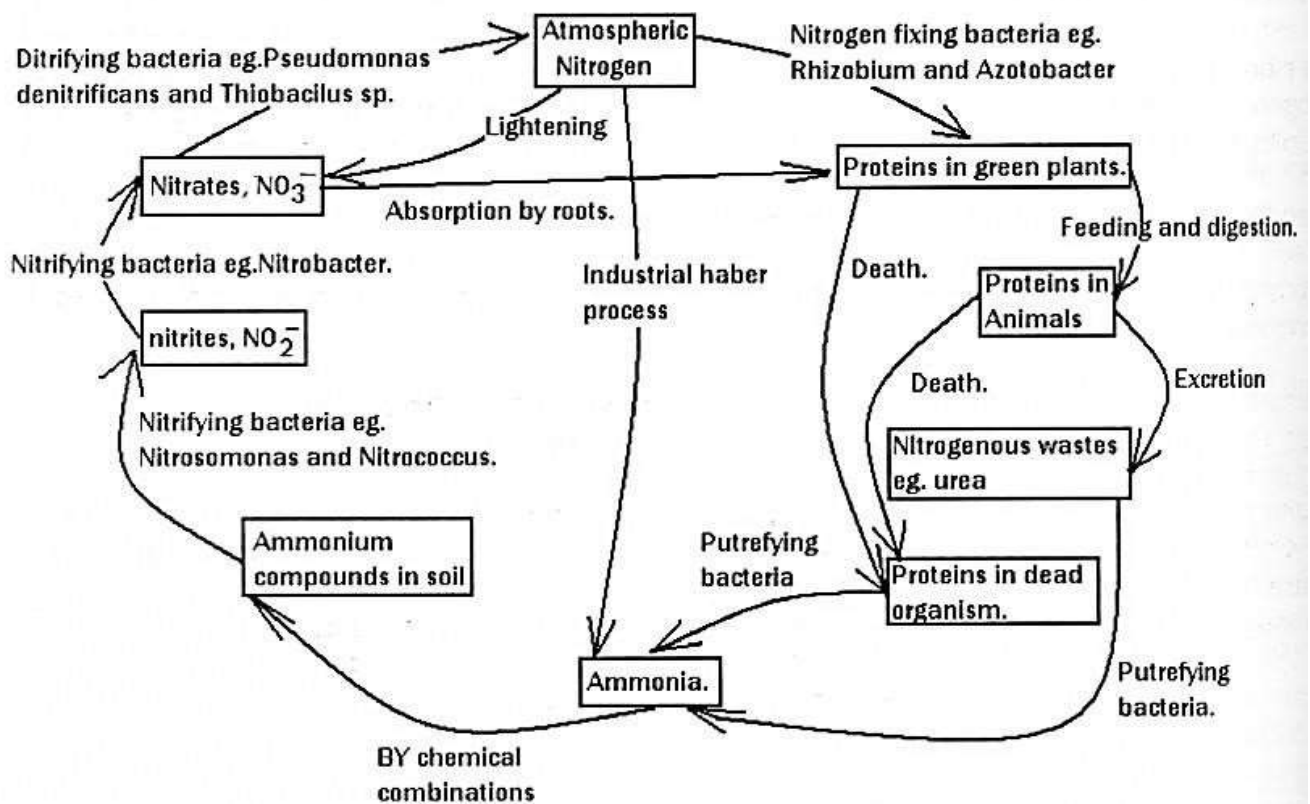
Denitrification is the process by which nitrates in the soil are converted into gaseous nitrogen which is given off into the atmosphere. It is carried out by anaerobic bacteria like *Pseudomonas dinitrificans* and *Thiobacillus dinitrificans*. The necessary anaerobic conditions are in water logged soils, where the denitrificans thrive and by converting nitrates to atmospheric nitrogen, they reduce soil fertility. This is why farmers plough and dig up their land in order to improve drainage and aeration so as to avoid anaerobic conditions but instead promote aerobic conditions for the activities of the nitrifying bacteria.

Note that, nitrogen enters the food chain in the following ways,

- Lightening. Includes electrical and photochemical fixation of atmospheric nitrogen to form nitrates.
- Nitrification process.
- Nitrogen fixation.
- Use of organic fertilizers.

Denitrification releases nitrogen into the atmosphere.

THE NITROGEN CYCLE IN AN ECOSYSTEM.



SIGNIFICANCE OF NITROGEN IN ECOSYSTEM

- Used for synthesis of amino acids and proteins in plants.
- The amino acids and proteins are used for making structural and fibrous proteins e.g. Muscles and cartilage in animals. The proteins are also used to form functional proteins like enzymes, antibodies and hormones.
- Forms structure of vitamins needed for healthy body.

- (iv) Used in synthesis of nucleotides which are subunits for nucleic acids, DNA and RNA.
- (v) Utilized in synthesis of chlorophyll which traps sun energy for photosynthesis.
- (vi) Components of plant hormones auxin, responsible for cell division, elongation resulting into growth. Also used in synthesis of insulin in animals, required for regulation of sugar levels in blood.

Deficiency of Nitrogen in plants causes, stunted growth, Chlorosis (yellowing of leaves). While in animals, its deficiency is due to deficiency of proteins in the diet and causes, Kwashiorkor, Stunted growth, General body weakness, and oedema.

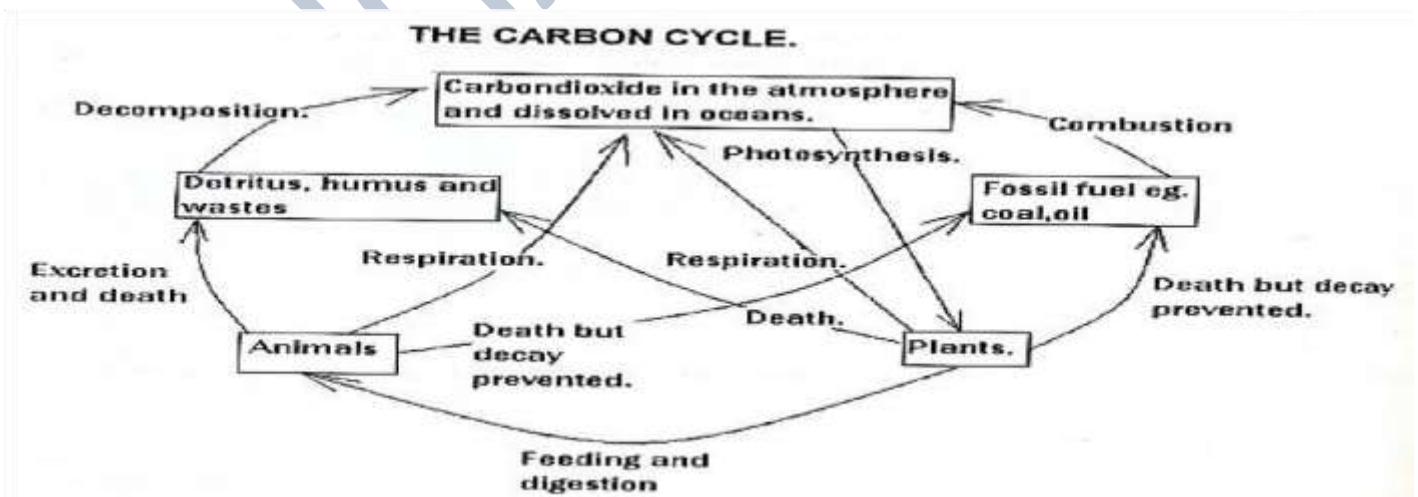
CARBON CYCLE.

The composition of carbon dioxide in the atmosphere is about 0.03%. Despite this small proportion, carbon dioxide is the major pool of carbon for plants and animals in an ecosystem.

Carbon dioxide is removed from the atmosphere by the process of **photosynthesis** by photosynthetic organisms. In this case, green plants absorb carbon dioxide from the atmosphere, phytoplankton absorb dissolved carbon dioxide from the water. The carbon dioxide is utilized for the manufacture of carbohydrates, proteins and fats in a process of photosynthesis. The plants are eaten by herbivores which digest and assimilate the foods originally synthesized by the plants. The herbivores are in turn eaten by the carnivores which also acquire the assimilated carbon.

Carbon dioxide is subsequently returned into the atmosphere through the following processes,

- Aerobic respiration by many living organisms produce carbon dioxide.
- Death of plants and animals and rapid decomposition or decay of their remains by the activities of the saprophytes or putrefying bacteria, this releases carbon dioxide.
- When large quantities of dead plants and animals accumulate in anaerobic conditions and prevented from decaying, they form coal, oil and other fossil fuels. Combustion of these fossil fuels produce large amounts of carbon dioxide into the atmosphere. The processes that absorb carbon dioxide from the atmosphere and those returning it into the atmosphere function in such a way that the concentration of the carbon dioxide is maintained fairly constant in the ecosystem/atmosphere.



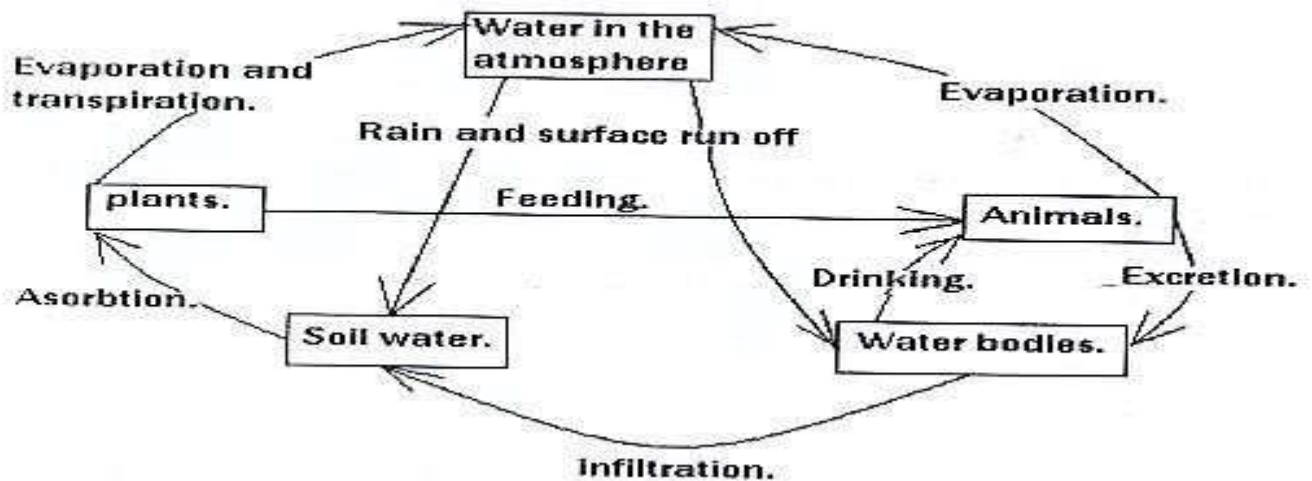
HYDROLOGICAL CYCLE (WATER CYCLE).

Water in the atmosphere exists as water vapour which form part of the cloud, subsequent condensation results into rain fall. Rain water is carried into water bodies and some rain water infiltrates the soil. Some water from various water bodies like rivers, lakes, seas also infiltrate into the soil to collect as soil water. Excretion of urine and faeces to a small extent add to the water bodies.

Plants absorb soil water by the root hairs. Animals drink water drawn from the water bodies. Animals can also obtain water when they feed on plant parts such as fruits, stem, roots which store high amounts of water.

Water is returned into the atmosphere when water evaporates from the surfaces of the skin of the animals, surfaces of the leaves, stem of plants through transpiration, and evaporation from water bodies.

DIAGRAM OF WATER CYCLE.



Human activities that affect water cycle.

- Dam construction which slows down the speed of water movements.
- Swamp and land reclamation which drains water bodies and reduces the amount of water in the open water systems.
- De-forestation which reduces the rate at which underground water is reabsorbed by the plants since the trees are cleared which absorb the underground water.
- Over utilization of the underground water by excessive construction of boreholes and use of underground water pumping machines.

Human activities that affect nutrient cycling and energy flow in an ecosystem.

• Deforestation.

This is cutting down or felling down of trees. It reduces amount of sunlight absorbed due to decrease in number of producers. Soil erosion occurs, resulting into loss of more nutrients since soil layer is removed in the process.

• Air pollution.

This results from addition in excess of greenhouse gasses into the atmosphere, such gases include, carbon dioxide, chlorofluorocarbon (CFC), and sulphur dioxide gas. Greenhouse gases results into depletion of ozone layer. While the rain water can dissolve sulphur dioxide gas to form acid rains.

Ozone depletion results into global warming may cause death of many consumers.

Global warming and acid rains cause destruction of producers, decreasing the number of producers, productivity is lowered which also lowers energy along the trophic levels.

- **Use of green houses and lighting of red and blue.** Red and blue Wave lengths increase photosynthesis and number of producers, increasing light energy trapped.
- **Mulching** reduces weed growth, thereby decreasing light energy absorbed by plants.
- **Harvesting of crops.** It involves removal of crops which reduces food energy available for herbivores. The herbivores (primary consumers) are eaten by humans.
- **Hunting.** This removes energy available for carnivores and other organisms in food web.
- **Burning dead organisms** including humans. Forest fires started by humans reduces energy available for decomposers and detritivores.
- **Use of pesticides and herbicides.** This affect decomposers making recycling of materials slower their survival.

Impacts of bio accumulation and bio magnification on life and ecosystems

Bioaccumulation (some molecules of the pesticide may be stored in specific organs or tissues at levels higher than would be expected) and **biological magnification** (the pesticide may get more concentrated as it passes along the food chains and webs) may occur. E.g. If Dichlorodiphenyl trichloroethane, DDT is sprayed on plants, to kill green flies, some survive, and absorb the chemical into their bodies. When eaten by small birds, DDT accumulates and when birds are eaten by other predators, e.g. birds of prey, the accumulation of DDT reaches a level which burns up and kills the final consumer.

Non-biodegradable chemicals on the other hand accumulate in tissues (**bioaccumulation**) and increase in succeeding levels in the food chain (**bio magnification**). At the individual level, organisms exposed to bio accumulated substances can suffer from various health problems.

These include

- ✓ neurological damage
- ✓ reproductive issues
- ✓ Suppression of the immune system, making them more susceptible to diseases.

FEED CONVERSION RATIO (ACR) AND ITS APPLICATIONS

Feed conversion ratio or FCR is a measure of an animal's efficiency to convert feed into increased body mass. It can be defined as feed intake divided by weight gain.

It indicates how efficient an animal is to convert feed mass to the desired output. The expected outcome may be anything, from milk for dairy cows and goats, eggs for laying birds, meat for meat animals such as broilers, goats, pigs, etc., wool for wool animals like sheep, goats, rabbits, etc.

An FCR helps farmers to determine whether or not an animal is an efficient food converter. In addition to this, it also allows farmers to prepare budgets for the feed for the entire cycle.

FCR is the mathematical relationship between the input of the feed given to the livestock over a period of time and weight gain of a population.

FCR is the mass of feed consumed or ingested divided by the output over a given period.

FCR = Feed Eaten/Animal weight gain or FCR = Mass of Input/ Mass of Output Applications of FCR Output

Applications of FCR

Aquaculture Management: In fish farming, FCR is critical because feed often costs >50% of total inputs for example: An FCR of 1.2 in tilapia ponds shows efficient feed use, while an FCR of 2.5 indicates wastage or poor feeding practices. This helps fish farmers optimize feeding schedules and reduce water pollution from uneaten feed.

Trial example

1. A farmer in Wakiso district is testing two different types of feed for his rabbits to determine which one is more efficient.

- Group A (10 rabbits) is fed on maize bran meal. Over 30 days, they consume 150 kg of feed in total and gain 60 kg of body weight (combined).
- Group B (10 rabbits) is fed on pelleted commercial rabbit meal. Over the same period, they consume 120 kg of feed in total and gain 70 kg of body weight (combined).

Calculate the Feed Conversion Ratio (FCR) for:

a) Group A (maize bran meal)

b) Group B (pelleted commercial feed) (Use the formula: $FCR = \text{Feed intake} \div \text{Weight gain}$)

c) Which feed is more efficient in promoting rabbit growth? Explain your answer using the calculated FCR values.

d) If the farmer's goal is to reduce production costs and maximize profits, which feed should he choose and why

d) EXPLAIN THE CONCEPT OF CARBON FOOTPRINT IN RELATION TO CLIMATE

CHANGE, INCLUDING ITS MEASUREMENT, AS WELL AS THE ROLE OF CARBON SEQUESTRATION IN MITIGATING CLIMATE CHANGE.

- ✓ The concept of carbon footprint and its measurement.
- ✓ Activities that contribute to carbon output and key sources of greenhouse gas emissions
- ✓ How carbon sequestration in forests reduces the impact of climate change.
- ✓ How carbon sequestration mitigates climate change.

The concept of carbon footprint and its measurement.

Carbon footprint is the total amount of greenhouse gases that is emitted directly or indirectly by an entity. For example, a person, product or business.

In other words, it is one measure of the impact their activities are having on the environment, and how much they are contributing to climate change.

Measurement of carbon foot print Example (Simple Household Measurement)

Imagine a family uses in one year:

200 liters of petrol for a car $\rightarrow 200 \times 2.3 = 460 \text{ kg CO}_2\text{e}$

1,000 kWh of electricity $\rightarrow 1,000 \times 0.1 = 100 \text{ kg CO}_2\text{e}$

30 kg of beef consumed $\rightarrow 30 \times 27 = 810 \text{ kg CO}_2\text{e}$

Total = 1,370 kg CO₂e ($\approx$ 1.37 tons CO₂e)

Trial number

1. A factory in Fort Portal wants to estimate their annual carbon footprint and you have been contacted for help, use the emission factors provided.

Activity Data (1 year)

- **Electricity: 1,200 kWh**
- **Petrol (car): 300 L**
- **Charcoal (cooking): 200 kg**
- **LPG/cooking gas: 24 kg**
- **Household size: 5 people**

Emission Factors (use these)

- **Electricity (Uganda grid): 0.10 kg CO₂e per kWh**
- **Petrol: 2.31 kg CO₂e per L**
- **Charcoal: 2.90 kg CO₂e per kg**
- **LPG: 2.98 kg CO₂e per kg**

Tasks for Students

i) Calculate emissions by source

- a) Electricity**
- b) Petrol**
- c) Charcoal**
- d) LPG**

ii) Total annual household footprint: Sum a–d.

iii) Per-capita footprint: Divide the total by 5 people.

iv) For each source, calculate its percentage of the total and rank them from largest to smallest.

v) Propose two realistic actions that the factory would undertake to reduce on their emission and estimate how many kg CO₂e the factory could save in a year and what the new total would be if your plan is implemented. (Show the math.)

Activities that contribute to carbon output and key sources of greenhouse gas emissions

Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns.

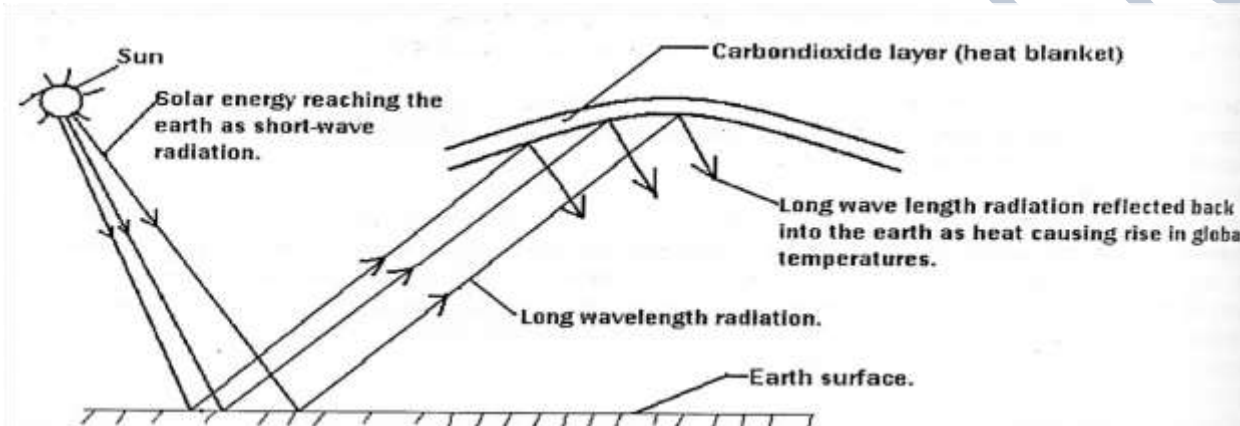
- ✓ **Burning fossil fuels,**
- ✓ **releasing chemicals into the atmosphere**

- ✓ *reducing the amount of forest cover/deforestation*
- ✓ *the rapid expansion of farming*
- ✓ *development of industrial activities are releasing carbon dioxide into the atmosphere*

Carbon dioxide and Global warming.

Increase in carbon dioxide or greenhouse gases in the atmosphere absorbs and retains heat or reflects the long wave-radiation back into the earth. This causes unnecessary rise or increase in the global temperatures above the usual, a phenomenon called global warming. This could cause change in the climate. The effect of global is detected in rising sea levels, an increase in the melting of ice caps at arctic and Antarctic regions, changes in the vegetation and unusual weather patterns.

Diagram showing process of global warming in an ecosystem.



Effects of the global warming.

- *It leads to melting of the ice caps in the polar regions of the earth. This result into increased volume of water bodies, causing floods that displace a number of plants and animal communities living at the shores of the rivers, lakes and oceans.*
- *The increased atmospheric temperatures increase evaporation of water from the surfaces of the water bodies causing rampant heavy convectional rain fall seasons known as Elninoes. Elnino rain causes destruction of crops and leads to famine, outbreak of water borne diseases like cholera, causing mass death of people.*
- *It leads to extinction of species of organisms which cannot adapt to extremely high temperatures. This causes changes in the Bio-diversity of plants and animals.*
- *High temperatures increase primary productivities. Demand for essential nutrients increase, resulting in competition among plant species for such nutrients.*

How carbon sequestration in forests reduces the impact of climate change.

What is Carbon Sequestration in Trees

Carbon sequestration refers to the process of capturing carbon dioxide from the atmosphere and storing it in a way that prevents its release back into the atmosphere.

Carbon sequestration can occur naturally in ecosystems or through human-engineered techniques. The term "carbon sequestration" encompasses both natural processes and intentional techniques that involve removing CO₂ from the atmosphere or diverting it away from emission sources.

*These techniques aim to **store carbon in various reservoirs such as the ocean, terrestrial environments (including vegetation, soils, and sediments), and geological formations.** Before the significant increase in human-generated CO₂ emissions, the natural processes within the global "carbon cycle" maintained a delicate equilibrium between CO₂ uptake and release. However, the existing mechanisms for CO₂ uptake, often referred to as carbon sinks, are inadequate to counterbalance the rapid pace of emissions resulting from human activities*

Or

*Carbon sequestration in trees refers to the process by which trees absorb CO₂ during photosynthesis and store it in their trunks, branches, leaves, and roots. This stored carbon remains in the tree until it dies and decomposes or is harvested. Trees act as carbon sinks, and the longer they live and the larger they grow, the more carbon they can store. For instance, a mature Live Oak can store approximately **10,994 kilograms of CO₂** over its lifetime.*

NOTE;

When a tree photosynthesizes, it takes in CO₂ from the air and uses sunlight to convert it into sugars and other organic compounds. These compounds are then used to build leaves, wood, roots, and other tissues, effectively locking away carbon for as long as that biomass remains intact.

Forest carbon therefore represents a critical natural reservoir, holding a share of the carbon that would otherwise be circulating in the atmosphere the storage of that carbon in living biomass and soils.

The central mechanism behind tree-based carbon sequestration is photosynthesis. During this process, trees absorb CO₂ through small pores in their leaves and combine it with water absorbed by their roots.

Using the energy from sunlight, they convert these raw materials into carbohydrates and oxygen, with the carbohydrates serving as the building blocks of plant tissue.

Over years and decades, the tree adds rings of wood, thickens its trunk, extends branches, and expands its root system. Each new layer of biomass contains carbon that was once in the atmosphere.

Even when leaves fall or branches die, a portion of that carbon can remain stored in forest litter and eventually in the soil. The sum of these living and dead materials forms the forest carbon stock, an essential component of natural climate regulation.

Below ground, roots and soil organic matter form an often overlooked but significant carbon pool. As roots grow and die, and as fallen leaves and woody debris decompose, organic material is incorporated into the soil.

Importance of Tree Carbon Sequestration

1. **Reduces Atmospheric CO₂:** Trees capture and store carbon during photosynthesis that would otherwise contribute to global warming, helping to slow climate change.
2. **Promotes Biodiversity:** Many high-carbon-storing trees also support diverse wildlife habitats, benefiting ecosystems beyond just carbon storage.
3. **Improves Soil and Water Quality:** Certain trees, like mangroves, help stabilize soil and filter pollutants, enhancing overall ecosystem health.

How Trees Help Fight Global Warming Beyond Carbon

While carbon sequestration is the most discussed climate benefit of trees, forests also influence climate in other ways.

By providing shade and releasing water vapor through evapotranspiration, trees cool local climates and can moderate extreme heat.

This cooling effect is particularly noticeable in urban environments and regions exposed to high temperatures.

Forests also support complex ecosystems, providing habitat for countless species and stabilizing soils and watersheds.

Healthy, biodiverse forests are more resilient to disturbances like pests, disease, and wildfires, which means they are better able to maintain their forest carbon stocks over time. This ecological stability strengthens the role of trees as a long-term climate ally.

Best Trees for Carbon Sequestration

Not all trees are equally effective at sequestering carbon. Some of the best species include:

- **Live Oak:** Known for its longevity and large biomass, making it a top carbon sink.
- **Mangroves:** Highly effective in coastal areas, they store significant amounts of carbon in both their biomass and the soil.
- **Pines:** Fast-growing species that can absorb large amounts of CO₂ during their early years.

Factors Influencing Carbon Sequestration

- **Growth Rate:** Fast-growing trees sequester more carbon in their early years.
- **Lifespan:** Long-lived trees can store carbon for generations without releasing it through decomposition.
- **Canopy Size:** Trees with larger leaves and wider crowns can maximize photosynthesis, enhancing carbon capture

INVASIVE SPECIES

e) **Examine the impact of invasive species on native biodiversity, ecosystems, and economies, as well as strategies for their management and control.** (u, s, gs, v/a)

Using problem-based learning method, learners analyze terrestrial or aquatic invasive species case study to find the:

- i) characteristics of invasive species
- ii) their impacts on native biodiversity, ecosystems, and economies.

iii) Strategies to manage and control the invasive species. Each group writes a report to present their findings.

c) Using problem-based learning method, Learners examine a case study of a pest infestation controlled using biological control.

Invasive species/alien species/exotic/non-indigenous species is an introduced, on-native organism (disease, parasite, plant, or animal) that begins to spread or expand its range from site of its original introduction and has the potential to cause harm to the environment, the economy or to human health. Usually spread rapidly due to lack of its natural predator.

Examples of animal invasive species.

- ❖ Burmese pythons.
- ❖ Cane Toads that was introduced to control agricultural pests, but became dangerous at all life stages to native environment.
- ❖ Zebra mussels
- ❖ Feral Hogs
- ❖ Lionfish
- ❖ Green crab preys on shell fish and destroys eelgrass.

Examples of plants invasive species.

- ❖ Kudzu known as vine which destroys trees and vegetation.
- ❖ Purple loosestrife which invades wetlands, outcompeting native plants and reducing biodiversity.
- ❖ Water hyacinth. Forms a thick mats on water surfaces, blocking sunlight and reducing oxygen for fish.

Characteristics of invasive species

- ❖ Rapid reproduction rate increasing rate of survival and its mode of spread to cover a large area and to cause greater effect to the environment.
- ❖ Rapid growth and maturation. Mature faster than the native species, allowing them to dominate resources easily and outcompete the native.
- ❖ High dispersal ability. Exhibit fast dispersal mechanisms such as wind dispersal or use of larvae allowing them to colonise new areas earlier.
- ❖ Phenotypic plasticity/Adaptability. Have high tolerance to diverse conditions such as varying temperatures, light levels.
- ❖ Depend on broad diet. Able to feed on wide variety of food sources.
- ❖ Lack of natural Enemies. Upon their introduction, they rarely have predators, diseases, or parasites that could control their population.

- ❖ *Aggressive competition. Have better mechanisms of capturing light, water, nutrients than the native ones.*

Impacts /effects of Invasive species on the native biodiversity, ecosystem and economies.

- ❖ Decline in number of native species due to predation, competition for resources, like water, light.
- ❖ Extinction of native species reducing biodiversity of species, species interaction in an ecosystem.
- ❖ Decrease in productivity of an ecosystem due to extinction of native species that provides food, pollinating agents. This can also be due to disruption of food chain, and webs.
- ❖ Agricultural losses. Invasive species destroys native agricultural plants reducing their productivity and food production.
- ❖ Infrastructure damage. Aquatic invasive species like zebra mussels block water intake pipes, impacting power plants and water systems.
- ❖ Management Costs. Expensive to control invasive species, including manual removal, chemical treatment, and research.
- ❖ Water transport hindrances as water hyacinth covers the water body surfaces.

Strategies to manage and control the invasive species

- ❖ **Physical and mechanical control method.** Which involves direct removal of smaller, localized populations of invasive species. These include manual hand-pulling of plants, tilling, dredging, or installing physical barrier.
- ❖ **Chemical control.** Spraying using specific pesticides or herbicides to kill invasive species.
- ❖ **Biological control.** Involves introduction of natural enemies such as predators, parasites, or pathogens to feed, and reduce the population of invasive species.
- ❖ **Restoration of native ecosystems.** Involves replanting native vegetation to prevent future invasions.

Integrated pest management (IPM). Combining multiple strategies based on the specific site and species to achieve the most effective results. Like combining removal methods and low-impact herbicide use. Research more.

Using problem-based learning method, Learners examine a case study of a pest infestation controlled using biological control.

- ❖ Introducing fish in a pond to feed on mosquito larvae to control the spread of malaria amongst humans.
- ❖ Use of vedalia beetles/lady bird beetles to feed on the cottony cushion scale/scale insects.

TRIAL SCENARIOS

1. Victoria Nile is a source of food and income for the communities living along it. However, the community near a textile factory have reported to the district authorities that the fish catches have significantly reduced over the past few months. The authorities requested Dr. Achen, a fisheries biologist from National Environmental Management Authority (NEMA) to carry out an investigation. She suspected that the cause was pollution from the factory that releases wastes containing heavy metals and cyanide into the lake.

She caged fish at two different sites; a clean control site (no pollution) and a site near the factory outflow. She investigated the effects of the heavy metals on the gill and mitochondrial structures and ATP synthesis. The data she collected is provided in table 1.

Table 1: You are tasked with analyzing her findings and proposing a course of action.

Fish group	ATP Concentration	Thickness of squamous cells	Number of ribosomes per mitochondrion	Concn of oxidized NAD
Control(no pollution)	9.5	Thin	9.8	7.2
Polluted site-factory outflow	2.2	Thick	3.5	1.3

Task.

Analyze how cellular and tissue changes in the fish from the polluted site affect respiration and result in reduced fish catches to propose and justify a sustainable management plan to ensure health of organisms in the river.

2. A cooperative of smallholder farmers on the slopes of Mount Elgon has reported a 50% failure rate in their new coffee seedlings. The seedlings wilt and die within weeks of transplanting, despite adequate rainfall. A soil analysis ruled out common nutrient deficiencies. An agronomist from the National Agricultural Research Organization (NARO) suspects the problem is linked to root development and water transport. She investigates a healthy seedling from a nursery and a wilting seedling from the field.

Table: Comparative Analysis of Coffee Seedling Tissues

Parameter	Healthy Seedling	Wilting Seedling
Root Hair Density (hairs/mm)	45	12
Lignin Deposition in Xylem Vessels (Relative %)	100%	40%
Stomatal Density (pores/mm ²)	250	310
Absciscic Acid (ABA) concentration (ng/g)	5	25
Rate of Water Uptake (ml/hr)	10	3

Task.

a) Analyse the data to explain how the structural and hormonal differences between the healthy and wilting seedlings lead to the failure in water transport and subsequent wilting.

(b) Using the principles of plant growth and osmoregulation, propose a three-stage plan for the farmers to improve seedling survival rates before and after transplanting.

3.A community project in Nakasongola District aimed at achieving food security through tomato farming is failing. The tomato plants grow tall and leafy but produce very few flowers and almost no fruit. The farmers have been using a fertilizer rich in nitrogen and phosphorus. A field visit also revealed an absence of bees and other pollinators. A biology student suggests the issue might be related to plant coordination and nutrient allocation. Table: Hormonal and Resource Allocation in Tomato Plants

Tissue Sample	Auxin Level (relative)	Gibberellin Level (relative)	Cytokinin Level (relative)	Sugar Concentration in Fruits (mg/g)
Vegetative Shoot Tip	90	85	40	N/A
Floral Bud	10	15	60	N/A
Developing Fruit	25	30	75	50 (in the few fruits that formed)

Task:

(a) Explain how the observed hormonal imbalance (high auxin/gibberellin in shoots, low in flowers) leads to excessive vegetative growth at the expense of flower and fruit development (a phenomenon known as apical dominance).

(b) Propose biological strategies to promote flowering and fruiting, and one ecological strategy to address the pollination issue, ensuring a sustainable tomato yield for the community.

4.In a village outside Jinja, people and cattle share a pond for water. Recently, several children developed severe neurological symptoms, and some cattle died. The symptoms include uncontrolled muscle spasms and impaired neural function. Investigators found a nearby small-scale gold mining operation that uses mercury. Mercury is known to bind to sulphhydryl groups in proteins, inhibiting their function.

Table: Physiological Data from Affected Individuals

Sample	Synaptic Vesicle Count (vesicles/end-plate)	Acetylcholine Release per Stimulus (molecules)	Muscle ATP Level (% of normal)	Blood Mercury Level (ppb)
Healthy Child	2.0×10^7	1.0×10^8	100%	<5
Symptomatic Child	2.1×10^7	2.0×10^6	45%	55

Task

- a) Analyse how mercury contamination affects impulse transmission at the synapse and disrupts cellular energy production, leading to the observed neurological symptoms and muscle failure.
- (b) Propose strategies to prevent further contamination and provide clean water, ensuring the community's health and food security (from livestock).

5. The home range of a famous mountain gorilla family in Bwindi Impenetrable National Park has shrunk by 30% over the past decade due to agricultural encroachment. Park rangers have recorded concerning data on the group's health and behaviour. The gorillas are now more frequently in contact with another group, leading to conflicts. They also travel longer distances for less food.

Table: Gorilla Population and Health Metrics

Metric	10 Years Ago	Present Day
Group Size	15	18
Average Body Mass Index (BMI) of Adults	28	24
Frequency of Inter-group Conflicts (per year)	2	10
Number of Plant Species in Diet	65	48
Observed Genetic Diversity Index (from fecal samples)	0.81	0.73

Task:

- (a) Analyse how the reduction in habitat size and food availability is influencing the gorillas' population dynamics, social behaviour, and long-term genetic health.
- (b) Propose a sustainable conservation plan with key strategies that address the ecological and genetic challenges faced by this gorilla family, while also considering the needs of the local human population.

6. A new community farm was established on the slopes of Mount Rwenzori (3000m above sea level) to grow potatoes. However, the yield is very low, and the tubers are small. The plants appear stunted. A researcher suspects that the low atmospheric pressure and temperature at high altitude are affecting the plants' internal

physiology. She compares the Rwenzori potatoes with the same variety grown at a lower altitude (1200m). Table:
Physiological Comparison of Potato Plants

Parameter	Low-Altitude Plant	High-Altitude (Rwenzori) Plant
Chlorophyll Concentration (mg/g)	2.5	3.1
Stomatal Conductance (mmol/m ² /s)	250	180
Mitochondrial Density in Root Cells (per cell)	150	220
Sucrose concentration in Phloem (mg/ml)	25	15
Average Tuber Mass (g)	120	60

Task.

- a) Explain how high-altitude conditions could lead to the observed physiological changes and ultimately result in reduced tuber growth.
- (b) The community cannot relocate the farm. Propose practical strategies, involving agricultural practice and involving a technological solution, to mitigate the effects of high altitude and improve tuber yield.

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