ECOLOGY

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

A) ANALYSE POPULATION DYNAMICS AND THE FACTORS AFFECTING THEM IN DIFFERENT ECOSYSTEMS.

Discuss the following population dynamics in different ecosystems:

a) population dynamics in different ecosystems

i) population characteristics.

ii) population growth.

iii) factors affecting population density.

b) Estimation of population density using quadrats and capture-recapture techniques in different ecosystems.

POPULATION ECOLOGY

Population ecology is the study of the number of organisms and what determines their abundance and distribution. 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 Wynme Edcsards (1965), a population is an automated system.

POPULATION CHARACTERISTICS

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 Density

Population density refers to the number of individuals inhabiting a unit area or volume at a given time. e.g. The number of animals per sq. km or trees per hectare in a forest or planktons in a cubic meter per liter of water or diatoms and protozoan residues per liter per sq. meter of water.

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,

D = 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.

Dispersion

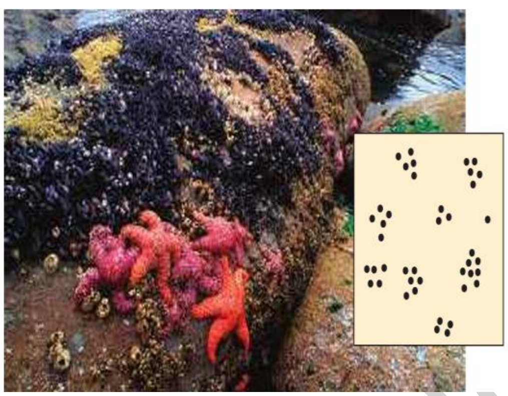
There are three types of dispersion patterns in a population.

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.

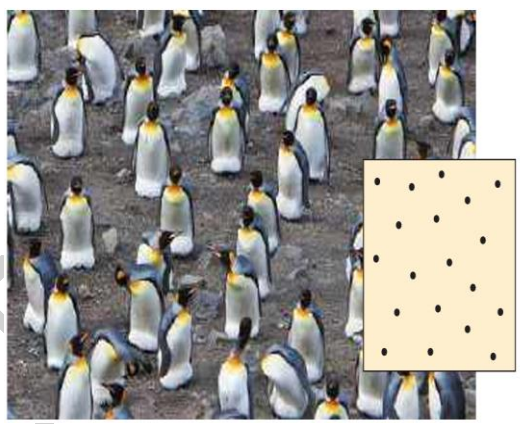
Random: The tendency to aggregate is absent in random dispersion. The environment is uniform throughout the habitat and competition is also absent. This allows the organisms to be anywhere in the habitat creating a random pattern. Such dispersion occurs through seed dispersal by air.

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

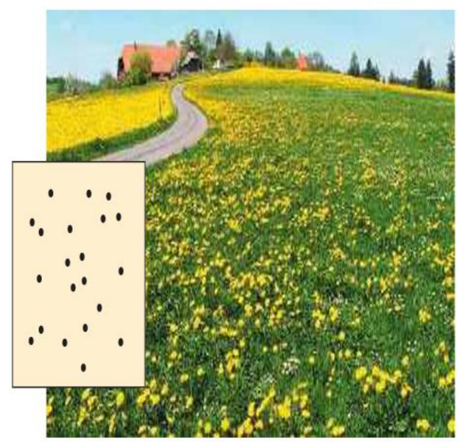
Clumped



Regular



random



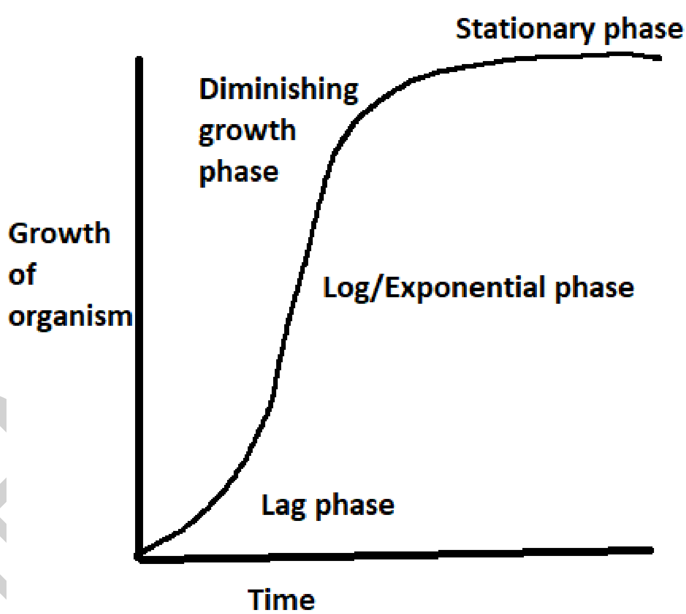
Natality (Birth Rate)

Natality is an expression of the production of new individuals in a population. It varies from organism to organism. The maximum number of births produced under ideal conditions of the environment, ie, ecological limiting factors, is called potential natality. This will be constant for a given population. When the actual number of births occurring under the existing conditions is much less, it is called seized natality.

The natality rate is computed per unit of time by the following formula.

A. S-Shaped or Sigmoid Growth curve

A more frequently encountered pattern of population growth is S shaped or sigmoid growth form, where growth starts slowly, accelerates rapidly in exponential form, and then decelerates and continues thereafter at a more or less constant level. The deceleration phase is a slowdown of population growth caused by the gradual increase of the environmental resistance present in the system. The deceleration continues until a more or less equilibrium level is reached and maintained. The upper asymptote of the sigmoid curve is often referred to as the carrying capacity of that environment the limit at which that environment can support a population. This growth curve is characteristic of larger organisms with larger life cycles and lower biotic potential.



Explanation

Lag phase

There is gradual population growth. Because little growth while organisms start synthesizing appropriate enzymes for new conditions. Because due to small

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

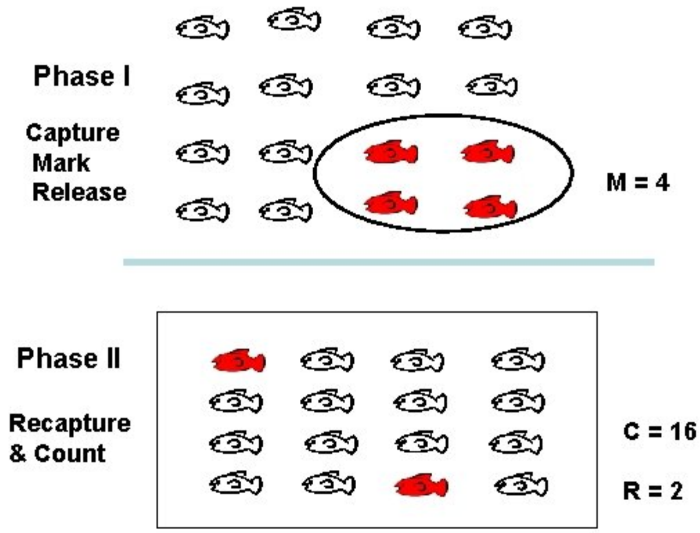
Understanding density-dependent factors is vital for ecological conservation and population management:

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.

Density-Independent Factors



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

Assumptions made when using the capture mark Release recapture method

- That organisms mix randomly within the population.
- That the time allowed for random mixing is enough.
- That changes in population size due to immigration, emigration, death and birth are negligible.
- That the movement of organisms is restricted geographically.
- That there is even dispersing of organisms within the study area.
- That the mark does not hinder the movement of organisms or make them conspicuous to predators.
- There are few, if any, deaths and births within the population.
- The mark or label is not lost or rubbed off during the investigation.

Examples

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 $=\frac{NIXN2}{P}$

P = $\frac{625X873}{129}$

P= **<u>4230 tilapia</u>**

<u>Trial examples</u>

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.

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

B) ANALYSE THE PROCESSES OF ECOLOGICAL SUCCESSION AND STRATEGIES FOR EFFECTIVE ECOLOGICAL RESTORATION PRACTICES IN DIVERSE ENVIRONMENTS

i) The role of primary and secondary succession in preserving biodiversity and restoration of degraded ecosystems.

ii) change in community structure in the seral stages.

iii) Techniques and benefits for restoring degraded ecosystems.

The role of primary and secondary succession in preserving biodiversity

Ecological successions

Ecological succession is a gradual change in community composition from the initial colonization of an area/habitat to establishing a relatively stable community.

It is a fairly orderly process of changes of communities in a region or an area. It involves replacement in the course of time of the dominant species within a given area by other species.

Succession progresses gradually from a small number of colonizing species known as **seres** or seral stages (i.e. communities that replace one another in a given area are called seres).

Pioneers are the first set of organisms to occupy the area, collectively being such organisms constitute the pioneer community. 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

Xersoere: suceesion in a dry environment

Lithosere: suceesion 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).

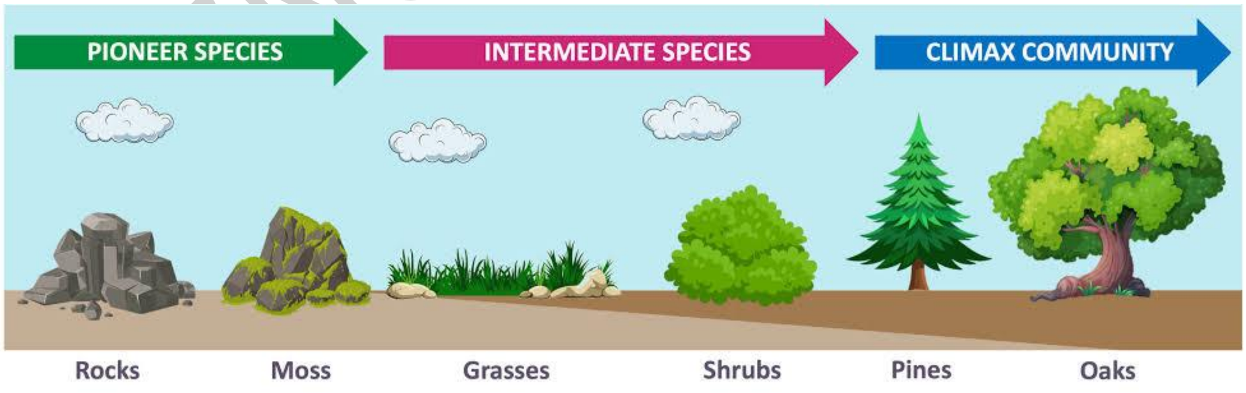
At climax community the net productivity/biomass tends to remain constant but dependent on species number and population size.

Primary succession

This is the gradual change in species composition of an area that has never had any vegetation growing on it. It occurs on bare rocks, newly cooled lava, newly created shallow pond, sand dunes, abandoned highways or parking yards.

During primary succession, lichens and mosses as colonizers attach to bare rocks and start forming soil by trapping wind – blown soil particles, producing tiny bits of organic matter and secreting mild acids that slowly breakdown the rock by chemical weathering.

Alternate heating and cooling also cause breakdown of rocks. As patches of soil build up and spread, eventually the pioneer species are replaced by the early successional plants like small grasses and ferns, as pioneer plants whose seeds and spores respectively germinate after arriving by wind or in droppings of birds. Some of their roots penetrate and break rocks in to soil particles and death and decay of small grasses and ferns increases nutrients to the soil



Secondary succession

This is the gradual change in species composition in an area where the natural community of organisms has been disturbed, removed or destroyed by some soil or bottom sediment remains.

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

Techniques and benefits for restoring degraded ecosystems.

<u>Ecosystem restoration</u> 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

- function.

Techniques to restore the eco system

Passive restoration strategies

- **natural regeneration processes**

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

- **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

- **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.

- **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.

- ➢ 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.

The study of energy flow through ecosystems is called **energetics.**

The energy flow of ecosystem means the pathway energy takes to move from one organism to another in an ecosystem. The energy flow of an ecosystem is a fundamental concept of ecological studies. The direction of flow of energy in an ecosystem is unidirectional and is typically in the form of food energy that flows from one trophic level to another. It harnesses the energy that cascades through the food chain and food webs.

All the biotic components in this ecosystem need energy for their survival.

Impacts of bio accumulation and bio magnification life and ecosystems

. At the individual level, organisms exposed to bioaccumulated 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 CONVERSATION RATIO 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

6. 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

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 = Feed intake ÷ Weight gain)

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

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 → 200 × 2.3 = 460 kg CO_2e

1,000 kWh of electricity → 1,000 × 0.1 = 100 kg CO_2e

30 kg of beef consumed → 30 × 27 = 810 kg CO_2e

Total = 1,370 kg CO_2e (≈ 1.37 tons CO_2e)

Trial number

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 CO_2e per kWh***
- ***Petrol: 2.31 kg CO_2e per L***
- ***Charcoal: 2.90 kg CO_2e per kg***
- ***LPG: 2.98 kg CO_2e 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 CO_2e 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
- ✓ the rapid expansion of farming
- ✓ development of industrial activities are releasing carbon dioxide into the atmosphere