Republic of Rwanda
Ministry of Education

RTB | RWANDA TVET BOARD

RQF LEVEL 5

FOOD AND BEVERAGE OPERATIONS

GENAB502

Applied Biology

TRAINER MANUAL

April, 2025

Republic of Rwanda
Ministry of Education

RTB | RWANDA TVET BOARD

APPLY BASIC KNOWLEDGE OF ECOLOGY

2025

AUTHOR'S NOTE PAGE (COPYRIGHT)

Original published version: April 2025

ACKNOWLEDGEMENTS

Rwanda TVET Board (RTB) would like to recognize all parties who contributed to the development of the trainer's and trainee's manuals for the TVET Certificate V in Food and Beverage Operations trade for the module: **"GENAB502– Applied Biology."**

Thanks to the EU for financial support and Ubukerarugendo Imbere Project for technical support on the implementation of this project.

We also wish to acknowledge all trainers, technicians and practitioners for their contribution to this project.

The management of Rwanda TVET Board appreciates the efforts of its staff who coordinated this project.

Finally, RTB would like to extend its profound gratitude to the MCT Global team that technically led the entire assignment.

This training manual was developed:

Under Rwanda TVET Board (RTB) guiding policies and directives

Under European Union financing

Under Ubukerarugendo Imbere Project implementation, technical support and guidance

COORDINATION TEAM

Aimable Rwamasirabo

Felix Ntahontuye

Eugène Munyanziza

Production Team

Authoring and Review

Jean de Dieu Sindambiwe

Venuste Habimana

Rene David Nsabimana

Conception, Adaptation and Editorial works

Jean Marie Vianney Muhire

Vincent Havugimana

John Paul Kanyike

Formatting, Graphics, Illustrations, and infographics

Asoka Niyonsaba Jean Claude

Ngamije Hildebrand

Augustin Habimana

Coordination and Technical support

Ubukerarugendo Imbere Project and RTB

Project Implementation

MCT Global Ltd.

TABLE OF CONTENT

LIST OF ABBREVIATIONS AND ACRONYMS

CBET: Competence Base Education and Training

PPE: Personal Protective Equipment

RQF: Rwanda Qualification Framework

RNA: Ribonucleic Acid

DNA: Deoxyribonucleic Acid

RTB: Rwanda TVET Board

TVET: Technical and Vocational Education and Training

REMA: Rwanda Environment Management Authority

INTRODUCTION

This Trainer's Manual encompasses all methodologies necessary to guide you to properly deliver the module titled: **Apply Basic Knowledge of Ecology** Students undertaking this module shall be exposed with practical activities that will develop and nurture their competences. The writing process of this training manual embraced competency-based education and training (CBET) philosophy by providing practical opportunities reflecting real life situations.

The Trainer's Manual is subdivided into Learning Outcomes, each learning outcome has got various topics. You will start guiding a self-assessment exercise to help students rate themselves on their level of skills, knowledge and attitudes about the unit.

The Trainer's Manual will give you the information about the objectives, learning hours, didactic materials, proposed methodologies and crosscutting issues.

A discovery activity is followed to help students discover what they already know about the unit.

This manual will give you tips, methodologies and techniques about how to facilitate students to undertake different activities as proposed in their Trainee's Manuals. The activities in this training manual are prepared such that they give opportunities to students to work individually and in groups.

After going through all activities, you shall help students to undertake progressive assessments known as formative and finally facilitate them to do their self-reflection to identify your strengths, weaknesses and areas for improvements.

Remind them to read the point to remember section which provides the overall key points and takeaways of the unit.

APPLIED BIOLOGY

Learning Outcomes	Learning Hours	Topic
1. Discuss theories of evolution and their evidence.	10	1.1. Explanation of the origin of life
		1.2. Description of Human evolution and Present-day evolution
2. Describe ecosystems	10	2.1. Explanation of ecological factors
		2.2. Description of ecosystems
		2.3. Explanation of relationship between living organisms
3. Illustrate mechanisms of environmental conservation	10	3.1. Description of biogeochemical cycles
		3.2. Explanation of ecosystem degradation
		3.3. Application of environmental protection Strategies.

LEARNING OUTCOME 1: THEORIES OF EVOLUTION AND THEIR EVIDENCE

Learning outcome 1: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:
    a. What do the illustrations show?
    b. What topics do you think will be covered under this unit based on the illustration?
2. After the discussion, inform students that this unit is intended to provide them with the knowledge, skills and attitudes to **discuss theories of evolution and their evidence.**
3. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:

a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.

b. There are no right or wrong ways to answer this assessment. It is for their own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.

c. They should think about themselves: do they think they have the knowledge, skills or attitudes to do this? How well?

d. They read the statements across the top and put a check in column that best represents their level of knowledge, skills or attitudes.

4. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement and actions to be taken.

Key Competencies:

Knowledge	Skills	Attitudes
Explain scientific theories and evolution basics.	Communicating scientific ideas	Open-mindedness
Describe the origin of life	Evaluate origin of life and Seeking evidence to support claims.	Analytical reasoning
Explain history of the human evolution.	Develop bipedalism, tool use, and language use.	Empathetic and Responsible to global citizens.
Describe development in technology and innovations trend	Apply research technology proficiency.	Adaptability
Demonstrate scientific evidence,	Conducting research using various sources,	Change management on environmental dynamics
Explain the limitations of scientific knowledge	Illustrate Factors influencing present day evolution	A willingness to change one's beliefs in light of new evidence
Describe Mechanisms of present-day evolution	Collect information from multiple sources to form a coherent argument	Environmentally friendly attitude
Explain common Ancestry.	Tracing the evolutionary relationships between different organisms.	Appreciation of biodiversity
Compare the complexity and the diversity of life on Earth	Analyzing complex ecological relationships	Being loyal to vastness of the natural world

Steps:

Discovery Activity

Task 1:

Instructions to the trainer

1. Introduce the whole topic 1.1 of unit 1
2. Using an appropriate methodology such as individual work, pair-share, small group discussions, guided small or large group discussion, guide trainees to read the scenario and answer questions under the task 1 in their Trainee's Manuals. Make sure if all instructions are respected, encourage all the students to participating actively and avail necessary materials/tools.
3. Guide trainees while reading the scenario, remind them to answer the related questions and perform the assignment.
4. Conclude the activity with feedback and reflection. Emphasize that the purpose was not to find right answers and look how they draw but to get understanding the origin of life

Topic 1.1: Explanation of the origin of life

Objectives:

By the end of the topic, trainees will be able to:

a. Explain how Evolution is an ongoing process that continues to shape life on Earth.

b. Demonstrate how Human activities, such as climate change and pollution, can accelerate evolutionary change.

c. Describe how Understanding evolution is crucial for addressing global challenges, such as disease, climate change, and biodiversity loss.

d. Analyse how by studying evolution, we can gain insights into the past, present, and future of life on Earth.

Time Required: 5 hours

Learning Methodology: Group discussion, Trainer guided, Videos, brainstorming and demonstration

Materials, Tools and Equipment Needed: Computer, projector, white board/chalkboard, Flipcharts, papers, wall charts, Pictures, Markers, chalks, tutorial videos

Preparation:

- ❑ Brainstorming, demonstration and simulation, individual and group work, group discussion, documentary research
- ❑ Written assessment, oral presentation

Cross Cutting Issues:

- ✓ Climate change and environment protection

Prerequisites:

- General Biology (botany and zoology)

Activity 1: Problem-Solving

Task 2: The Story of Life's Evolution

1. Using various methodologies like individual work, pair-share, or small group discussions, guide trainees to read the scenario provided in the trainee's manual and answer questions on task 2 in their trainee manuals. Ensure that scenario is clear and understood, and that each student actively participates in the activity.
2. Provide necessary materials and tools for the task.
3. Employing suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session**.**
4. After the sharing session, refer students to **Key facts 1.1** and discuss them together and harmonize their responses with objectives of the session
5. Based on the scenario ask the trainees to answer questions from their Trainee's Manual

Activity 2: Guided Practice

1. Utilizing various methodologies like individual work, pair-share, or small group works, direct trainees to read the scenario presented in trainee's manual and guide them while performing the task outlined in their trainee manuals.
2. Throughout the task, encourage students to apply the knowledge and skills acquired in the previous activity independently. Your role as a trainer is to guide them by posing probing questions such as Why? What? and how? This approach enables students to formulate informed responses while fostering critical thinking and problem-solving abilities.

Task 3:

Activity 1: Form Group of 3-5 Students and ask them to read Task 3 written in their Trainee's Manual under Task 3.

Step 1: Ask the students to Plan the Presentation using:

Storyboard the use of textual, Images, and potential activities to foreground the key concepts. For instance, to differentiate complex ideas, construct an essay that includes typical examples.

Step 2: Ask the students to Answer various questions under task 3 and encourage them to participate, while you are providing expert view encourage them to ask for Clarification.

Activity 3: Application

Task 4:

1. Using an appropriate methodology such as individual work, pairs, or small groups, trainees will read the statement provided on task 4 in the trainees' manual and perform the task. Ensure that all instructions are clear and understood by the trainees, and facilitate active participation among all students.
2. Provide necessary materials and tools for the task to be completed effectively.
3. This activity requires students to work independently with limited support from the trainer. During the task, students should be given a high degree of independence to apply the knowledge, skills, and attitudes acquired to real-life situations. Your role as the trainer is to set clear instructions, methodology, and timeframe for submitting the report.
4. Encourage trainees to utilize the knowledge and skills they have acquired throughout the training program to analyze the scenario critically and develop informed responses.

Scenario: In a biology class, students analyze fossils and DNA samples to construct an evolutionary timeline of a species. They observe how environmental changes influenced

adaptations over millions of years, tracing traits like limb structure and diet. Using this data, they discuss how understanding evolutionary timelines aids in biodiversity conservation.

Step 1: Building Evolutionary Timelines

Students will produce a timeline that marks important events in the birth of life, and in evolutionary history, such as abiogenesis, multicellularity and major evolutionary transitions.

Step 2: You are required to illustrate these events with the available materials, then annotate such events with brief explanations.

Step 3: **Analysing Evidence**

In small groups, students will analyze samples of "evidence for evolution," such as diagrams fossil records. Each group will present how their evidence supports the theory of evolution and answer related questions.

These are possible answers for asked questions:

1. What is the significance of homologous structures in understanding evolution?
    - Homologous structures are anatomical features in different species that share a common ancestry, even if their functions have diverged. They provide strong evidence for evolution by demonstrating that different species evolved from a common ancestor. The underlying similarity in their structure, despite differences in function, points to a shared developmental origin. This showcases the concept of divergent evolution.
2. How does the fossil record provide evidence for the theory of evolution?
    - The fossil record provides a chronological sequence of life's history, showing how organisms have changed over time. It reveals:
        - *Transitional fossils: These show intermediate forms between ancestral and modern species, demonstrating gradual evolutionary change.*
        - *The appearance and disappearance of species: This shows how life on Earth has changed over geological time scales.*
        - *The progression of complexity: Fossils reveal a general trend from simpler to more complex life forms.*

- *It allows scientists to reconstruct evolutionary lineages, tracing the descent of modern species from their ancestors.*

3. Why is the universal genetic code considered strong evidence for a common origin of life?

   - The universal genetic code refers to the fact that virtually all living organisms use the same DNA codons to specify the same amino acids. This remarkable similarity strongly suggests that all life on Earth shares a common ancestor. It is highly improbable that such a complex system would have evolved independently multiple times.

4. Describe how natural selection drives evolutionary change in populations.

   - Natural selection is the process by which organisms with traits better suited to their environment survive and reproduce more successfully. It works as follows:
     - *Variation: Individuals within a population exhibit variation in their traits.*
     - *Inheritance: These variations can be passed on from parents to offspring.*
     - *Selection: Some variations provide a survival or reproductive advantage in a particular environment.*
     - *Differential reproduction: Individuals with advantageous traits are more likely to survive and reproduce, passing those traits to their offspring.*
     - *Over time, the frequency of advantageous traits increases in the population, leading to evolutionary change.*

5. What role did endosymbiosis play in the development of complex cells?

   - Endosymbiosis is the process by which one organism lives inside another. It played a crucial role in the development of complex eukaryotic cells. Specifically:
     - *Mitochondria: These organelles, responsible for cellular respiration, are thought to have originated from aerobic bacteria that were engulfed by ancestral eukaryotic cells.*
     - *Chloroplasts: These organelles, responsible for photosynthesis in plants and algae, are thought to have originated from photosynthetic bacteria that were engulfed by ancestral eukaryotic cells.*
   - The endosymbiotic theory proposes that these engulfed bacteria established a symbiotic relationship with their host cells, eventually evolving into the organelles we see today. This process allowed for the development of more complex and efficient cells.

Topic 1.2: Description of Human evolution and Present-day evolution

	**Objectives:** By the end of the topic, trainees will be able to: a. Explain Present-Day Evolution concept in line with the relevance of present-day evolution b. Interpret the mechanisms of present-day evolution c. Differentiate factors influencing present-day evolution
	**Time Required:** 5 hours
	**Learning Methodology:** Group discussion, Trainer guided, Site visit, brainstorming and demonstration.
	**Materials, Tools and Equipment Needed:** Computer, projector, white board/chalkboard Flipcharts, papers, wall charts, picturesMarkers, chalks, tutorial videos
	**Preparation:** ❑ Brainstorming, demonstration and simulation, individual and group work, group discussion, documentary research ❑ Written assessment, oral presentation
	**Cross Cutting Issues:** ✓ Climate change and environment change

	**Prerequisites:** ➢ Theory of origin of life

 Activity 1: Problem-Solving

 Task 5:

1. Using various methodologies like individual work, pair-share, or small group discussions, guide trainees to read the scenario provided in the trainee's manual and answer questions on task 5 in their trainee manuals. Ensure that scenario is clear and understood, and that each student actively participates in the activity.
2. Provide necessary materials and tools for the task.
3. Employing suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session**.**
4. After the sharing session, refer students to **Key facts 1.2** and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.
5. **Ask Students to read the scenario in their Trainee's Manual under task 5 and by prior to their experience on Human creation History, answer the related asked questions**

Here below are possible answers for asked questions:

1. How do scientists use fossils to trace the evolutionary history of humans?

- **Dating and Stratigraphy:** Scientists use radiometric dating techniques and stratigraphy (the study of rock layers) to determine the age of fossils. This establishes a timeline of human evolution.
- **Morphological Analysis:** By comparing the physical characteristics of fossilized bones (e.g., skull shape, limb structure, teeth), scientists can reconstruct the anatomy of extinct hominins and identify evolutionary trends.

- **Phylogenetic Analysis:** Fossils are used to create phylogenetic trees, which illustrate the evolutionary relationships between different hominin species. This helps trace the lineage leading to modern humans.
- **Understanding Behavioral Changes:** Fossilized tools, footprints, and other artifacts found alongside hominin fossils provide insights into the behavior, diet, and social structure of our ancestors.

2. What similarities and differences exist between modern humans and our closest primate relatives?

    - **Similarities:**
        - **Shared DNA:** Humans and chimpanzees share a high percentage of their DNA.
        - **Social behavior:** Both exhibit complex social structures, communication, and tool use.
        - **Anatomical features:** Similar skeletal structures, including opposable thumbs.
        - **Parental care:** Both have extended periods of parental care.
    - **Differences:**
        - **Bipedalism:** Humans are habitually bipedal (walk on two legs), while chimpanzees are primarily quadrupedal.
        - **Brain size:** Humans have significantly larger brains relative to body size.
        - **Language:** Humans possess complex language capabilities.
        - **Tool use:** While chimpanzees use tools, humans have developed a much wider range and complexity of tools.
        - **Dental structure:** Differences in tooth shape and size.
        - **Skeletal structure:** Differences in the shape of the pelvis, spine, feet, and limbs.

3. What evidence supports the theory that humans and chimpanzees share a common ancestor?

- **Genetic Evidence:** DNA analysis reveals a high degree of genetic similarity between humans and chimpanzees, suggesting a relatively recent common ancestor.
- **Fossil Evidence:** Fossil discoveries have revealed transitional forms that share characteristics of both humans and apes, supporting the idea of a common ancestor.
- **Comparative Anatomy:** Homologous structures, like the skeletal structure of the limbs, indicate a shared ancestry.
- **Endogenous Retroviruses:** Shared endogenous retroviruses (ERV's) in the genome. ERV's are viral DNA that inserts into the host genome. Because the location of these insertions is random, when two species share the same insertions, it is very strong evidence of shared ancestry.

4. How did the development of bipedalism influence early human lifestyles and survival?

- **Freeing the Hands:** Bipedalism freed the hands for carrying objects, using tools, and manipulating the environment.
- **Improved Vision:** Standing upright provided a wider field of view, allowing early humans to spot predators and prey more easily.
- **Energy Efficiency:** Bipedalism is more energy-efficient for long-distance travel than quadrupedal, enabling early humans to cover larger territories in search of food.
- **Thermoregulation:** Standing upright reduces the amount of body surface exposed to direct sunlight, helping to regulate body temperature in hot environments.
- **Changes in diet:** Free hands could be used to gather and process a wider variety of foods.
- **Tool Development:** Free hands allowed for the creation and use of more advanced tools.

Activity 2: Guided Practice

Task 6:

1. Utilizing various methodologies of small groups, direct trainees to read Key Concepts presented in trainee's manual and guide them while performing the assignment under task 6.
2. Throughout the task, encourage students to apply the knowledge and skills acquired in the previous activity independently. Your role as a trainer is to guide them by posing probing questions such as Why? What? and how? This approach enables students to formulate informed responses while fostering critical thinking and problem-solving abilities.
3. Upon completion of the task, utilize methodologies like question and answer in a large group, or pair and small group presentations, for students to share their answers. Document their responses for reference and encourage all students to contribute their views, promoting collaborative learning.

Group work activity

Objective: To deepen understanding of the mechanisms and relevance of present-day evolution.

Materials:

i. Blackboard or projector

ii. Markers or pens

iii. Handouts and Papers

Procedure:

1. Step: Review Key Concepts (10 minutes)
    - Briefly review the following concepts:
        - *Natural selection*
        - *Mutation*
        - *Technological Effects*
2. Step: Case Study Analysis (20 minutes)
    - Divide the class into groups of 4-5 students.
    - Provide each group with a case study related to present-day evolution:
        - *The evolution of antibiotic resistance in bacteria*
        - *The impact of climate change on species distribution and behaviour*
    - Ask each group to identify the key evolutionary mechanisms at play.
    - Have groups present their findings to the class, explaining how the concepts of natural selection, Technology and mutation apply to the specific case.
3. **Step**: Relevance of Present-Day Evolution (20 minutes)
    - Facilitate a class discussion on the relevance of present-day evolution, focusing on the following questions:
        - *How does the understanding of evolution impact human health and medicine?*
        - *What are the implications of genetic engineering for human evolution?*
        - *How can evolutionary principles be applied to conservation efforts?*

- *What are the ethical considerations of human-induced evolutionary change?*

Activity 3: Application

Task 7:

Activity 1: Nature Walk and Observation

Procedure:

1. Take a nature walk in a local park or natural area.
2. Observe different species and their adaptations to the environment.
3. Discuss how natural selection has shaped the diversity of life.
4. Create a poster or presentation summarizing observations.

Activity 2: Evolutionary Timeline

Procedure:

1. Form groups.
2. By using a specific hominid species of your choice.
3. Make group search on species and create a poster with key information:
    - *Name of the species*
    - *Time period*
    - *Physical characteristics*
    - *Important tools or behaviors*
4. Facilitate trainees while arranging the posters in chronological order on the timeline.
5. Guide Class Discussion on the major trends in human evolution and the role of natural selection in shaping our species.

Formative Assessment

Formative Assessment: Apply Basic Knowledge of Ecology LO1

Section A: Answer all Questions:

1. Define the following terms:

a. Natural selection

b. Genetic drift

c. Gene flow

d. Mutation

2. Explain the role of technology in influencing present-day evolution.
3. List three mechanisms of present-day evolution.
4. Describe the relevance of present-day evolution for human health and medicine.
5. Discuss the impact of climate change on species evolution.
6. Explain how genetic engineering can accelerate evolutionary change.
7. Define the concept of evolutionary fitness.
8. Describe the role of mutation in generating genetic variation.
9. Explain the concept of adaptive radiation.
10. Discuss the ethical implications of human-induced evolution.

Section B: Choose five (5) Questions out of Ten (10) of Your Choice.

1. Compare and contrast natural selection and genetic drift.
2. Explain the role of gene flow in maintaining genetic diversity within a population.
3. Discuss the impact of human activities on the rate of evolution.
4. Evaluate the potential benefits and risks of genetic engineering.
5. Explain how evolutionary theory can be applied to conservation biology.
6. Critically analyse the concept of biological determinism.
7. Discuss the future implications of emerging technologies, such as artificial intelligence, on human evolution.

8. Explain the concept of coevolution and provide examples.
9. Evaluate the role of chance in evolutionary processes.
10. Discuss the concept of punctuated equilibrium and its implications for understanding the pace of evolution.

Answers:

Section A:

1. Define the following terms:

a. **Natural selection:** The process by which organisms with traits better suited to their environment survive and reproduce more successfully, passing those traits to their offspring.

b. **Genetic drift:** Random fluctuations in allele frequencies within a population, especially in small populations, due to chance events.

c. **Gene flow:** The transfer of genetic material from one population to another, often through migration.

d. **Mutation:** A change in the DNA sequence of an organism, which can create new alleles.

2. Explain the role of technology in influencing present-day evolution.

    - *Technology, such as antibiotics, pesticides, and genetic engineering, creates selective pressures that drive rapid evolution in organisms like bacteria, insects, and crops.*

3. List three mechanisms of present-day evolution.

    - *Antibiotic resistance in bacteria*
    - *Pesticide resistance in insects*
    - *Evolution of viruses (e.g., influenza, COVID-19)*

4. Describe the relevance of present-day evolution for human health and medicine.

    - *Understanding present-day evolution is crucial for combating antibiotic resistance, developing new vaccines, and understanding the evolution of diseases.*

5. Discuss the impact of climate change on species evolution.

    - *Climate change creates new selective pressures, leading to adaptations like changes in migration patterns, altered breeding times, and shifts in species distribution.*

6. Explain how genetic engineering can accelerate evolutionary change.

- *Genetic engineering allows for the direct manipulation of an organism's genome, introducing new traits and accelerating the pace of evolutionary change compared to natural processes.*

7. Define the concept of evolutionary fitness.

    - *Evolutionary fitness refers to an organism's ability to survive and reproduce successfully in its environment, measured by its contribution to the next generation's gene pool.*

8. Describe the role of mutation in generating genetic variation.

    - *Mutations are the ultimate source of new genetic variation, introducing new alleles into a population that can be acted upon by natural selection or genetic drift.*

9. Explain the concept of adaptive radiation.

    - *Adaptive radiation is the rapid diversification of a lineage into many new species, each adapted to a different ecological niche.*

10. Discuss the ethical implications of human-induced evolution.

    - *Human-induced evolution raises ethical concerns about unintended consequences, the potential for misuse, and the alteration of natural ecosystems.*

Section B:

1. Compare and contrast natural selection and genetic drift.

    - *Natural selection is driven by selective pressures and leads to adaptation, while genetic drift is driven by random chance and can lead to the fixation of neutral or even maladaptive traits. Both change allele frequencies, but through different mechanisms.*

2. Explain the role of gene flow in maintaining genetic diversity within a population.

    - *Gene flow introduces new alleles into a population, increasing genetic diversity and reducing differences between populations, which can counteract the effects of genetic drift and local adaptation.*

3. Discuss the impact of human activities on the rate of evolution.

    - *Human activities, such as habitat destruction, pollution, and the use of antibiotics and pesticides, are accelerating the rate of evolution in many species, often leading to rapid adaptation to human-altered environments.*

4. Evaluate the potential benefits and risks of genetic engineering.

- *Benefits include improved crop yields, disease resistance, and medical advancements. Risks include unintended ecological impacts, the potential for misuse, and ethical concerns about altering the human genome.*

5. Explain how evolutionary theory can be applied to conservation biology.

    - *Evolutionary theory informs conservation efforts by helping to understand species adaptation, genetic diversity, and the impacts of environmental change, guiding strategies for preserving biodiversity.*

6. Critically analyze the concept of biological determinism.

    - *Biological determinism is the idea that genes or biological factors determine human behavior and social traits. It is often criticized for ignoring the role of environmental and social factors and for its potential to justify social inequalities.*

7. Discuss the future implications of emerging technologies, such as artificial intelligence, on human evolution.

    - *Emerging technologies may influence human evolution through increased longevity, genetic enhancements, and the potential for human-machine integration, raising ethical and societal questions.*

8. Explain the concept of coevolution and provide examples.

    - *Coevolution is the reciprocal evolutionary influence between two or more interacting species. Examples include the relationship between flowering plants and their pollinators, or predator and prey relationships.*

9. Evaluate the role of chance in evolutionary processes.

    - *Chance plays a significant role in evolution through genetic drift, mutations, and unpredictable environmental events. These random factors can influence the direction and pace of evolutionary change.*

10. Discuss the concept of punctuated equilibrium and its implications for understanding the pace of evolution.

    - *Punctuated equilibrium proposes that evolution is characterized by long periods of stasis punctuated by short bursts of rapid change, challenging the traditional view of gradualism and highlighting the importance of environmental disruptions in driving evolutionary change.*

Points to Remember

- **Evolution is an ongoing process that continues to shape life on Earth.**
- **Human activities, such as climate change and pollution, can accelerate evolutionary change.**
- **Understanding evolution is crucial for addressing global challenges, such as disease, climate change, and biodiversity loss.**
- **By studying evolution, we can gain insights into the past, present, and future of life on Earth.**

Self-Reflection

1. Ask learners to re-take the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to Identify their areas of strength, areas for improvement and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

Learning outcome 2: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:

a. What do the illustrations show?

b. What topics do you think will be covered under this unit based on the illustration?

2. After the discussion, inform students that this unit is intended to provide them with the knowledge; skills and attitudes on describe ecosystems.

3. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:

a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.

b. There are no right or wrong ways to answer this assessment. It is for their own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.

c. They should think about themselves: do they think they have the knowledge, skills or attitudes to do this? How well?

d. They read the statements across the top and put a check in column that best represents their level of knowledge, skills or attitudes.

4. At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement and actions to be taken.

Key Competencies:

Knowledge	Skills	Attitudes
Describe of the energy flows, nutrient cycles, and habitat types.	Apply environmental science to identify environmental factors	Environmental awareness and responsibility.
Explain interdependencies, and scientific inquiry.	Interpret interactions (symbiosis, competition)	Respect for ecological balance,

Knowledge	Skills	Attitudes
Define the effects of human activities on ecosystems	Generate solutions to real-world problems.	Having sense of responsibility to use scientific knowledge for the environment.
Compare biodiversity and ecosystem	Observe, and analyze complex environmental	Curiosity and appreciation to the ecosystems' conservation.
Differentiate biotic and abiotic factors and nutrient cycling.	Analyze interactions between living and non-living components.	Adaptation to the new concept

Steps:

Discovery Activity

Task 8:

1. Take students through the following steps:

a. Firstly, organize trainees into pairs or small groups and guide them through a structured discussion about questions on task 8 in trainee's manual. Ensure active participation and understanding of instructions.

b. Secondly, bring the trainees back together as a large group for presentations. Each pair or group should summarize their discussions, sharing insights and learnings with the class. Encourage all trainees to contribute their own experiences and reflections.

2. Read the short scenario on Explanation of ecological factors in their Trainee's Manual and answer questions under task 8:

Here below are possible Answers of asked questions:

1. **Define the terms abiotic factor and biotic factors and give three examples on each.**

- **Abiotic factors:** These are the non-living chemical and physical parts of the environment that affect living organisms and the functioning of ecosystems.
    - Examples:

- *Temperature*
- *Sunlight*
- *Water (precipitation, humidity)*
- *Soil pH*
- *Wind*

- **Biotic factors:** These are the living components of an ecosystem that affect other organisms.
    - Examples:
        - *Predators*
        - *Competitors (for resources)*
        - *Disease-causing organisms (pathogens)*
        - *Plants*
        - *Bacteria*

2. How does temperature affect the distribution of organisms?

- Temperature affects the metabolic rates of organisms. Each species has a range of temperatures within which it can survive and reproduce.
- Extreme temperatures (too high or too low) can denature proteins and disrupt cellular processes, leading to death.
- Temperature influences the distribution of organisms by limiting them to areas where temperatures are within their tolerance range.
- For example, polar bears are adapted to very cold climates, and tropical plants are adapted to warm climates.

3. Explain the role of water in an ecosystem.

- Water is essential for all living organisms. It is a solvent for many biological molecules, a medium for metabolic reactions, and a transport medium for nutrients and wastes.
- In ecosystems, water availability influences plant growth, which in turn affects the entire food web.
- Aquatic ecosystems rely on water as the habitat for organisms.
- Water also plays a large role in the cycling of nutrients.

4. What is the significance of sunlight as an ecological factor?

- Sunlight is the primary source of energy for most ecosystems.
- Through photosynthesis, plants and other autotrophs convert sunlight into chemical energy, which is then passed on to other organisms through food chains.
- Sunlight also influences the behavior and physiology of animals, such as their daily and seasonal activity patterns.

- Sunlight is also a factor that can determine the temperature of an area.

5. How does soil quality influence plant growth and the entire ecosystem?

- Soil provides plants with essential nutrients, water, and physical support.
- Soil quality (e.g., pH, nutrient content, texture) affects plant growth, which in turn influences the availability of food and habitat for other organisms.
- Healthy soils support a diverse community of soil organisms, which contribute to nutrient cycling and soil fertility.
- Soil quality also affects water retention and drainage.

6. How do organisms adapt to changes in their environment due to ecological factors?

- Organisms adapt to environmental changes through evolution, which involves changes in their genetic makeup over generations.
- Adaptations can be structural (e.g., changes in body shape or size), physiological (e.g., changes in metabolism), or behavioral (e.g., changes in foraging strategies).
- Natural selection drives adaptation by favoring individuals with traits that increase their survival and reproduction in a particular environment.
- Organisms can also adapt through acclimation, which is a short-term physiological response to environmental change.

Topic 2.1: Explanation of ecological factors

Objectives:

By the end of the topic, trainees will be able to:

a. The learner will be able to identify Ecological factors properly referring to their effects on living organism

Time Required: 4 hours

Learning Methodology: Group discussion, Trainer guided, Videos, brainstorming and demonstration

Materials, Tools and Equipment Needed: Computer, projector, white board/ chalkboard, Flipcharts, papers, wall charts, Markers, chalks, tutorial videos, pictures

Preparation:

- ❑ Brainstorming, demonstration and simulation
- ❑ Individual and group work, group discussion

Cross Cutting Issues:

- ✓ Living together in peace harmony

Prerequisites:

- ➢ Origin of life
- ➢ Human evolution

Activity 1: Problem-Solving

Task 9:

1. Take students through the following steps:

a. Firstly, Introduce the topic **2.1: Explanation of ecological factors**

b. Secondly, organize trainees into pairs or small groups and guide them through a structured discussion about questions on task 9 in trainee's manual. Ensure active participation and understanding of instructions.

c. Bring the trainees back together as a large group for presentations. Each pair or group should summarize their discussions, sharing insights and learnings with the class. Encourage all trainees to contribute their own experiences and reflections.

2. Take students through Completing this task, their will gain a deeper understanding of ecological concepts and the importance of considering environmental impacts in decision-making.

A local community is considering building a new shopping mall on a piece of land that is currently a small forest. As an environmental scientist, you are tasked with conducting an ecological impact assessment of the proposed development. What type of ecosystem is present on the land?

Step 1: In the garden ecosystem guide trainees to identify the following:

- *The type of ecosystem is present in the Gardened area*
- *The dominant plant and animal species in this ecosystem?*

Step 2: Guide trainees to Assess Abiotic Factors by:

- *Identifying factors which influence the ecosystem.*
- *Explaining how construction and operation of the classroom affect these factors*

Step 3: In ecosystem guide trainees to analyse Biotic Interactions by;

- *Describing the food web and energy flow within the ecosystem.*
- *Identifying any keystone species or endangered species that may be affected by the development.*

- *Advise the local government on how might the development disrupt the interactions between different species. (Three sentences are enough)*

Step 4: Predict Potential Impacts

- *List the potential negative impacts of the classroom blocks on the ecosystem.*
- *Explain clearly to the local government how the development might affect the local community and its residents.*

Step 5: Propose Mitigation Strategies to:

- *Minimize the negative impacts of the development by consider strategies such as wildlife corridors, noise barriers, and pollution control measures.*

3. Conclude the activity with feedback and reflection.

Possible Answers:

1. What are the dominant plant and animal species in this ecosystem?

- To answer this, you need to observe or research the specific ecosystem. Dominant species are those that are most abundant and have the greatest influence on the ecosystem's structure and function. For example:
  - *In a forest: Dominant plants might be oak or pine trees, and dominant animals might be deer or squirrels.*
  - *In a grassland: Dominant plants could be various grass species, and dominant animals might be bison or prairie dogs.*
  - *In a coral reef: Dominant plants would be algae, and dominant animals would be many types of coral, and fish.*

2. Identify the key abiotic factors that influence the ecosystem.

- Abiotic factors vary depending on the ecosystem. Common ones include:
  - *Temperature: Affects metabolic rates and species distribution.*
  - *Water availability: Determines plant growth and habitat suitability.*
  - *Sunlight: Drives photosynthesis and influences animal behavior.*
  - *Soil composition: Affects nutrient availability and plant growth.*
  - *Wind: Influences temperature, water loss, and seed dispersal.*

3. Describe the food web and energy flow within the ecosystem.

- The food web shows the interconnected feeding relationships between organisms. Energy flows from:

- *Producers (plants) → Herbivores (primary consumers) → Carnivores (secondary and tertiary consumers) → Decomposers (bacteria, fungi).*
- *Energy is lost at each trophic level, so there is less energy available for higher-level consumers.*

4. **What are the potential negative impacts of the development on the ecosystem?**

- Potential impacts include:
    - *Habitat destruction and fragmentation.*
    - *Loss of biodiversity.*
    - *Pollution (air, water, soil).*
    - *Disruption of natural water cycles.*
    - *Introduction of invasive species.*
    - *Soil erosion.*
    - *Increased noise and light pollution.*

5. **How might the development affect the local community and its residents?**

- Potential effects include:
    - *Economic benefits (jobs, increased revenue).*
    - *Displacement of residents.*
    - *Changes in air and water quality.*
    - *Increased traffic and noise.*
    - *Loss of recreational areas.*
    - *Changes to the cultural identity of the area.*

6. **How can we balance economic development with environmental conservation?**

- Strategies include:
    - *Implementing sustainable development practices.*
    - *Conducting environmental impact assessments.*
    - *Establishing protected areas.*
    - *Promoting eco-tourism.*
    - *Enforcing environmental regulations.*
    - *Using resources efficiently.*
    - *Restoring degraded habitats.*

7. **What are the long-term consequences of destroying natural habitats?**

- Consequences include:
    - *Loss of biodiversity and ecosystem services.*
    - *Climate change.*

- *Increased risk of natural disasters.*
- *Disruption of food chains.*
- *Spread of diseases.*
- *Extinction of species.*

8. **How can we promote sustainable development that minimizes harm to the environment?**

- Strategies include:
    - *Using renewable energy sources.*
    - *Reducing waste and pollution.*
    - *Conserving water and energy.*
    - *Promoting sustainable agriculture.*
    - *Educating the public about environmental issues.*
    - *Supporting policies that protect the environment.*
    - *Creating green infrastructure.*

Activity 2: Guided Practice

Task 10:

1. Instruct the students to Read the scenario under Task 10 of their Trainee's Manual to understand the concept of ecological factors and their impact on living organisms

Instructions:

Description of changes and characteristics of a forcing shaped freshwater pond would include that the aquatic organisms as aquatic plants rely on sunlight for photosynthesis, temperature; and pH levels that remain undecided would all affect fish and microorganisms. Oxygen depletion occurred during a heatwave where the water temperature increased and the bacteria put stress on fish. Further aluminum runoff from nearby farms initiates an algal bloom, thus decreasing oxygen levels. This entire situation describes how abiotic factors like sunlight, temperature, and water quality, plus interactions with biotic factors like algae, directly or indirectly affect the whole pond ecosystem.

2. Form groups of 5 students.

    1. Instruct the groups to do the practice in the classroom or outdoors (if possible).

    2. Define biotic and abiotic factors.

    3. Have groups presentation on their findings to the class, explaining how each factor influences living organisms.

    4. Explain how these factors interact to shape ecosystems.

3. Then after presentation Facilitate a class discussion on the following questions:

    1. How do abiotic and biotic factors interact to create a balanced ecosystem?

    2. What happens when an ecosystem is disrupted by human activities or natural disasters?

    3. How can we protect and conserve ecosystems?

Possible Answers:

1. **How do abiotic and biotic factors interact to create a balanced ecosystem?**

    - Abiotic factors provide the physical and chemical foundation for life. For example, sunlight provides energy for plants (biotic) to perform photosynthesis. Water and soil nutrients (abiotic) support plant growth, which in turn provides food and habitat for animals (biotic).
    - Biotic factors, in turn, modify abiotic conditions. Plants, for instance, release oxygen into the atmosphere and their roots stabilize soil. Animals contribute to nutrient cycling through decomposition and waste.
    - The interaction between these factors creates a dynamic equilibrium. For instance, the availability of sunlight (abiotic) influences plant growth (biotic), which then affects the population of herbivores (biotic) that feed on the plants. The population of predators (biotic) that feed on the herbivores is then influenced by the herbivore population.
    - This constant interplay results in a system where energy flows, nutrients cycle, and populations remain relatively stable over time, creating a balanced ecosystem.

2. **What happens when an ecosystem is disrupted by human activities or natural disasters?**

    - **Disruption of Food Webs:** The removal or decline of a key species can cascade through the food web, impacting other organisms.

- **Loss of Biodiversity:** Habitats may be destroyed, leading to the extinction of species and a reduction in overall biodiversity.
- **Nutrient Cycling Disruption:** Soil erosion, pollution, and deforestation can disrupt the natural cycling of nutrients, affecting plant growth and ecosystem productivity.
- **Changes in Abiotic Factors:** Pollution can alter water and soil chemistry. Deforestation can change local climate patterns. Natural disasters can cause extreme changes to the landscape.
- **Invasive Species:** Disruption creates opportunities for invasive species to establish themselves, outcompeting native species and further disrupting the ecosystem.
- **Reduced Ecosystem Services**: Disrupted ecosystems provide fewer ecosystem services, such as clean water, air purification, and pollination.
- **Instability:** A disrupted ecosystem becomes less resilient, and less able to recover from further disturbances.

3. How can we protect and conserve ecosystems?

- **Establish Protected Areas:** Create national parks, wildlife refuges, and marine reserves to safeguard critical habitats.
- **Reduce Pollution:** Implement regulations to control air, water, and soil pollution. Promote the use of sustainable technologies.
- **Promote Sustainable Resource Use:** Practice sustainable forestry, fishing, and agriculture to minimize habitat destruction and resource depletion.
- **Restore Degraded Habitats:** Replant forests, restore wetlands, and remove invasive species to help ecosystems recover.
- **Control Invasive Species: Implement** measures to prevent the introduction and spread of invasive species.
- **Educate the Public:** Raise awareness about the importance of ecosystems and the need for conservation.
- **Implement Environmental Policies:** Enact and enforce laws that protect ecosystems and promote sustainable development.
- **Reduce Carbon Footprint:** Take action to mitigate climate change, which poses a significant threat to ecosystems.
- **Support Conservation Organizations:** Contribute to organizations working to protect and restore ecosystems.
- **Practice Responsible Consumption:** Reduce consumption, reuse materials, and recycle to minimize waste and resource use.

Activity 3: Application

Task 11:

Activity 1: Introduce Ecological Impact Assessment of a Proposed Development in scenario 4 in their trainee's manual.

Scenario 4: A local government is considering a proposal to build a new Classroom Block in a Gardened area. As an Ecological scientist, your task is to conduct an ecological impact assessment of the proposed project.

By completing this task, you will gain a deeper understanding of ecological factors and their importance in maintaining ecosystem health. Make groups of 4-5 students then instruct them to answer the following Questions and develop critical thinking and problem-solving skills that can be applied to real-world environmental issues.

Activity 2:

1. Provide necessary materials and tools for the task to be completed effectively.
2. This activity requires students to work independently with limited support from the trainer. During the task, students should be given a high degree of independence to apply the knowledge, skills, and attitudes acquired to real-life situations. Your role as the trainer is to set clear instructions, methodology, and timeframe for submitting the report.
3. Encourage trainees to utilize the knowledge and skills they have acquired throughout the training program to analyze the scenario critically and develop informed responses.
4. Facilitate the students to respond the proposed Questions in the following steps.

Step 1: Identify the Ecosystem

a. What type of ecosystem is present in the Gardened area?

b. What are the dominant plant and animal species in this ecosystem?

Step 2: Assess Abiotic Factors

a. Identify the key abiotic factors that influence the ecosystem.
b. How might the construction and operation of the classroom affect these factors?

Step 3: Analyze Biotic Interactions

a. Describe the food web and energy flow within the ecosystem.
b. Identify any keystone species or endangered species that may be affected by the development.
c. How might the development disrupt the interactions between different species?

Step 4: Predict Potential Impacts

a. What are the potential negative impacts of the classroom blocks on the ecosystem?
b. How might the development affect the local community and its residents?

Step 5: Propose Mitigation Strategies

a. Suggest ways to minimize the negative impacts of the development.
b. Consider strategies such as wildlife corridors, noise barriers, and pollution control measures.

Answer:

Step 1: Identify the Ecosystem

a. What type of ecosystem is present in the Gardened area?

- This is likely a **small-scale, human-influenced (anthropogenic) ecosystem**, often referred to as a cultivated or managed garden ecosystem. It may also have elements of a terrestrial ecosystem if there are naturally occurring organisms.

b. What are the dominant plant and animal species in this ecosystem?

- **Plants:** This depends on what's planted. Common examples include vegetables (tomatoes, lettuce, carrots), flowers (marigolds, petunias), and herbs (basil, rosemary). Also, common weeds like dandelions and grasses are often present.

- **Animals:** Insects (bees, butterflies, ants, earthworms, spiders), small birds (sparrows, robins), and possibly small mammals (squirrels, voles) could be present.

Step 2: Assess Abiotic Factors

a. Identify the key abiotic factors that influence the ecosystem.

- **Sunlight:** Essential for plant growth.
- **Water:** Rainfall or irrigation.
- **Soil:** Composition, pH, and nutrient content.
- **Temperature:** Seasonal and daily variations.
- **Air quality:** Pollution levels.
- **Wind:** Can affect pollination and moisture levels.

b. How might the construction and operation of the classroom affect these factors?

- **Sunlight:** Buildings can cast shadows, reducing sunlight exposure.
- **Water:** Construction can disrupt drainage patterns and increase runoff. Classroom usage might increase water usage.
- **Soil:** Construction can compact or remove topsoil.
- **Temperature:** Buildings can create localized temperature changes (heat island effect).
- **Air quality:** Construction generates dust and pollutants. Classroom operation can add to pollution.
- **Noise:** construction and classroom activities will increase noise levels.

Step 3: Analyze Biotic Interactions

a. Describe the food web and energy flow within the ecosystem.

- **Producers:** Plants capture sunlight and convert it into energy.

- **Consumers:** Insects and herbivores eat plants. Birds and other predators eat insects. Decomposers (earthworms, bacteria) break down dead organic matter.
- **Energy Flow:** Sunlight -> Plants -> Herbivores -> Predators -> Decomposers.

b. Identify any keystone species or endangered species that may be affected by the development.

- **Keystone species:** Bees (pollinators) are crucial. Earthworms (soil health) are also very important.
- **Endangered species:** This depends on the specific location. Check local lists.

c. How might the development disrupt the interactions between different species?

- **Habitat loss:** Reduces space for plants and animals.
- **Noise and light pollution:** Disrupts animal behavior.
- **Soil compaction:** Affects plant growth and soil organisms.
- **Pollinator disruption:** Reduced floral resources and increased noise.

Step 4: Predict Potential Impacts

a. What are the potential negative impacts of the classroom blocks on the ecosystem?

- Loss of biodiversity.
- Reduced habitat for wildlife.
- Soil degradation.
- Increased pollution.
- Disruption of natural processes (pollination, nutrient cycling).

b. How might the development affect the local community and its residents?

- Loss of green space.
- Increased noise and traffic.
- Potential reduction in aesthetic value.
- Possible loss of educational opportunities associated with the garden.

- Potential for increased flooding due to increased runoff.

Step 5: Propose Mitigation Strategies

a. Suggest ways to minimize the negative impacts of the development.

- Design the building to minimize shadows.
- Preserve existing trees and vegetation.
- Create green roofs or walls.
- Use permeable paving materials.
- Implement rainwater harvesting systems.
- Create a smaller, but higher quality gardened area.

b. Consider strategies such as wildlife corridors, noise barriers, and pollution control measures.

- **Wildlife corridors:** Plant native vegetation to connect fragmented habitats.
- **Noise barriers:** Use sound-absorbing materials in construction.
- **Pollution control:** Implement dust suppression measures during construction, use low-emission building materials, and install efficient ventilation systems.
- Create a compost and recycling program at the classroom.
- Educate the students on the importance of the ecosystem.

Topic 2.2: Description of ecosystems

Objectives:

By the end of the topic, trainees will be able to:

a. Distinguish Types of ecosystems clearly based on relationships among living organisms

Time Required: 3 hours

Learning Methodology: Group discussion, Trainer guided, Site visit, brainstorming and demonstration.

Materials, Tools and Equipment Needed: Computer, projector, white board/ chalkboard, Flipcharts, papers, wall charts, Markers, chalks, tutorial videos, pictures

Preparation:

- ❑ Brainstorming, demonstration and simulation, individual and group work, group discussion
- ❑ Written assessment, oral presentation

Cross Cutting Issues:

- ✓ Climate change and global warming

Prerequisites:

- ➢ Origin of life
- ➢ Human evolution
- ➢ Ecological factors

Activity 1: Problem-Solving

Task 12:

1. Introduce the topic **Topic 2.2: Description of ecosystems**
2. Provide necessary materials and tools for the task.
3. Use suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session**.**
4. After Introducing this short description on Nyungwe ecosystem and help the students to read the scenario related to the task 12 and answer the asked Questions in their trainee's Manuals:
5. Before concluding this session refer trainees to the **Key Facts 2.2** and Compare their answers with the content in their trainee Manual, Encourage them to ask for Clarification

Here below are possible answers:

1. **What is the difference between a biotic and an abiotic factor?**
    - **Biotic factors** are the living components of an ecosystem. This includes all organisms, such as plants, animals, fungi, and bacteria. They interact with each other in various ways, such as through predation, competition, and symbiosis.
    - **Abiotic factors** are the non-living components of an ecosystem. This includes physical and chemical factors, such as temperature, sunlight, water, soil, and air. They influence the distribution and abundance of organisms.
2. **Name two major types of ecosystems.**
    - Terrestrial ecosystems (e.g., forests, grasslands, deserts)
    - Aquatic ecosystems (e.g., oceans, lakes, rivers, wetlands)
3. **What is the role of decomposers in an ecosystem?**

- Decomposers, primarily bacteria and fungi, break down dead organic matter (e.g., dead plants and animals, waste products) into simpler inorganic substances.
- This process releases nutrients back into the soil or water, making them available for producers (plants) to use.
- Decomposers play a crucial role in nutrient cycling, ensuring that essential elements are recycled within the ecosystem.

4. Explain the concept of limiting factors in relation to productivity.

- Limiting factors are environmental conditions that restrict the growth, abundance, or distribution of organisms in an ecosystem.
- In relation to productivity, a limiting factor is any factor that restricts the rate of primary production (the rate at which producers convert sunlight into organic matter).
- For example, in a terrestrial ecosystem, water or nutrients might be limiting factors. In an aquatic ecosystem, sunlight or dissolved nutrients might be limiting factors.
- Essentially, even if all other needed resources are abundant, the resource that is in shortest supply will limit the productivity of the system.

5. What is the role of sunlight in primary productivity?

- Sunlight is the primary source of energy for most ecosystems.
- Through photosynthesis, producers (plants, algae, and some bacteria) use sunlight to convert carbon dioxide and water into glucose (a type of sugar) and oxygen.
- This process, known as primary production, is the foundation of most food webs, as it provides the energy that sustains all other organisms in the ecosystem.
- The amount of sunlight available directly impacts the rate of photosynthesis, and therefore the amount of primary productivity.

6. Discuss the impact of human activities on ecosystem productivity.
    - **Deforestation:** Reduces the number of producers, decreasing primary productivity and disrupting nutrient cycling.
    - **Pollution:** Contaminates water and soil, harming producers and reducing their ability to photosynthesize.
    - **Climate change:** Alters temperature and precipitation patterns, affecting the distribution and growth of producers.
    - **Overfishing/Overhunting:** Disrupts food webs, reducing the abundance of consumers and indirectly affecting producer populations.
    - **Agricultural practices:** Excessive use of fertilizers can lead to nutrient runoff, causing eutrophication in aquatic ecosystems, while unsustainable farming can deplete soil nutrients.
    - **Urbanization:** Habitat destruction and fragmentation reduce the area available for producers.
    - **Introduction of invasive species:** Invasive species can outcompete native producers, reducing biodiversity and ecosystem productivity.

Activity 2: Guided Practice

Task 13:

1. Provide necessary materials and tools for the task.
2. Use suitable methodologies such as think-pair-share-square, question and answer in small or large groups presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session**.**
3. Conclude by emphasizing the interconnectedness of productivity and trophic with answering the questions asked under task 13 :

Here below are possible answers:

1. **What role does primary productivity play in an ecosystem?**
    - Primary productivity is the foundation of energy flow in an ecosystem. It's the rate at which producers (plants, algae, and some bacteria) convert sunlight or chemical energy into organic matter (biomass).
    - It essentially sets the limit for how much energy is available to support all other organisms in the ecosystem (herbivores, carnivores, and decomposers).
    - Primary productivity influences the abundance and diversity of life within an ecosystem. A highly productive ecosystem can support more organisms at higher trophic levels.
2. **Why does energy decrease as it moves up trophic levels?**
    - The second law of thermodynamics states that energy conversions are never 100% efficient; some energy is always lost as heat.
    - When an organism consumes food, only a portion of the energy is converted into its own biomass. The rest is:
        - Used for metabolic processes (respiration), which releases heat.
        - Lost as undigested material (feces).
    - On average, only about 10% of the energy from one trophic level is transferred to the next. This is known as the "10% rule." The other 90% is lost.
3. **How does net productivity affect the energy available for higher levels?**
    - Net productivity (NPP) is the gross primary productivity (GPP) minus the energy used by producers for respiration. It represents the amount of energy stored as biomass that is available to consumers.
    - A higher NPP means more energy is available for herbivores, which in turn means more energy is available for carnivores, and so on.
    - Conversely, a low NPP limits the energy available for higher trophic levels, potentially leading to lower populations or fewer species at those levels.
    - Essentially NPP is the energy that is actually "available" to move up the food chain.
4. **Why are there fewer apex predators than primary consumers?**
    - Due to the 10% rule of energy transfer, there is significantly less energy available at higher trophic levels.
    - Apex predators are at the top of the food chain, so they rely on energy that has passed through multiple trophic levels.

- Because of the energy loss at each level, there is simply not enough energy to support a large population of apex predators.
- Therefore, ecosystems typically have a pyramid-shaped structure, with a wide base of producers and progressively smaller levels of consumers, culminating in a relatively small population of apex predators.

5. A diagram of ecosystem productivity (showing primary productivity, gross productivity, and net productivity)

Sunlight
↓
Producers (Plants, Algae)
↓
Gross Primary Productivity (GPP)
↓
Respiration (Energy Used by Producers)
↓
Net Primary Productivity (NPP)
↓
Available Energy for Consumers

- **Gross Primary Productivity (GPP):** The total amount of energy captured by producers through photosynthesis.
- **Respiration:** The energy used by producers for their own metabolic processes (growth, maintenance, etc.).
- **Net Primary Productivity (NPP):** The remaining energy after respiration, which is stored as biomass and available to consumers.

Activity 3: Application

Task 14:

1. Provide necessary materials and tools for the assignment under task 14 in Trainee's Manuals.
2. Use interactive methodologies such as class discussion sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session**.**
3. After the sharing session, refer students to **the Previous Key facts 2.2** and discuss them together. While harmonizing the points of view from different groups presentations, provide your expert view and answer any questions which may be raised.
4. Facilitate trainees in Exploring Ecosystems and Ecological Principles by helping the to read the task 14 and performing related assignments

Here below are possible results on task 14 about comprehensive understanding of ecology, Ecosystem Dynamics, and Human Impacts

1. **Defining Key Terms:**
   - **Ecology:** The scientific study of the interactions between organisms and their environment.
   - **Ecosystem:** A community of living organisms (biotic factors) and their non-living environment (abiotic factors) interacting as a system.
   - **Biotic Factors:** The living components of an ecosystem, such as plants, animals, fungi, and bacteria.
   - **Abiotic Factors:** The non-living components of an ecosystem, such as temperature, sunlight, water, and soil.
2. **Types of Ecology:**
   - **Population Ecology:** The study of how populations of a single species interact with their environment.
   - **Community Ecology:** The study of how different species interact within a given area.
   - **Ecosystem Ecology:** The study of how energy and nutrients flow through an ecosystem.

3. **Observing the School Environment:**

- **Identifying Biotic Factors:**
    - Plants (grass, trees, shrubs)
    - Insects (ants, bees, butterflies)
    - Birds (pigeons, sparrows)
    - Small mammals (squirrels, rodents)
    - Microorganisms in the soil
- **Identifying Abiotic Factors:**
    - Sunlight
    - Temperature
    - Rainfall/water availability
    - Soil type and pH
    - Air quality
    - Wind
- **Interactions:**
    - Plants use sunlight for photosynthesis.
    - Insects pollinate flowers.
    - Birds eat insects.
    - Rainfall affects plant growth.
    - The temperature of the area impacts what plants can grow there.
- **Ecosystem Type:**
    - Likely a terrestrial ecosystem, potentially a small urban/suburban ecosystem.
- **Ecosystem Components:**
    - Producers (plants)
    - Consumers (insects, birds, mammals)

- Decomposers (bacteria, fungi in soil)

4. **Creating a Food Chain/Web:**
   - **Example Food Chain:**
     - Grass (producer) → Grasshopper (primary consumer) → Sparrow (secondary consumer) → Hawk (apex predator)
   - **Energy Flow:**
     - Energy flows from the sun to the grass (photosynthesis).
     - Energy is transferred to each consumer as they eat.
   - **Energy Loss:**
     - Approximately 90% of energy is lost as heat at each trophic level (10% rule).
     - Energy is used for metabolism, movement, and heat production.
5. **Gross and Net Productivity:**
   - Gross Productivity: The total amount of energy captured by producers.
   - Net Productivity: The energy remaining after producers use some for respiration.
   - Factors Affecting Productivity:
     - Sunlight availability
     - Water availability
     - Soil nutrient content
     - Temperature
6. **Biological Relationships:**
   - Predation: A sparrow eating a grasshopper.
   - Competition: Grass competing for sunlight and nutrients.
   - Symbiosis:
     - Mutualism: Bees pollinating flowers, both benefit.
     - Commensalism: Birds nesting in trees, birds benefit, tree unaffected.
     - Parasitism: Fleas on a rodent, the flea benefits, and the rodent is harmed.
   - Cooperation: Ants working together to gather food.

7. **Human Impacts:**
    - **Positive Impacts:**
        - Planting trees and creating green spaces.
        - Recycling and waste management.
        - Maintaining gardens.
    - **Negative Impacts:**
        - Littering and pollution.
        - Use of pesticides and herbicides.
        - Habitat destruction from construction.
        - Excessive noise.
    - **Sustainable Solutions:**
        - Promote recycling and composting.
        - Plant native species.
        - Reduce pesticide and herbicide use.
        - Create wildlife habitats.
        - Use less single use plastics.
        - Use more public transport or walk/bike.
8. **Report Components:**
    - Introduction: Defining key terms and outlining the task.
    - Observation Section: Detailing observations of the school environment, including biotic and abiotic factors.
    - Analysis Section: Describing the ecosystem type, food chain/web, energy flow, and biological relationships.
    - Discussion Section: Analyzing human impacts and proposing sustainable solutions.
    - Conclusion: Summarizing findings and reflecting on the importance of ecological understanding.
    - Diagrams: Visual representations of the food chain/web, energy flow, and ecosystem components.

- Examples: specific instances observed in the school environment.

Topic 2.3: Explanation of relationship between living organisms

Objectives:

By the end of the topic, trainees will be able to:

a. Discuss Relationship between living organisms effectively in reference with their biological community

Time Required: 3 hours.

Learning Methodology: Group discussion, trainer guided, site visit, brainstorming and demonstration.

Materials, Tools and Equipment Needed: Computer, projector, white board/ chalkboard, Flipcharts, papers, wall charts, Markers, chalks, tutorial videos, pictures

Preparation:

- ❑ Brainstorming, demonstration and simulation, individual and group work, group discussion
- ❑ Written assessment, oral presentation

Cross Cutting Issues:

- ✓ Influence of Abiotic Factors
- ✓ Evolutionary History and Constraint
- ✓ Interconnectedness Across Trophic Levels

Prerequisites:

- ➢ Basic biological classification
- ➢ Types of species interactions
- ➢ Understanding of evolutionary principles

Activity 1: Problem Solving

Task 15:

9. Introduce the **topic 2.3**: Explanation of relationship between living organisms
10. Provide necessary materials and tools for the task.
11. Employing suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session.
12. Instruct the students to Explore relationship between living organisms in the following scenario then answer the Discovering Questions asked under task 15 in their trainee Manuals:

Here below are possible Answers:

1. **What are the main types of interactions among organisms in a biological community?**
    - **Predation:** One organism (predator) kills and consumes another (prey).
    - **Competition:** Organisms vie for the same limited resource (food, space, and mates).
    - **Symbiosis:** Close and long-term interactions between two different species. This includes:
        - ***Mutualism:*** *Both organism's benefit.*
        - ***Commensalism:*** *One organism benefit, and the other is neither harmed nor helped.*
        - ***Parasitism:*** *One organism benefit, and the other is harmed.*
    - **Cooperation:** Organisms work together for mutual benefit.
2. **How does predation influence population dynamics?**
    - Predation can control prey populations, preventing them from exceeding the carrying capacity of their environment.
    - Predator-prey interactions often lead to cyclical population fluctuations.

- Predation can drive evolutionary adaptations in both predators and prey (e.g., camouflage, speed).

3. **What role does competition play in resource allocation among species?**
    - Competition determines which species have access to limited resources.
    - It can lead to resource partitioning, where species divide resources to minimize competition.
    - Competition can also lead to competitive exclusion, where one species outcompetes another and drives it out of the area.
4. **Can symbiotic relationships benefit both organisms? Provide examples.**
    - Yes, mutualistic symbiotic relationships benefit both organisms.

    Examples:

    - *Bees and flowers: Bees get nectar, and flowers get pollinated.*
    - *Mycorrhizal fungi and plant roots: Fungi enhance nutrient and water uptake for plants, and plants provide sugars for fungi.*
    - *Bacteria in the digestive system of ruminants: Bacteria help break down cellulose, and ruminants get nutrients.*
5. **How does cooperation between species contribute to ecosystem stability?**
    - Cooperation can enhance resource acquisition, defense, and reproduction, leading to increased survival and stability.
    - It can create more resilient ecosystems that are better able to withstand disturbances.
    - For example, social insects like ants working together to build and maintain their nests.
6. **What factors determine the nature of interactions between organisms?**
    - Resource availability.
    - Environmental conditions.
    - Population densities.
    - The size and strength of the interacting organisms.
    - Evolutionary history.
    - Behavioral adaptations.

7. **How do environmental changes affect these interactions?**
    - Changes in temperature, precipitation, or habitat can alter resource availability and stress organisms, impacting competition and predation.
    - Environmental changes can disrupt symbiotic relationships.
    - Extreme events can lead to population crashes and changes in community structure.
8. **What is the impact of human activities on these relationships?**
    - Habitat destruction and fragmentation disrupt predator-prey relationships.
    - Pollution can weaken organisms and make them more susceptible to disease.
    - Introduction of invasive species can disrupt native interactions.
    - Climate change is altering the timing of biological events, disrupting symbiotic relationships, and changing the distribution of species.
    - Overharvesting of certain species can remove key players from the food web.
9. **How do these interactions influence biodiversity?**
    - Diverse interactions create complex food webs and niches, supporting higher biodiversity.
    - Predation and competition can prevent any one species from dominating, allowing for greater species richness.
    - Symbiotic relationships can create new niches and support unique species.
10. **Why are balanced interactions essential for ecosystem health?**
    - Balanced interactions maintain ecosystem stability and resilience.
    - They ensure efficient energy flow and nutrient cycling.
    - They prevent any one species from becoming overly dominant, which could lead to ecosystem collapse.
    - A healthy ecosystem is more resistant to disturbances and better able to provide ecosystem services.

Activity 2: Guided Practice

Task 16: Understanding Relationships Between Living Organisms by Exploring Relationships in a Local Ecosystem

1. Ask trainees to read the statement formulated on the task 16 and accomplish the assignment
2. Facilitate class discuss on the observations as a whole class about identified the different types of relationships.
3. Form a group of five (5) students then explain different types of relationships between living organisms,
4. After a research on specific ecosystem ask them to post created presentation or the illustrations on various relationships within ecosystem.
5. Use plenary session and help trainees to compares their findings/outcomes then provide your expert vies by linking this session with the objectives of the topic.

Activity 3: Application

Task 17:

- Provide necessary materials and tools for the task.
- Employing suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session**.**
- After the sharing introduction session and discuss with them together while harmonizing their responses provided in the sharing session and answer any questions they have.
- Instruct the students to Explore interactions between living organisms in the following scenario then explain the case study analysis:

Formative Assessment

Instructions: Answer the following questions to the best of your ability.

Section A: ALL Questions are Compulsory

1. Define:

a. Species

b. Population

c. Community

d. Niche

e. Biome

f. Biosphere

2. List Three different types of Ecology.
3. Define Abiotic and Biotic factors. Give two examples of each.
4. Define Ecosystem.
5. List Five different types of Ecosystems.
6. Define Producer, Primary Consumer, Secondary Consumer, Tertiary Consumer.
7. Define Productivity in an ecosystem.
8. List Two types of productivity in an ecosystem.
9. Define Predation, Competition, Symbiosis.
10. Define Parasitism, Mutualism, Commensalism, Amensalism.
11. Explain The concept of energy flow in an ecosystem.
12. Describe The difference between a food chain and a food web.
13. List Three major human impacts on the ecosystem.
14. Imagine a pond ecosystem List three biotic factors and three abiotic factors that might influence the organisms living in that pond.
15. You observe a bird building its nest in a tree. Identify the type of symbiotic relationship.
16. A lion hunts and kills a gazelle. Identify the type of relationship.

17. Two species of squirrels compete for the same food source in a forest. Identify the type of relationship.
18. A farmer plants a field of corn. Explain how this activity might impact the local ecosystem.
19. Explain How do abiotic factors influence the distribution and abundance of organisms in an ecosystem?
20. Why is biodiversity important for the stability of an ecosystem?
21. How does the loss of a top predator affect the rest of the food web?
22. Evaluate The impact of deforestation on biodiversity and ecosystem function.
23. Evaluate The effectiveness of different conservation strategies in protecting ecosystems.
24. How do the concepts of competition and niche relate to the distribution of species in a community?

Section B: Answer only 3 Questions of your Choice

1. Explain how human activities can disrupt the balance of energy flow in an ecosystem.
2. Design a simple experiment to investigate the impact of a specific abiotic factor on plant growth.
3. Design A poster illustrating the different trophic levels in a marine ecosystem.
4. Develop A short story or poem that depicts the interconnectedness of living organisms in an ecosystem.
5. Propose A solution to a local environmental problem based on your understanding of ecological principles.
6. Develop A presentation on the importance of protecting endangered species and their habitats.

Answer:

1. Define:

a. **Species:** A group of living organisms capable of interbreeding and producing fertile offspring.

b. **Population:** A group of individuals of the same species living in the same area at the same time.

c. **Community:** All the different populations of organisms living together in a particular area.

d. **Niche:** The role an organism plays in its environment, including its habitat, resources, and interactions with other species.

e. **Biome:** A large naturally occurring community of flora and fauna occupying a major habitat, e.g., forest or tundra.

f. **Biosphere:** The part of Earth inhabited by living organisms, encompassing all ecosystems.

2. List Three different types of Ecology:

- Population ecology
- Community ecology
- Ecosystem ecology

3. Define Abiotic and Biotic factors. Give two examples of each.

- Abiotic factors: Non-living physical and chemical components of an ecosystem.

  Examples: Temperature, sunlight.

- Biotic factors: Living components of an ecosystem.

  Examples: Plants, animals.

4. Define Ecosystem.

- An ecosystem is a community of living organisms (biotic factors) and their non-living environment (abiotic factors) interacting as a system.

5. List Five different types of Ecosystems.

- Forest ecosystems
- Grassland ecosystems
- Desert ecosystems
- Freshwater ecosystems (lakes, rivers)
- Marine ecosystems (oceans, coral reefs)

6. Define: Producer, Primary Consumer, Secondary Consumer, Tertiary Consumer.

- **Producer:** An organism that produces its own food through photosynthesis or chemosynthesis (e.g., plants).
- **Primary Consumer:** An herbivore that eats producers (e.g., rabbits).
- **Secondary Consumer:** A carnivore that eats primary consumers (e.g., snakes).

- **Tertiary Consumer:** A carnivore that eats secondary consumers (e.g., hawks).

7. Define Productivity in an ecosystem.

- Productivity is the rate at which biomass (organic matter) is produced in an ecosystem.

8. List Two types of productivity in an ecosystem.

- Gross primary productivity (GPP)
- Net primary productivity (NPP)

9. Define Predation, Competition, Symbiosis.

- **Predation:** One organism (predator) kills and consumes another (prey).
- **Competition:** Organisms vie for the same limited resources.
- **Symbiosis:** A close and long-term interaction between two different species.

10. Define: Parasitism, Mutualism, Commensalism, Amensalism.

- **Parasitism:** One organism benefits, and the other is harmed.
- **Mutualism:** Both organisms benefit.
- **Commensalism:** One organism benefits, and the other is neither harmed nor helped.
- **Amensalism:** One organism is harmed, and the other is unaffected.

11. Explain The concept of energy flow in an ecosystem.

- Energy flows through an ecosystem in a one-way direction, starting with producers (converting sunlight to chemical energy), then moving through consumers (herbivores, carnivores), and finally to decomposers. Energy is lost as heat at each trophic level.

12. Describe The difference between a food chain and a food web.

- Food chain: A linear sequence of organisms showing the transfer of energy from one trophic level to the next.
- Food web: A complex network of interconnected food chains, showing the multiple feeding relationships in an ecosystem.

13. List Three major human impacts on the ecosystem.

- Habitat destruction/fragmentation
- Pollution (air, water, soil)
- Climate change

14. **Imagine a pond ecosystem List three biotic factors and three abiotic factors that might influence the organisms living in that pond.**
    - Biotic factors: Fish, algae, insects.
    - Abiotic factors: Water temperature, sunlight, dissolved oxygen.
15. **You observe a bird building its nest in a tree. Identify the type of symbiotic relationship.**
    - Commensalism.
16. **a lion hunts and kills a gazelle. Identify the type of relationship.**
    - Predation.
17. **Two species of squirrels compete for the same food source in a forest. Identify the type of relationship.**
    - Competition.
18. **a farmer plants a field of corn. Explain how this activity might impact the local ecosystem.**
    - Reduces biodiversity, may increase erosion, can add chemical pollution through fertilizers and pesticides, can alter water runoff.
19. **Explain How do abiotic factors influence the distribution and abundance of organisms in an ecosystem?**
    - Abiotic factors (temperature, water, sunlight, etc.) determine which organisms can survive and reproduce in a given area, thus influencing their distribution and abundance.
19. **Why is biodiversity important for the stability of an ecosystem?**
    - Biodiversity increases ecosystem resilience, provides ecosystem services, and enhances the ability of the ecosystem to adapt to change.
20. **How does the loss of a top predator affect the rest of the food web?**
    - It can lead to an increase in prey populations, which can then overgraze producers, disrupting the balance of the ecosystem.
21. **Evaluate The impact of deforestation on biodiversity and ecosystem function.**
    - Deforestation leads to habitat loss, decreased biodiversity, increased erosion, disrupted water cycles, and contributes to climate change.
22. **Evaluate The effectiveness of different conservation strategies in protecting ecosystems.**

- Effectiveness varies: Protected areas are effective but can be limited by funding and enforcement. Sustainable resource management and community involvement are crucial.

23. How do the concepts of competition and niche relate to the distribution of species in a community?

- Competition can lead to niche differentiation, where species evolve to occupy different niches, reducing competition and allowing for coexistence.

24. Explain how human activities can disrupt the balance of energy flow in an ecosystem.

- Pollution, deforestation, and habitat destruction can reduce primary productivity, altering energy flow and impacting higher trophic levels.

25. Design a simple experiment to investigate the impact of a specific abiotic factor on plant growth.

- Experiment: Investigate the effect of light intensity on plant growth.
    - Setup: Grow identical plants under varying light intensities (e.g., different distances from a light source).
    - Measure: Plant height, leaf count, and biomass over a set period.

26. Design A poster illustrating the different trophic levels in a marine ecosystem.

- Poster: Show phytoplankton (producers), zooplankton (primary consumers), small fish (secondary consumers), and sharks (tertiary consumers). Include arrows showing energy flow.

27. Develop A short story or poem that depicts the interconnectedness of living organisms in an ecosystem.

- This would be a creative writing task.

28. Propose A solution to a local environmental problem based on your understanding of ecological principles.

- Example: If litter is a local problem, propose a community recycling and education program.

29. Develop A presentation on the importance of protecting endangered species and their habitats.

- Presentation: Cover topics like the role of endangered species in ecosystems, threats to their survival, and conservation efforts.

Points to Remember

- **There are 4 Types of Ecology (Population Ecology, Community Ecology, Ecosystem Ecology, and Landscape Ecology)**
- **There are TWO Ecological Factors (living components "biotic factors" and non-living components "Abiotic Factors").**
- **Here are relationships among Living Organisms:(Predation, Competition, Symbiosis, Mutualism, Commensalism, Parasitism, and Amensalism)**
- **Exist 7 Types of Ecosystems(Forest Ecosystems, Tundra, Ecosystems, Desert Ecosystems, Freshwater Ecosystems, Ocean Ecosystems, Grassland Ecosystems, Alpine Ecosystems)**

Self-Reflection

1. Ask learners to re-take the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to Identify their areas of strength, areas for improvement and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

LEARNING OUTCOME 3: ILLUSTRATE MECHANISMS OF ENVIRONMENTAL CONSERVATION

Learning outcome 3: Self-Assessment

1. Ask trainees to look at the unit illustration in their Trainee's Manuals and together discuss:
    a. What do the illustrations show?
    b. What topics do you think will be covered under this unit based on the illustration?
2. After the discussion, inform students that this unit is intended to provide them with the knowledge, skills and attitudes to **illustrate mechanisms of environmental conservation**
3. Ask trainees to fill out the self-assessment at the beginning of the unit in their Trainee's Manuals. Explain that:

a. The purpose of the self-assessment is to become familiar with the topics in the unit and for them to see what they know or do not know at the beginning.

b. There are no right or wrong ways to answer this assessment. It is for their own reference and self-reflection on the knowledge, skills and attitudes acquisition during the learning process.

c. They should think about themselves: do they think they have the knowledge, skills or attitudes to do this? How well?

d. They read the statements across the top and put a check in column that best represents their level of knowledge, skills or attitudes.

At the end of the unit, they will do a self-reflection, which includes re-taking the self-assessment and identifying their strengths, areas of improvement and actions to be taken.

Key Competencies:

Knowledge	Skills	Attitudes
Describe biogeochemical cycles and involve the elements	Analyze causes of biodiversity Loss	Awareness of environmental balance.
Explain ecological balance	Identifying the causes of bio-degradation	Awareness on ecosystem degradation and environment restorations.

Knowledge	Skills	Attitudes
Identify practices, policy regulations, conservation methods, and climate change adaptation.	Apply sustainability compliance/legislation practices, environmental protection strategies	Active role toward the conservation of resources and ecosystems.

Steps:

Discovery Activity

Task 18:

- Introduce the new Unit 3 and overall objectives
- Ask trainee to Read the scenario under task 18
- Provide necessary materials and tools for the task.
- Employing suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session**.**
- After the sharing introduction session and discuss with them together while harmonizing their responses provided in the sharing session and answer any questions if any.
- Instruct the students to Explore biogeochemical cycle in the following scenario then answer the questions:

Here below are possible Answers:

1. **What is a biogeochemical cycle?**
   - A biogeochemical cycle is the movement of chemical elements or molecules through the living and non-living parts of an ecosystem. These cycles ensure that essential nutrients are continuously recycled and available for life.
2. **List the key stages of the water cycle.**
   - Evaporation (and transpiration)

- Condensation
- Precipitation
- Infiltration
- Runoff
- Groundwater flow

3. Explain How does the water cycle contribute to the distribution of water on Earth?

- The water cycle distributes water through various processes, such as precipitation, runoff, and groundwater flow. This ensures that water is replenished in different locations, supporting diverse ecosystems and human activities. It also moves water from oceans to land via evaporation and precipitation.

4. Explain How does carbon dioxide enter the atmosphere?

- Respiration (by plants and animals)
- Decomposition of organic matter
- Burning of fossil fuels
- Volcanic eruptions
- Ocean outgassing

4. Explain How is carbon removed from the atmosphere?

- Photosynthesis (by plants and algae)
- Ocean absorption
- Formation of carbonate rocks

5. Explain Why is nitrogen fixation an important process in the nitrogen cycle?

- Nitrogen fixation converts atmospheric nitrogen (N_2), which is unusable by most organisms, into usable forms like ammonia (NH_3) or ammonium (NH_4^+). This process is essential for making nitrogen available for plant growth and therefore all life.

6. Explain How do humans impact the nitrogen cycle?

- Excessive use of fertilizers, leading to nutrient runoff and eutrophication.
- Burning of fossil fuels, releasing nitrogen oxides into the atmosphere.
- Industrial nitrogen fixation (Haber-Bosch process), increasing the amount of reactive nitrogen in the environment.
- Livestock farming, releasing ammonia.

7. Explain Why is phosphorus an essential element for living organisms?

- Phosphorus is a component of DNA, RNA, ATP (energy molecule), and phospholipids (cell membranes). It is also essential for bone and tooth formation in animals.

8. a) Explain How might a drought affect the water cycle in the local ecosystem?

- Reduced evaporation and transpiration.
- Decreased precipitation.
- Lower groundwater levels.
- Reduced streamflow and drying up of ponds and lakes.

b) Explain how might a drought impact the productivity of the ecosystem?

- Reduced plant growth due to water stress, leading to decreased primary productivity.
- Decreased food availability for herbivores and other consumers.
- Increased risk of wildfires.
- Reduced biodiversity due to habitat loss.

Topic 3.1: Description of biogeochemical cycles

Objectives:

By the end of the topic, trainees will be able to:

a. Describe Biogeochemical cycles appropriately based on their nature

Time Required: 5 hours

Learning Methodology: Group discussion, Trainer guided, Videos, brainstorming and demonstration

Materials, Tools and Equipment Needed: Computer, projector, white board/chalkboard, Flipcharts, papers, wall charts, pictures, Markers, chalks, tutorial videos

Preparation:

- ✓ Brainstorming,
- ✓ Demonstration and simulation,
- ✓ Individual and group work,
- ✓ Group discussion,
- ✓ Documentary research
- ✓ Written assessment,
- ✓ Oral presentation

Cross Cutting Issues:

- ❑ Climate feedback loops driven by nutrient availability.
- ❑ Human disruption of interconnected elemental fluxes.
- ❑ Scale-dependent impacts of biodiversity on cycle resilience.

Prerequisites:

- Understanding basic chemical cycling
- Knowledge of ecosystem structure and function
- Familiarity with fundamental ecological principles

Activity 1: Problem-Solving

Task 19:

- Introduce the **topic 3.1:** Description of biogeochemical cycles
- Provide necessary materials and tools for the task.
- Employing suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, Refer students to the key fact 3.1 and prompt help students to share their answers with the rest of class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session**.**
- After the sharing introduction session and discuss with them together while harmonizing their responses provided in the sharing session and answer any questions they have.
- Instruct the students to answer the asked Questions on biogeochemical cycles under task 19.

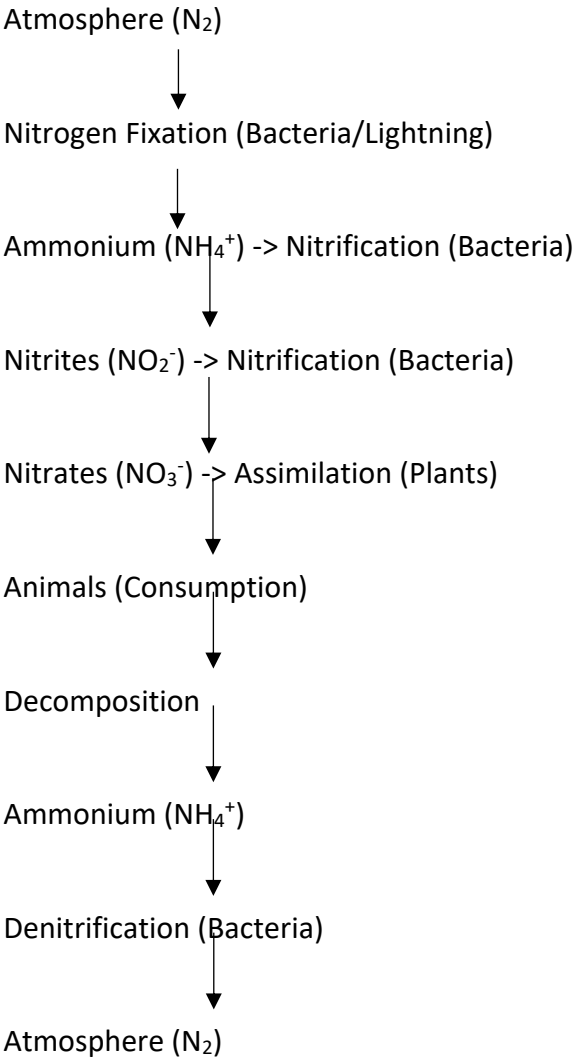
Here below are possible answers:

1. **Define biogeochemical cycles.**
    - Biogeochemical cycles are the natural processes by which elements and molecules essential for life (like carbon, nitrogen, phosphorus, and water) are continuously recycled through the Earth's living (biotic) and non-living (abiotic) components.
2. **Explain the difference between the water cycle and the carbon cycle.**
    - **Water Cycle (Hydrologic Cycle):**
        - Focuses on the movement of water in its various forms (liquid, vapor, ice) through processes like evaporation, condensation, precipitation, and runoff.
        - Primarily involves physical changes of state.

- Emphasis on the distribution and availability of water.

- **Carbon Cycle:**
  - Focuses on the movement of carbon through the atmosphere, oceans, land, and living organisms.
  - Involves chemical transformations, such as photosynthesis, respiration, and combustion.
  - Emphasis on the storage and transfer of carbon, which is crucial for climate regulation.

3. Design a simple diagram illustrating the nitrogen cycle.



4. Analyze the impact of deforestation on the carbon cycle.

- Deforestation reduces the number of trees, which are major carbon sinks.

- Burning of felled trees releases large amounts of CO_2 into the atmosphere.
- Reduced photosynthesis leads to less CO_2 being removed from the atmosphere.
- Soil disturbance can release stored carbon.
- This all contributes to increased atmospheric CO2, exacerbating climate change.

5. **Evaluate the effectiveness of different strategies for reducing human impact on the water cycle.**
    - **Water conservation:** Effective in reducing demand but requires behavioral changes.
    - **Sustainable agriculture:** Reduces runoff and pollution, but implementation can be challenging.
    - **Wastewater treatment:** Crucial for preventing pollution, but requires infrastructure and funding.
    - **Reforestation:** Enhances water retention and infiltration, but requires long-term commitment.
    - **Rainwater harvesting:** Effective at a local level, but limited in scale.
    - The most effective strategies are those that combine different approaches and are tailored to local conditions.
6. **Develop a creative story or poem that explains the interconnectedness of the biogeochemical cycles.**
    - (This requires creative writing. I can provide a short example)
        - "The rain fell soft, a water's gentle sigh,
        - To nourish roots where carbon shadows lie.
        - The leaves breathed deep, a gift of solar grace,
        - While nitrogen flowed, in earth's embrace.
        - A cycle turned, a web of life's design,
        - Where water, carbon, nitrogen intertwine."
7. **List the key stages of the water cycle.**
    - Evaporation (and transpiration)
    - Condensation
    - Precipitation
    - Infiltration

- Runoff
- Groundwater flow

8. Explain the role of decomposers in the nitrogen cycle.

- Decomposers (bacteria and fungi) break down organic matter containing nitrogen (e.g., dead plants and animals, waste).
- This process releases ammonium (NH4+) into the soil, which can then be used by plants or further transformed by other bacteria.

9. Compare and contrast the water cycle and the phosphorus cycle.

- **Water Cycle:**
    - Primarily involves physical changes of state.
    - Has a significant atmospheric component.
    - Relatively rapid cycling.
- **Phosphorus Cycle:**
    - Primarily involves chemical changes in rocks, soil, and water.
    - Lacks a significant atmospheric component.
    - Very slow cycling, primarily through geological processes.
- **Both:**
    - Essential for life.
    - Involve movement through biotic and abiotic components.
    - Can be impacted by human activity.

10. Assess the potential impact of climate change on the biogeochemical cycles.

- **Water Cycle:** Altered precipitation patterns, increased evaporation, more frequent and intense droughts and floods.
- **Carbon Cycle:** Increased atmospheric CO_2, ocean acidification, changes in carbon storage in ecosystems.
- **Nitrogen Cycle:** Increased nitrogen deposition from atmospheric pollution, changes in nitrogen fixation and denitrification rates.
- **Phosphorus Cycle:** Changes in weathering rates, increased nutrient runoff due to altered precipitation.
- Overall, climate change is expected to disrupt the balance of biogeochemical cycles, leading to significant ecological and environmental consequences.

Activity 2: Guided Practice

Task 20:

1. Provide necessary materials and tools for the task.
2. Employing suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session.
3. After the sharing introduction session and discuss with them together while harmonizing their responses provided in the sharing session and answer any questions they have.
4. Instruct the students to Read the scenario into small groups of students and answer all the asked questions related to water cycles and carbon cycles under task 20 in their trainee manual.

Possible answers:

1. What could be causing the issues in Green Valley?

Possible issues and causes:

- **Water Scarcity:**
    - Reduced rainfall due to climate change.
    - Overuse of groundwater for agriculture or industry.
    - Deforestation, leading to decreased water retention.
    - Pollution of water sources.
- **Air Pollution:**
    - Increased fossil fuel combustion from vehicles and industries.
    - Deforestation, reducing carbon sequestration.
    - Agricultural activities releasing methane.

- **Soil Degradation:**
    - Deforestation, leading to erosion.
    - Intensive agriculture, depleting soil nutrients.
    - Pollution from industrial waste.
- **Loss of Biodiversity:**
    - Habitat destruction from development.
    - Pollution, affecting species survival.
    - Climate change, altering species distribution.

2. **Draw a diagram of the water cycle and Carbon Cycle identify specific processes and describe their role in maintaining balance and explain how do human activities impact these cycles?**

- **Water Cycle Diagram:**
    - (Imagine a diagram with these elements)
    - **Evaporation/Transpiration:** Water changing from liquid to vapor.
    - **Condensation:** Vapor forming clouds.
    - **Precipitation:** Water falling as rain/snow.
    - **Infiltration:** Water seeping into the ground.
    - **Runoff:** Water flowing over land.
    - **Groundwater Flow:** water flowing underground.
    - **Human Impacts:**
        - ***Deforestation:*** *Reduces transpiration and infiltration.*
        - ***Pollution:*** *Contaminates water sources.*
        - ***Overuse:*** *Depletes groundwater reserves.*
        - ***Climate change:*** *alters precipitation patterns.*
- **Carbon Cycle Diagram:**
    - (imagine a diagram with these elements)
    - **Photosynthesis:** Plants absorb CO_2.

- **Respiration:** Organisms release CO_2.
- **Combustion:** Burning fossil fuels releases CO_2.
- **Decomposition:** Organic matter releases CO_2.
- **Ocean Absorption:** Oceans absorb CO_2.
- **Human Impacts:**
  - ***Burning fossil fuels:*** *Increases atmospheric CO_2.*
  - ***Deforestation:*** *Reduces carbon sequestration.*
  - ***Agriculture:*** *Releases methane and CO_2.*

3. **Can you think of examples where disruptions to these cycles might affect the environment?**
   - Droughts due to altered water cycles.
   - Increased wildfires due to climate change (carbon cycle disruption).
   - Ocean acidification from increased atmospheric CO_2.
   - Flooding from altered precipitation patterns.
   - Loss of species due to habitat change.
4. **Discuss how activities like deforestation or increased fossil fuel use might disrupt this cycle, affecting Green Valley's ecosystem.**
   - **Deforestation:**
     - Reduces transpiration, impacting local rainfall.
     - Decreases carbon sequestration, increasing atmospheric CO_2.
     - Leads to soil erosion, impacting water quality.
   - **Increased Fossil Fuel Use:**
     - Increases atmospheric CO_2, contributing to climate change.
     - Alters precipitation patterns, impacting water availability.
     - Contributes to air pollution, affecting plant and animal health.
5. **Highlight how the processes connect and impact ecosystems.**
   - The water and carbon cycles are interconnected.
   - Photosynthesis (carbon cycle) relies on water (water cycle).

- Deforestation impacts both cycles, affecting local and global climates.
- Changes in precipitation patterns (water cycle) affect plant growth (carbon cycle).
- The cycles are essential for nutrient cycling, which is essential for healthy ecosystems.

Activity 3: Application

Task 21:

1. Provide necessary materials and tools for the task.
2. Employing suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session**.**
3. After the sharing introduction session and discuss with them together while harmonizing their responses provided in the sharing session and answer any questions they have.
4. Instruct the students to read the paragraph under task 21, analyze the Impact of Biochemical cycles on Nature and Climate and accomplish required assignments.

Trainer's Instruction

- **Activity 1:** In small groups, analyze Biochemical cycles such as diagrams of Water cycle, Carbon Cycle, Nitrogen Cycle and Phosphorous cycle. Each group will present how their evidence supports the description of biogeochemical cycles in Conservation of Nature then answer the following questions:
- **Activity 2:** On the Paper, create Four columns each for the water cycle, carbon cycle, Nitrogen Cycle and Phosphorous cycle. list effects of disruptions to each cycle. What solutions can reduce the negative effects on the water and carbon cycles?
- **Activity 3:** By using a short presentation comparing the water and carbon cycles, their key terms, processes, and effects that helps to connect theoretical concepts to practical applications.

Topic 3.2: Explanation of ecosystem degradation

Objectives:

By the end of the topic, trainees will be able to:

a. Explain clearly the Nutrient cycle, energy Flow and biodiversity Loss in ecosystem

b. Describe correctly the ecosystem degradation referring to natural equilibrium

Time Required: 3 hours

Learning Methodology: Group discussion, Trainer guided, Site visit, brainstorming and demonstration.

Materials, Tools and Equipment Needed: Computer, projector, white board/chalkboard, Flipcharts, papers, wall charts, Pictures, Markers, chalks, tutorial videos

Preparation:

- ❑ Brainstorming, demonstration and simulation, individual and group work, group discussion, documentary research
- ❑ Written assessment, oral presentation

Cross Cutting Issues:

- ✓ Pollution (air, water, soil)
- ✓ Invasive species and Climate change
- ✓ Overexploitation of resources

Prerequisites:

- ➢ Habitat destruction and fragmentation
- ➢ Knowledge of Ecological Stressors

Activity 1: Problem-Solving

Task 22:

1. Introduce the **topic 3.2** Explanation of ecosystem degradation
2. Provide necessary materials and tools for the task.
3. Employing suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session.
4. After the sharing introduction session and discuss with them together while harmonizing their responses provided in the sharing session and answer any questions they have.
5. Instruct the students in their respective group to work on the group project under the task 22, conducting assigned research

Activity 2: Guided Practice

Task 23:

1. Provide necessary materials and tools for the task.
2. Refer students to the key fact 3.2 and prior to the experience from previous task they continue on the following task nº 23
3. Use suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session.
4. Instruct the students for this group project, how identifying the issues and proposing sustainable solutions to restore balance in this ecosystem.
5. **In groups of five: Answer the Guided Task Questions:**

Here below are possible Answers:

1. **What is natural equilibrium, and why is it essential for maintaining ecosystem stability?**
    - **Natural Equilibrium:**
        - Natural equilibrium, also known as ecological balance, refers to a state of dynamic stability within an ecosystem. In this state, populations of organisms, nutrient cycling, and energy flow remain relatively constant over time, with fluctuations occurring within a range of natural variability.
        - It doesn't mean a static unchanging system. Rather it means a system where changes happen, but there is a system of feedback that returns the ecosystem to it's "normal" operating range.
    - **Importance for Ecosystem Stability:**
        - It maintains biodiversity by preventing any single species from dominating.
        - It ensures efficient resource utilization and nutrient cycling.
        - It enhances ecosystem resilience to disturbances, allowing it to recover from natural fluctuations.
        - It supports the provision of ecosystem services, such as clean water and air.
2. **How does nutrient cycling contribute to sustaining ecosystems, and what happens when it is disrupted?**
    - **Contribution of Nutrient Cycling:**
        - Nutrient cycling (e.g., carbon, nitrogen, phosphorus) ensures the continuous availability of essential elements for living organisms.
        - Decomposers recycle organic matter, releasing nutrients back into the soil or water.
        - Nutrient cycling supports plant growth, which forms the base of food webs.
        - It maintains soil fertility and water quality.

- **Disruption of Nutrient Cycling:**
    - **Eutrophication:** Excessive nutrient inputs (e.g., from fertilizers) lead to algal blooms and oxygen depletion in aquatic ecosystems.
    - **Soil Degradation:** Deforestation and unsustainable agriculture can deplete soil nutrients and increase erosion.
    - **Atmospheric Pollution:** Nitrogen and sulfur oxides contribute to acid rain, which alters soil and water pH.
    - Disrupted nutrient cycling decreases the productivity and resilience of the ecosystem.

3. **Explain the stages and types of energy flow in an ecosystem and their significance.**

- **Stages and Types of Energy Flow:**
    - **Solar Energy Capture:** Producers (plants, algae) capture sunlight through photosynthesis, converting it into chemical energy (gross primary productivity).
    - **Respiration:** Producers use some of the captured energy for their own metabolic processes (net primary productivity).
    - **Energy Transfer:** Energy is transferred to consumers (herbivores, carnivores) through food consumption.
    - **Energy Loss:** Energy is lost as heat at each trophic level (second law of thermodynamics).
- **Significance:**
    - Energy flow is unidirectional, starting with the sun and dissipating as heat.
    - It supports the trophic structure of ecosystems, determining the abundance and diversity of organisms.
    - It influences ecosystem productivity and efficiency.

4. **How does population regulation depend on balanced nutrient cycling and energy flow?**
    - **Population Regulation:**
        - Nutrient availability influences plant growth, which in turn affects herbivore populations.
        - Energy availability at each trophic level limits the population sizes of consumers.
        - Balanced nutrient cycling and energy flow maintain stable predator-prey relationships.
        - Disruptions can lead to population imbalances, such as overgrazing or predator decline, causing cascading effects throughout the ecosystem.
        - Populations are regulated through carrying capacity, which is directly linked to the amount of available energy and nutrients.
5. **What are the forms of ecosystem degradation observed, and what solutions can address these issues?**
    - **Forms of Ecosystem Degradation:**
        - **Habitat Destruction and Fragmentation:** Deforestation, urbanization, and agricultural expansion.
        - **Pollution:** Air, water, and soil contamination from industrial, agricultural, and urban activities.
        - **Climate Change:** Altered temperature and precipitation patterns, sea-level rise, and ocean acidification.
        - **Invasive Species:** Introduction of non-native species that disrupt native ecosystems.
        - **Overexploitation:** Overfishing, overhunting, and unsustainable resource extraction.
        - **Desertification:** Degradation of dryland ecosystems.

- **Solutions:**
    - **Protected Areas:** Establish and manage national parks and reserves.
    - **Sustainable Practices:** Promote sustainable agriculture, forestry, and fishing.
    - **Pollution Control:** Implement stricter regulations on industrial emissions and waste disposal.
    - **Climate Change Mitigation:** Reduce greenhouse gas emissions through renewable energy and energy efficiency.
    - **Habitat Restoration:** Reforestation, wetland restoration, and removal of invasive species.
    - **Community Engagement:** Empower local communities to participate in conservation efforts.
    - **Policy and Regulations:** Enact and enforce environmental laws and regulations.

Activity 3: Application

Task 24: In-Class and Outdoor Activity

Activity 1: Form the Group of 4 Students and instruct them to read the statements in their trainee Manuals under the task 24 and answer the asked questions

Here below are possible answers:

1. **What is biodiversity loss, and why is it important to address in ecosystems?**
    - **Biodiversity Loss:**
        - Biodiversity loss refers to the decline in the variety of life forms within a given ecosystem, region, or the entire planet. This includes the loss of species, genetic diversity within species, and the degradation of ecosystems.

- **Importance:**
    - Ecosystem Stability: Diverse ecosystems are more resilient to disturbances and better able to recover from them.
    - Ecosystem Services: Biodiversity provides essential services like pollination, water purification, and climate regulation.
    - Food Security: Many food sources rely on diverse ecosystems.
    - Human Health: Biodiversity is a source of medicines and contributes to overall well-being.
    - Ethical Considerations: Many believe that all species have an intrinsic right to exist.

2. **What are the major causes of biodiversity loss, and how can they be mitigated?**
    - **Major Causes:**
        - **Habitat Destruction and Fragmentation:** Deforestation, urbanization, agriculture.
        - **Pollution:** Air, water, and soil contamination.
        - **Climate Change:** Altered temperature and precipitation patterns.
        - **Invasive Species:** Introduction of non-native species.
        - **Overexploitation:** Overfishing, overhunting, unsustainable logging.
    - **Mitigation:**
        - **Habitat Protection:** Establish and manage protected areas.
        - **Sustainable Resource Use:** Promote sustainable forestry, fishing, and agriculture.
        - **Pollution Control:** Implement stricter regulations and promote clean technologies.
        - **Climate Change Mitigation:** Reduce greenhouse gas emissions.
        - **Invasive Species Management:** Implement control and eradication programs.

- **Restoration Ecology:** Restore degraded habitats.
- **Education and Awareness:** Raise public awareness about the importance of biodiversity.

3. **How do overgrazing, deforestation, and improper agricultural practices contribute to soil degradation?**
   - **Overgrazing:**
     - Removes vegetation cover, exposing soil to erosion.
     - Compacts soil, reducing water infiltration and aeration.
     - Reduces soil fertility by depleting organic matter.
   - **Deforestation:**
     - Removes tree cover, increasing soil erosion.
     - Reduces water retention and increases runoff.
     - Depletes soil nutrients and organic matter.
   - **Improper Agricultural Practices:**
     - Monoculture depletes soil nutrients.
     - Excessive tillage increases soil erosion.
     - Overuse of fertilizers and pesticides contaminates soil and water.
     - Lack of cover crops, and crop rotation, reduces soil health.
4. **What are the impacts of different types of environmental pollution on ecosystems and human well-being?**
   - **Air Pollution:**
     - Acid rain, damaging forests and aquatic ecosystems.
     - Respiratory problems and other health issues in humans.
     - Climate change due to greenhouse gas emissions.
   - **Water Pollution:**
     - Eutrophication, leading to oxygen depletion and fish kills.

- Contamination of drinking water, causing health problems.
- Harm to aquatic organisms and ecosystems.

- **Soil Pollution:**
  - Reduced soil fertility and plant growth.
  - Contamination of food crops.
  - Groundwater contamination.
  - Heavy metal accumulation in organisms.

- **Plastic Pollution:**
  - Entanglement of marine life.
  - Microplastic consumption by animals and humans.
  - Habitat destruction.

5. **What solutions can you propose to balance resource use and reduce biodiversity loss and pollution in this region?**

- **Integrated Land Management:**
  - Promote sustainable agriculture and forestry practices.
  - Implement land-use planning to minimize habitat destruction.
  - Restore degraded ecosystems.

- **Pollution Control:**
  - Invest in wastewater treatment and waste management systems.
  - Promote the use of renewable energy sources.
  - Implement regulations to control industrial emissions and agricultural runoff.

- **Biodiversity Conservation:**
  - Establish and manage protected areas.
  - Promote eco-tourism and community-based conservation.
  - Control invasive species.

- **Resource Efficiency:**
    - Promote recycling and waste reduction.
    - Encourage water conservation and efficient irrigation.
    - Support sustainable consumption patterns.
- **Education and Awareness:**
    - Raise public awareness about the importance of biodiversity and environmental protection.
    - Educate farmers and land managers about sustainable practices.
    - Incentive programs for sustainable practices.
- **Policy and Enforcement:**
    - Enact and enforce environmental laws and regulations.
    - Provide incentives for sustainable development.

Topic 3.3: Application of environmental protection Strategies.

Objectives:

By the end of the topic, trainees will be able to:

a. Discuss effectively the principles of Environmental conservation in maintaining ecological balance

b. Apply environmental protection approaches in accordance with its conservation principles.

c. Control effectively the environmental pollutions according to the wastes categories

Time Required: 2 hours.

Learning Methodology: Group discussion, trainer guided, site visit, brainstorming and demonstration.

Materials, Tools and Equipment Needed: Computer, projector, white board/chalkboard, Flipcharts, papers, wall charts, Pictures, Markers, chalks, tutorial videos

Preparation:

- ❑ Brainstorming
- ❑ Demonstration and simulation
- ❑ Individual and group work
- ❑ Documentary research and presentation

Cross Cutting Issues:

- ✓Emphasis on Preventative Measures
- ✓Community Engagement and Participation
- ✓Interdisciplinary Approaches

Prerequisites:

- ➢ Knowledge of Relevant Environmental Policies and Regulations
- ➢ Understanding of Environmental Impacts

Activity 1: Problem-Solving

Task 25:

1. Introduce the **topic 3.3** Application of environmental protection Strategies.
2. Using various methodologies like individual work, pair-share, or small group discussions, guide trainees to read the scenario provided in the trainee's manual and answer questions on task 25 in their trainee manuals. Ensure that scenario is clear and understood, and that each student actively participates in the activity.
3. Provide necessary materials and tools for the task.
4. Employing suitable methodologies such as question and answer sessions in large groups, or pair and small group presentations, prompt students to share their answers with the class. As they present, write down their responses for future reference. Encourage all students to contribute their perspectives and ideas during the sharing session.
5. After the sharing session, refer students to **Key facts 3.3** and discuss them together while harmonizing their responses provided in the sharing session and answer any questions they have.
6. Instruct students to read the scenario under the task 25 and answer related questions in their Training Manuals

Here are possible answers:

1. **Which agency is responsible for enforcing environmental protection laws in Rwanda?**
    - The Rwanda Environment Management Authority (REMA) is the primary agency responsible for enforcing environmental protection laws in Rwanda.
2. **How do city's laws regulate air quality in the city?**
    - City laws typically regulate air quality through:
        - Emission standards for vehicles and industries.
        - Restrictions on burning waste.
        - Promotion of public transportation and non-motorized transport.
        - Monitoring air quality levels.
        - Promoting green spaces to absorb pollutants.

3. **What measures are in place to protect water resources in Rwanda?**
    - Measures include:
        - Regulations on water abstraction and usage.
        - Protection of wetlands and riverbanks.
        - Wastewater treatment and discharge regulations.
        - Promotion of rainwater harvesting.
        - Protection of water catchment areas.
        - Regulations on activities that can cause water pollution.
4. **Describe the waste management strategies included in environmental framework.**
    - Waste management strategies typically include:
        - Waste segregation at source (recyclables, organic waste, general waste).
        - Promotion of recycling and composting.
        - Controlled landfill management.
        - Regulations on hazardous waste disposal.
        - Public awareness campaigns on waste reduction.
        - Promotion of the "polluter pays" principle.
5. **How do biodiversity conservation laws contribute to protecting wildlife and natural habitats?**
    - Biodiversity conservation laws contribute by:
        - Establishing protected areas (national parks, reserves).
        - Regulating hunting and poaching.
        - Controlling trade in endangered species.
        - Protecting critical habitats like forests and wetlands.
        - Promoting sustainable use of natural resources.
        - Implementing environmental impact assessments for development projects.
6. **What role do urban planning regulations play in ensuring sustainable development?**
    - Urban planning regulations play a role by:
        - Integrating environmental considerations into development plans.
        - Promoting green infrastructure (parks, green roofs).
        - Controlling urban sprawl.

- Ensuring adequate waste management and sanitation.
- Regulating building codes to promote energy efficiency.
- Zoning regulations to prevent environmentally harmful development.

7. **Why is an environmental impact assessment mandatory for major development projects in city?**

- An environmental impact assessment (EIA) is mandatory to:
  - Identify potential environmental impacts of the project.
  - Assess the significance of those impacts.
  - Propose mitigation measures to minimize negative impacts.
  - Ensure that development projects are environmentally sustainable.
  - To provide data to make informed decisions.

8. **What are the potential penalties for violating environmental protection laws?**

- Penalties can include:
  - Fines
  - Closure of businesses or projects.
  - Imprisonment.
  - Restoration orders (requiring the violator to restore damaged environments).
  - Confiscation of equipment.

9. **How do city's environmental protection laws evolve to address new challenges in sustainability?**

- City environmental protection laws evolve through:
  - Regular reviews and updates of existing laws.
  - Adoption of new regulations to address emerging issues (e.g., climate change, plastic pollution).
  - Incorporation of scientific research and best practices.
  - Public consultations and stakeholder engagement.
  - Alignment with national and international environmental agreements.
  - Increased monitoring, and enforcement capacity.

Activity 2: Guided Practice

Task 26:

1. Provide necessary materials and tools for the task.
2. Guide Students to read in Groups the following statements answer the asked questions from their training manual under task 26

Possible answers:

1. **What are the main environmental challenges facing Rwanda today?**
    - Deforestation and habitat loss.
    - Soil erosion and land degradation.
    - Water pollution and scarcity.
    - Air pollution, particularly in urban areas.
    - Waste management issues.
    - Climate change impacts (e.g., increased drought, rainfall variability).
    - Loss of biodiversity.
2. **Name two key environmental protection laws or policies implemented in Rwanda.**
    - The Organic Law Determining the Modalities of Protection, Conservation and Promotion of the Environment.
    - The National Environment and Climate Change Policy.
3. **How does Rwanda utilize protected areas for environmental conservation?**
    - Rwanda establishes national parks (e.g., Volcanoes National Park, Akagera National Park, Nyungwe Forest National Park) to protect biodiversity and critical habitats.
    - These areas serve as sanctuaries for endangered species, promote eco-tourism, and maintain ecosystem services.
    - They are also important for research and education.
4. **What role do community-based conservation initiatives play in Rwanda?**
    - Community-based conservation initiatives empower local communities to participate in environmental management.

- They promote sustainable resource use, reduce poaching and illegal logging, and enhance local livelihoods.
- They foster a sense of ownership and responsibility for conservation.
- They are important for the long-term sustainability of conservation efforts.

5. **How does Rwanda promote sustainable agriculture?**
    - Promotion of terracing and agroforestry to prevent soil erosion.
    - Use of organic farming and integrated pest management to reduce chemical use.
    - Promotion of crop diversification and livestock management.
    - Education and training for farmers on sustainable practices.
    - Promotion of efficient irrigation techniques.
6. **Analyze the effectiveness of Rwanda's reforestation efforts in mitigating soil erosion and climate change.**
    - Rwanda has had very successful reforestation campaigns.
    - Effectiveness:
        - Reforestation has significantly reduced soil erosion by stabilizing slopes and improving water retention.
        - It has increased carbon sequestration, contributing to climate change mitigation.
        - It has enhanced biodiversity and restored degraded habitats.
        - Challenges include ensuring long-term maintenance of planted forests and addressing the root causes of deforestation.
7. **Discuss the challenges and opportunities of integrating environmental protection with economic development** in Rwanda.
    - Challenges:
        - Balancing economic growth with environmental sustainability.
        - Ensuring that development projects are environmentally sound.
        - Addressing the costs of environmental protection.
        - Enforcing environmental regulations.
    - Opportunities:

- Promoting green growth and eco-tourism.
- Investing in renewable energy and sustainable technologies.
- Creating green jobs and enhancing livelihoods.
- Enhancing Rwanda’s reputation as an environmentally responsible nation.

8. **How does Rwanda address the issues of illegal logging and wildlife trafficking?**
    - Strengthening law enforcement and increasing patrols in protected areas.
    - Implementing strict penalties for illegal activities.
    - Collaborating with international organizations to combat wildlife trafficking.
    - Engaging local communities in monitoring and reporting illegal activities.
    - Promoting sustainable forest management.
9. **Evaluate the role of international cooperation and funding in supporting environmental protection** initiatives in Rwanda.
    - International cooperation and funding are crucial for supporting Rwanda's environmental initiatives.
    - They provide financial and technical assistance for conservation projects, capacity building, and research.
    - They facilitate knowledge sharing and technology transfer.
    - They support Rwanda's efforts to meet international environmental obligations.
    - They help to fund projects that Rwanda may not have the budget for.
10. **How can Rwanda effectively communicate the importance of environmental conservation to its citizens and promote greater public awareness and participation?**
    - Integrating environmental education into school curricula.
    - Conducting public awareness campaigns through media and community outreach.
    - Organizing environmental events and activities.
    - Engaging local leaders and community groups in conservation efforts.
    - Using social media and digital platforms to reach a wider audience.
    - Providing incentives for environmentally friendly behaviors.

Activity 3: Application

Task 27:

1. Using an appropriate methodology such as individual work, pairs, or small groups, trainees will read the statement provided on task 27 in the trainees' manual and perform the task. Ensure that all instructions are clear and understood by the trainees, and facilitate active participation among all students.
2. Provide necessary materials and tools for the task to be completed effectively.
3. This activity requires students to work independently with limited support from the trainer. During the task, students should be given a high degree of independence to apply the knowledge, skills, and attitudes acquired to real-life situations. Your role as the trainer is to set clear instructions, methodology, and timeframe for submitting the report.
4. Encourage trainees to utilize the knowledge and skills they have acquired throughout the training program to analyze the scenario critically and develop informed responses.
5. Provide to the students this Statements:
6. The United States employs a multifaceted environmental protection strategy focusing on legislation, innovation, and community action. Key laws like the Clean Air Act and Clean Water Act regulate pollution, while agencies like the Environmental Protection Agency (EPA) enforce standards. Renewable energy initiatives, conservation programs, and climate policies aim to reduce greenhouse gas emissions and protect ecosystems. Public awareness campaigns and partnerships with private sectors foster sustainable practices, ensuring environmental resilience and resource preservation for future generations.
7. Form group of 5 students and facilitate the class activities while create own proposals on environmental protection strategy and Answering the Questions in their training Manuals under task 26.

Here are possible answers:

1. **How does your chosen strategy address the root causes of the environmental challenge?**
    - **Root Causes of Deforestation/Soil Erosion:**

- Unsustainable agricultural practices.
- Demand for fuelwood and charcoal.
- Lack of alternative livelihood options.
- Inadequate land management planning.

- **Agroforestry/Sustainable Land Management Strategy:**
  - A**ddresses Unsustainable Agriculture:** Agroforestry integrates trees with crops and livestock, improving soil fertility, reducing erosion, and diversifying income.
  - **Reduces Fuelwood Demand:** Agroforestry provides a sustainable source of fuelwood, reducing pressure on natural forests.
  - **Creates Alternative Livelihoods:** It offers diverse income opportunities through timber, fruit, and other tree products.
  - **Promotes Better Land Planning:** Encourages land-use planning that incorporates agroforestry and sustainable practices.

2. **What are the potential economic and social benefits of implementing your strategy?**

- **Economic Benefits:**
  - Increased agricultural productivity.
  - Diversified income for farmers.
  - Reduced costs associated with soil erosion (e.g., reduced fertilizer use).
  - Creation of jobs in agroforestry and related industries.
  - Increased value of land.

- **Social Benefits:**
  - Improved food security.
  - Enhanced community resilience to climate change.
  - Improved livelihoods and reduced poverty.
  - Strengthened social cohesion through community-based projects.
  - Improved health due to better nutrition.

3. **What are the potential challenges and risks associated with implementing your strategy?**
    - **Challenges:**
        - Resistance to change from traditional farming practices.
        - Initial investment costs and time required for trees to mature.
        - Lack of access to training and technical assistance.
        - Land tenure issues.
        - Potential for pest and disease problems.
    - **Risks:**
        - Climate variability, which can affect tree growth.
        - Market fluctuations for agroforestry products.
        - Potential for conflicts over land use.
4. **How can you ensure the long-term sustainability of your chosen strategy?**
    - **Community Involvement:** Engage local communities in planning and implementation.
    - **Capacity Building:** Provide training and technical assistance to farmers.
    - **Policy Support:** Implement policies that promote agroforestry and sustainable land management.
    - **Market Development:** Create markets for agroforestry products.
    - **Monitoring and Evaluation:** Regularly assess the effectiveness of the strategy and make adjustments as needed.
    - **Financial Incentives:** Offer subsidies or tax breaks to encourage adoption.
    - **Diversification:** Promote a variety of agroforestry systems to reduce risks.
5. **How can you effectively communicate the importance of your strategy to the Rwandan public?**
    - **Public Awareness Campaigns:** Use radio, television, and social media to disseminate information.
    - **Demonstration Farms:** Establish demonstration farms to showcase the benefits of agroforestry.

- **Community Meetings:** Organize community meetings to discuss the strategy and address concerns.
- **Educational Programs: Integrate** agroforestry and sustainable land management into school curricula.
- **Farmer Field Schools: Provide** hands-on training to farmers.
- **Success Stories:** Share success stories of farmers who have adopted agroforestry.
- **Collaboration:** Partner with local leaders, NGOs, and government agencies to communicate the message.
- **Use of local languages:** Communicate in Kinyarwanda.

Formative Assessment

Section A: Answer all Questions

1. Define the term "evaporation."
2. Describe the role of transpiration in the water cycle.
3. Explain how human activities can disrupt the water cycle.
4. Explain the process of photosynthesis in the context of the carbon cycle.
5. How does the burning of fossil fuels impact the carbon cycle?
6. What are the potential consequences of an imbalance in the carbon cycle?
7. Describe the role of nitrogen-fixing bacteria in the nitrogen cycle.
8. Explain how the use of fertilizers can affect the nitrogen cycle.
9. What is the importance of nitrogen for living organisms?
10. Why is the phosphorus cycle considered as relatively slow cycle?
11. Explain how human activities, such as mining, can disrupt the phosphorus cycle.
12. What are the potential consequences of excess phosphorus in aquatic ecosystems?
13. Explain how predation can act as a density-dependent factor in population regulation.
14. Describe how deforestation contributes to soil erosion.
15. Discuss the potential consequences of soil pollution for human health.

Section B: Answer Only Three (3) Questions of your Choice

1. Explain the "polluter pays" principle and provide an example of its application.
2. Describe the importance of protected areas for biodiversity conservation.
3. Explain how air pollution can contribute to acid rain.
4. Describe the potential impacts of water pollution on aquatic ecosystems.

5. Discuss the importance of waste reduction and recycling in environmental pollution control.

Answers:

Section A:

1. **Define the term "evaporation."**
    - Evaporation is the process by which a liquid, typically water, changes into a gas or vapor. It occurs when molecules in the liquid gain enough kinetic energy to escape from the liquid's surface and enter the atmosphere.
2. **Describe the role of transpiration in the water cycle.**
    - Transpiration is the process by which water is absorbed by plant roots, transported through the plant, and then evaporated from its leaves and other aerial parts into the atmosphere. It plays a significant role in moving water from the soil to the atmosphere, contributing to atmospheric moisture and rainfall.
3. **Explain how human activities can disrupt the water cycle.**
    - Human activities such as:
        - ***Deforestation:*** *Reduces transpiration and increases runoff.*
        - ***Urbanization:*** *Increases impermeable surfaces, leading to increased runoff and decreased groundwater recharge.*
        - ***Over-extraction of groundwater:*** *Depletes aquifers and lowers water tables.*
        - ***Pollution:*** *Contaminates water sources, making them unusable.*
        - ***Climate change:*** *alters precipitation patterns, and increases evaporation rates.*
4. **Explain the process of photosynthesis in the context of the carbon cycle.**
    - Photosynthesis is the process by which plants, algae, and some bacteria use sunlight, water, and carbon dioxide (CO_2) to produce glucose (sugar) and oxygen. In the carbon cycle, photosynthesis removes CO_2 from the atmosphere, storing carbon in organic molecules, thus acting as a carbon sink.

5. **How does the burning of fossil fuels impact the carbon cycle?**
    - Burning fossil fuels (coal, oil, and natural gas) releases large amounts of stored carbon into the atmosphere as CO2. This increases the concentration of atmospheric CO2, contributing to the greenhouse effect and climate change.
6. **What are the potential consequences of an imbalance in the carbon cycle?**
    - Potential consequences include:
        - *Global warming and climate change.*
        - *Ocean acidification.*
        - *Changes in precipitation patterns.*
        - *Increased frequency and intensity of extreme weather events.*
        - *Disruption of ecosystems.*
7. **Describe the role of nitrogen-fixing bacteria in the nitrogen cycle.**
    - Nitrogen-fixing bacteria convert atmospheric nitrogen gas (N2), which is unusable by most organisms, into ammonia (NH3), a form of nitrogen that plants can absorb. This process is essential for making nitrogen available to living organisms.
8. **Explain how the use of fertilizers can affect the nitrogen cycle.**
    - Excessive use of nitrogen-based fertilizers can lead to:
        - *Leaching of nitrates into groundwater, contaminating drinking water.*
        - *Runoff into aquatic ecosystems, causing eutrophication.*
        - *Release of nitrous oxide (N_2O), a potent greenhouse gas, into the atmosphere.*
9. **What is the importance of nitrogen for living organisms?**
    - Nitrogen is a crucial component of:
        - ***Proteins:*** *Essential for building and repairing tissues.*
        - ***Nucleic acids (DNA and RNA):*** *Carry genetic information.*
        - ***Chlorophyll:*** *Used by plants for photosynthesis.*

10. Why is the phosphorus cycle conceded as relatively slow cycle?

- The phosphorus cycle is slow because phosphorus is primarily found in rocks and sediments. It is released through slow processes like weathering and erosion, and there is no atmospheric component to the cycle.

11. Explain how human activities, such as mining, can disrupt the phosphorus cycle.

- Mining for phosphate rock increases the rate at which phosphorus is released from the Earth's crust.
- Excess phosphorus ends up in fertilizers, and then runs off into waterways.
- Deforestation reduces the amount of phosphorus held in biomass.
- These actions move large amounts of phosphorus much faster than natural processes.

12. What are the potential consequences of excess phosphorus in aquatic ecosystems?

- Excess phosphorus can lead to eutrophication, which causes:

- ***Algal blooms:*** *Rapid growth of algae, which block sunlight and deplete oxygen.*
- ***Dead zones:*** *Areas of low oxygen where aquatic life cannot survive.*
- *Loss of biodiversity.*

13. Explain how predation can act as a density-dependent factor in population regulation.

- Predation is density-dependent because predators often focus their hunting efforts on areas with higher prey densities. As prey populations increase, predators have more food available, leading to increased predator populations or hunting success, which in turn reduces the prey population.

14. Describe how deforestation contributes to soil erosion.

- Deforestation removes the protective cover of vegetation, which:

- *Reduces water infiltration.*
- *Increases runoff.*
- *Exposes soil to wind and rain, which can easily erode it.*
- *The root systems that hold the soil in place are removed.*

15. Discuss the potential consequences of soil pollution for human health.

- Soil pollution can lead to:
  - *Contamination of food crops, leading to ingestion of toxins.*
  - *Contamination of groundwater, affecting drinking water supplies.*
  - *Direct exposure to pollutants through skin contact or inhalation, causing various health problems such as respiratory issues, neurological damage, and cancer.*

Section B:

1. Explain the "polluter pays" principle and provide an example of its application.

- The "polluter pays" principle states that those who produce pollution should bear the costs of managing it to prevent damage to the environment.
- Example: A factory that discharges untreated wastewater into a river would be required to pay for the cleanup of the river and any damage caused to aquatic ecosystems. Carbon taxes are another example.

2. Describe the importance of protected areas for biodiversity conservation.

- Protected areas:
  - *Provide habitats for diverse species.*
  - *Maintain ecosystem integrity.*
  - *Protect endangered species.*
  - *Serve as genetic reservoirs.*
  - *Allow for scientific research and monitoring.*

3. Explain how air pollution can contribute to acid rain.

- Air pollutants, such as sulfur dioxide (SO2) and nitrogen oxides (NOx), released from burning fossil fuels, react with water, oxygen, and other chemicals in the atmosphere to form sulfuric acid and nitric acid. These acids then fall to the Earth as acid rain.

4. Describe the potential impacts of water pollution on aquatic ecosystems.

- Water pollution can:
  - *Reduce dissolved oxygen levels, harming aquatic life.*
  - *Introduce toxic chemicals, causing death or disease in organisms.*
  - *Cause eutrophication, leading to algal blooms and dead zones.*

- *Alter the pH of water, affecting sensitive species.*
- *Reduce biodiversity.*

5. **Discuss the importance of waste reduction and recycling in environmental pollution control.**

    - Waste reduction and recycling:

    - *Reduce the amount of waste sent to landfills, minimizing soil and groundwater contamination.*
    - *Conserve natural resources by reusing materials.*
    - *Reduce energy consumption and greenhouse gas emissions associated with manufacturing new products.*
    - *Reduce the amount of pollution created by the extraction of raw materials.*

Points to Remember

- **Biogeochemical Cycles encompasses the movement and transformation of elements (carbon, nitrogen, phosphorous and water) through the Earth's systems.**
- **Biodiversity Loss refers to the decline in the variety of life on Earth at all levels, including species, genetic, and ecosystem diversity.**
- **Natural Equilibrium describes the stable state of an ecosystem where populations, resources, and environmental conditions remain relatively constant.**
- **Environmental Conservation involves the protection and preservation of natural resources and ecosystems to ensure their sustainability for future generations.**
- **Ecosystem Degradation refers to the deterioration of ecosystem health and function, often caused by human activities.**

Self-Reflection

1. Ask learners to re-take the self-assessment at the beginning of the unit. They should then fill in the table in their Trainee's Manual to Identify their areas of strength, areas for improvement and actions to take to improve.
2. Discuss trainees' results with them. Identify any areas that are giving many trainees difficulties and plan to give additional support as needed (ex. use class time before you begin the next learning outcome to go through commonly identified difficult concepts).

REFERENCES:

1. Charles Darwin,1859, "On the Origin of Species" ((at: https://en.wikipedia.org/wiki/On_the_Origin_of_Species)
2. Jerry A. Coyne, January 1, 2008 "Why Evolution Is True" (at: https://www.goodreads.com/book/show/4005310-why-evolution-is-true)
3. Richard Dawkins,1987, Reissue Edition "The Blind Watchmaker"
4. "Ecology and Ecosystem Conservation" by Oswald J. Schmitz https://www.academia.edu/33324897/Ecology_and_Ecosystem_Conservation_Ecology_and_Ecosystem_Conservation
5. James,A., K. J. Gaston, and A. Balmford. 2001. Can we afford to conserve biodiversity? Bio- Science 51:43–52.
6. Lubchenco, J., S. R. Palumbi, S. D. Gaines, and S.Andelman. 2003. Plugging a hole in the ocean:
7. The emerging science of marine reserves. Ecological Applications 13 (supplement):S3–S7.
8. Sinclair,A. R. E., D. Ludwig, and C.W. Clark. 2000. Conservation in the real world. Science
9. "Conservation Biology" by Bradley J. Cardinale, Richard B. Primack, and James D. Murdoch.
10. William Berryman Scott, 2010 "The Theory of Evolution: With Special Reference to the Evidence Upon Which It Is Founded" (at: https://www.amazon.com/Theory-Evolution-Special-Reference-Evidence/dp/1163769029)

RTB | RWANDA TVET BOARD

April, 2025