ENVIRONMENTAL SCIENCE

CLASS XI

Department of Curriculum and Professional Development
Ministry of Education
Thimphu

Published by
Department of Curriculum and Professional Development (DCPD)

Revised edition 2018

Acknowledgment

The development and implementation of Environmental Science in secondary schools in Bhutan is a joint endeavour and collaborative effort. For which, the Royal Education Council (REC) extends sincere gratitude to the National Environmental Commission (NEC), Thimphu and the DiPECHO - Save the Children Comprehensive Disaster Management Project for Bhutan, for providing financial and technical assistance in the development and implementation of the Environmental Science for Class XI and XII.

The REC remains indebted to Mr Changa Tshering, UWICE, Bumthang, for contributing chapters on Phenology and facilitating the integration of Google Apps in learning activities, Doe Doe, National Soil Protection, MoAF, for contribution on Pollution and Toxicology. With their unfailing keen interest and zeal to making the conceptual ideas and learning activities life relevant and meaningful, these two chapters in classes XI and XII are enriched extensively.

We owe our gratitude to all teachers for their sincere and dedicated commitment and diligence on researching and writing, and review of chapters for both the textbooks, without which these textbooks would not have classroom relevance. We acknowledge the timeless sacrifices that each of the writer made with the noble intention of grooming environment friendly young generation.

We extend our sincere acknowledgment to authors, publishers and websites for using information, illustrations and other relevant materials in this textbook. We reaffirm that these resources are for educational purposes only

Advisor

Dasho Chencho Dorji, Secretary, NEC, Thimphu
Kesang Choden Dorji, Director, REC, Paro

Technical experts

Wangpo Tenzin (Curriculum Specialist), Dean, CDC, REC, Paro
Surjay Lepcha, Curriculum Officer, CDC, REC, Paro
Changa Tshering, UWICE, Bumthang

Editors

Sharda Rai, Subject Coordinator, BCSEA, Thimphu
Sonam Pelden, Teacher, Drukgyel CS, Paro
Wangpo Tenzin, Curriculum Specialist, REC, Paro

Illustrations & Lay out design

Sherab Tenzin, Drukgyel HSS, Paro
Surjay Lepcha, Curriculum Officer, REC, Paro

ISBN: 978-99936-0-440-2

Reprint 2022

Contributors of Environmental Science Textbook for Class XI

Panel members:

1. Wangpo Tenzin (Curriculum Specialist), Dean, CDC, REC, Paro.
2. Surjay Lepcha, Curriculum Developer, CDC, REC, Paro.
3. Bhoj Raj Rai, Unit head, STEM, CDC, REC, Paro.
4. Namgay Dema, Programme Officer, BTFEC, Thimphu.
5. Prem Timsina, Nagkor HSS, Pemagatsel.
6. Changa Tshering, UWICE, Bumthang.
7. Tshering Dorji, NEC, Thimphu.
8. Karma Tenzin, PDC, REC

Participants:

1. Tshering Lham, Gongzim Ugyen Dorji Central School, Haa (Group Leader)
2. Nima Dema, Khangkhu MSS, Paro (Group Leader)
3. Tshering Tobgay, Bajothang HSS, Wangduephodrang (Group Leader)
4. Jamyang Drukda, Punakha Central School, Punakha (Group Leader)
5. Karma Wangchuk, Kabesa MSS, Punakha
6. Phuntsho Penjor, Tendruk HSS, Samtse
7. Uma Acharya, Gomtu MSS
8. Jamyang Tenzin, Shari HSS, Paro
9. Karma Choedup, Punakha Central School, Punakha
10. Jigme Tenzin, Dotey LSS, Paro
11. Sonam Tobgay, Gedu HSS, Chukha
12. Pema Lhazin, Zelukha MSS, Thimphu
13. Tshering Zangmo, Punakha Central School, Punakha
14. Tenzin Nima, Jampeling HSS, Kanglung, Trashigang
15. Karma Jamtsho, Nganglam HSS, Pemagatshel
16. Yeshey Nidup, Tshangkha Central School, Trongsa
17. Gyembo, Pelrithang MSS, Gelephu, Sarpang
18. Tshewang Dhendup, Changangkha MSS, Thimphu

FOREWORD

The 21st century presents a new set of challenges to young generation, which calls for contemporary genre of knowledge, skills and attitudes with competencies. The educational processes provide students opportunities to develop those relevant knowledge and competencies crucial to deal with the realities of life, so that they can lead a happy and successful life. Learners are taught to think, understand, integrate, and evaluate diverse situations they face in their lives as the future citizens of the country - politically, socially, culturally and economically. This pre-empts that the education be visionary and future-oriented. Educational innovations, therefore, are an imperative, not an option. The Bhutan Vision 2020 envisages that the school curriculum is diversified so as to provide learners the choice of subjects of their taste and ability, and broaden the career opportunities of children. The environmental science in classes XI and XII is an example of such endeavour.

Besides the social setting challenges, the present generation and the natural world are confronted with numerous natural and human-made emerging environmental issues that impact the existence of humans and the natural world. It is imperative that learners acquire the art of discovering and articulating ways and means of living in harmony in society and with the environment. Opportunities to help them understand and recognize that the quality of our environment determines the long term economic and social health of the country is the epitome of educational process in Bhutan.

Understanding of environmental science and practices of the basic laws of the subject should find link to the tertiary level and transcend to career opportunities for learners. The diverse environmental science learning experiences and opportunities should engender love and care for the natural world in every learner and instill the sense of responsibility of stewardship of the beautiful environment that we live in. Perhaps, this serves as an insurance of transferring the natural wealth intact and healthy as used by the present generation to many future generations.

The Royal Education Council looks forward that teachers and students derive meaningful learning from this textbook and be able to link their learning to the real world in sincerity and diligent practices, guided by the Bhutanese values of Gross National Happiness.

Kesang Choden Dorji
DIRECTOR

Table of Content

Introduction

Environmental Science is the study of environmental systems, the threads of life that every life form is linked with. The study exposes students to fundamentals of physical, chemical, geological, biological, and social processes that interact to shape the environments of the planet that we inhabit. Stemming from this is the holistic understanding of the environmental systems which students gain, promoting them to draw and relate their learning from other disciplines. This helps students to connect various processes in the system together, which is extremely important in treating challenges as a whole and not in isolation.

The study of environmental science relies heavily on applied-learning; hence it equips students with skills and competencies that are necessary to explore, analyse and build knowledge based on various aspects of environment. It engages students in hands on experiences, exposes them to complex challenges, encourages critical thinking, and assists them to develop problem solving skills. Since field studies require students to work together, it promotes the development of teamwork skills and leadership qualities. With this array of skills, environmental science prepares students for a wide variety of career opportunities.

Therefore, the environment science offers an integrated, quantitative, interdisciplinary and students-centered approach. The multidisciplinary nature of the study, integrating physical, chemical, biological and social sciences, guided by the cultural and spiritual belief of human societies brings the holistic perspective making the subject a unique and interesting among the widely taught school courses. It connects the concepts and principles of various sciences to the real life situations and promote the healthy environmental practices.

All the above noble intentions of the subject empowers students to make right choices for sustainable future with global perspectives, and transform them to become responsible and productive citizens of the 21st century world.

Reprint 2022

The Goal

The goal of the environmental science is to build a cadre of young people equipped with knowledge, skills and values to engage them in the conservation of natural heritage, promoting sustainable and equitable use of natural resources, preventing all forms of environmental degradation in the pursuit of GNH.

Objectives

i. To develop knowledge and skills for conserving the natural heritage including rich biodiversity.
ii. To equip students with tools for addressing sustainable production and utilisation, and equitable distribution of natural resources.
iii. To instill positive attitudes and values towards the environment so that students demonstrate environment friendly behaviour in the sustainable management of the environment.
iv. To motivate students to take actions towards environmental conservation and uphold the principles of GNH.
v. To empower students to make right choices for sustainable future with global perspectives and transform them to be responsible and productive citizens in the 21st century world.
vi. To contribute towards the general education of students and prepare them as life long learners.

The Design

The development of environmental science curriculum is guided by six principles as illustrated in Figure 1. These six criteria collectively are essential to students to develop relevant environmental knowledge, skills, values, and attitudes.

i. Environment in totality: The environment integrates almost all disciplines-physical, biological, social, cultural and spiritual. The holistic understanding of the environmental systems is important for students to draw and link their learning from other disciplines, and for them to connect various processes in the system together and not in isolation. The understanding of interrelationships helps students to identify environmental concerns and enables them to assess alternative solutions for resolving the challenges.

ii. Inter-disciplinary: The environmental science, by its nature, contains the concepts and principles from different disciplines such as biology, geography, physical sciences, social sciences, mathematics, history, and economics and so on. The study of environmental science, therefore, needs to provide students with the opportunity to extend their understanding of the disciplines better. Environmental science curriculum, therefore, must draw the essential concepts and principles from these disciplines.

iii. Life long process: Environment is a part of everyday life as people live in it and live by it. There needs to be continuous interaction and interdependence of all living things with each other and the habitat. Environmental science perceives the learning about the environment as a continuous life long process, beginning at the per-school and continuing through formal and non-formal stages, for people to take conscious decisions towards the use, preservation and conservation of the environment.

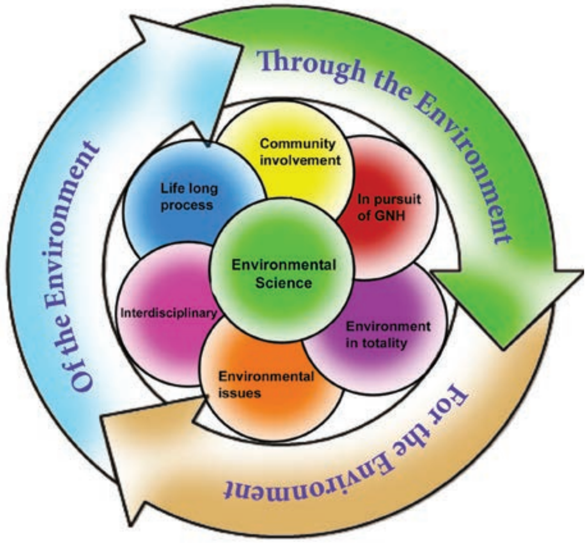


Figure. 1. Principles of Environmental Science Curriculum

iv. Environmental issues-based: The diverse learning context and approaches are crucial for the meaningful learning. Students should explore the natural environment by engaging themselves in hands-on activities, including the laboratory activities, to gain deeper understanding of the issues and concerns. Students should be able to examine major environmental issues from local, national, regional and global spheres with focus on the current emerging environmental situations. The content need to be effectively conveyed when embedded in a local context, giving students a chance to explore and experience what is around them. Effective environmental education should empower students with skills to address environmental issues, with a sense of personal and civic responsibility.

v. Pursuit of GNH: The GNH, which is the country's developmental philosophy accords importance to the environment. Therefore, environmental sciences while deliberating on the elements of the environment need to incorporate the principles of GNH in the delivery process of the content.

vi. Community involvement: It is evident that the local communities are the custodians of the environment and they possess wider knowledge about the local environment passed on through many generations. Communities also play a major role in local environmental conservation. The study, therefore, needs to engage students with the local communities to gain better understanding of the local environment. This understanding should serve as platform to apply to wider context.

The Strands

Strands represent major themes. Strands also show logical flow of learning, starting from the concepts to environmental concerns, to management and to sustainability. The following are the strands for Environmental Science.

- **Strand 1: Systems in Nature**
- **Strand 2: Environmental Issues and Concerns**
- **Strand 3: Natural Resource Management**
- **Strand 4: Sustainable Development**

Strand 1: Systems in Nature

This strand gives the basic understanding of the ecosystem, its structure, and function. Students learn basic concepts like food webs, trophic levels, energy flow, biogeochemical cycles, etc. They learn about the organisation in ecosystems, types of ecosystems, the diversity of flora and fauna, and the adaptations made for survival. They develop an understanding of how an ecosystem functions and its carrying capacity. Students recognise that the components of ecosystems and their interdependency and interactions are critical in maintaining balance in nature. They realise that any imbalance in nature will lead to degradation of environment, and that the Earth's resources are limited.

Strand 2: Environmental Issues and Concerns

From the understanding of balance in ecosystems, students move on to learning about balance in nature, and how the imbalances are created. They understand the interactions of human societies with environment for subsistence, livelihood and luxury. They also realise how human societies over the years have over-harvested the Earth's resources and have interfered in the ecosystem processes creating imbalance in nature. Students study the consequences of imbalance such as the environmental degradation, depletion of natural resources, various types of pollution and how incidences of natural disasters are increasing due to anthropogenic interferences. This strand gives students a feel of the issues and concerns of environment and human relationship with nature.

Strand 3: Natural Resource Management

Students after recognising the issues of environment caused by human actions now move on to learn how to manage the ecosystem and its resources. They understand the meaning of terms like conservation and management. They also are introduced to the ways and methods, including technologies to solve the some of the problems arising out of the human actions. Students learn to respect indigenous knowledge and appreciate traditional practices in the management of natural resources. They also appreciate the steps taken by the government, communities, other institutions and individuals to protect the environment and its resources like biodiversity, soil, land, water, and air. Students are motivated to participate in the activities resulting in the conservation of resources such as energy conservation, soil water management, and waste management. They also learn how their lifestyle affects the environment and increase the ecological foot print. Students realise that they need to change their consumption pattern.

Strand 4: Sustainable Development

Students after learning the conservation and management methods understand the concepts of development, its measurement, indicators, how environment is a part of the development and not an interference. Students appreciate the contribution of natural resources in the development of the country. They realise that human resources are also very important in the growth of the country. Finally, they are presented with the concept of sustainable development and to the understanding that environment , economics and society are the three major pillars needed to sustain any development and they must be seen in totality. Students explore ways to link the sustainable development concepts to GNH, the development philosophy of Bhutan.

Reprint 2022

The perspective across the strands

From local to global

As the learning progresses from local environment to regional to national to global understanding, students realise that the concerns at local level impacts the nation and the world at large. They realise that the actions at the local level is important and they as students can contribute significantly to the process of environmental conservation.

From understanding to action

Since environmental science is application oriented, approaches to its teaching and learning are extremely important. The curriculum recommends development of various skills among students through activity-based approach including indoor, outdoor activities, hands on experiences, experiments, case studies, surveys, debates, discussion, team work, folk art and so on. It encourages teachers to engage students continuously in experimentation, investigation, and project works, designing of different experiments and associated principles, reasoning and arguments with scientific evidence, analyzing and interpreting data to develop coherent knowledge and understanding.

The curriculum emphasizes techniques of focused observation, recognition of a scientific questioning that can be investigated, the need for repeated measurements and skills in devising measurement processes, ways of recording data and representing data for analysis (e.g. understanding 'sample size' in making observations in the field), and reporting.

In the early stages of students' development, the curriculum recommends only the strand 1, which emphasizes the understanding of environment by using all students' senses and appreciate the component of environment and develop a sense of respect towards them. The curriculum does not recommend introduction of any concerns and issues and management related teaching at that level. Once students develop the sense of value, they at the later stages develop concerns towards the natural resources and come forward to take actions for the protection of the natural world.

Assessment

Educational assessment is a process of documenting, usually in measurable terms, the outcomes of knowledge, skills, attitudes and beliefs of students. This includes the processes of gathering and interpreting information about the progress of students' learning. In order to be valuable to individuals and organization, an assessment must be accurate and objective. Students should be well informed about, what will be assessed and how will they be assessed. Teachers can play an important role in students' achievement by effectively monitoring their learning and giving learners the feedback on how they can improve.

Assessment is an integral part of teaching and learning process because it:

i. helps improve students' learning through the provision of feedback and comments.
ii. enables teachers to identify which strategies and resources work best.
iii. empowers students to be self-reflective learners who monitor and evaluate their own progress.
iv. assesses the strengths and weaknesses of students in learning, as well as in the personal development, and identify their special needs and help them to realise their innate talents.
v. guides teachers to incorporate varied teaching and learning strategies and resources to ensure that students are improving their academic learning, as well as, in their personal development.
vi. provides evidences to grade and promote students to the higher level.
vii. helps to inform parents and other stakeholders about the achievements of students.

I. Components of Assessment in Environmental Science

The assessment in environmental science focuses on measuring students' performance and achievements based on the three domains of environmental science learning objectives, which are briefly described below.

i. Content knowledge

Through this domain, learners are assessed on the following areas:

Systems in Nature: students' understanding of physical and ecological systems such as, interdependent relationships in ecosystems; cycles of matter and energy transfer in ecosystems; interaction among Earth's major systems; the roles of water in Earth's surface processes; climate change and the effects of human activities on the Earth's climate; and conservation of energy and energy transfer. This area also includes humans as variables in ecosystems and Earth systems, which includes concepts associated with: the ecosystem services and natural capital on which humans (and all life) depend; adverse human impacts to these systems; and humans as agents in the protection and restoration of these systems.

Environmental Issues and Concerns: students' understanding of a variety of environmental situations that arise from biophysical impacts apparent in the natural world, and the causes and effects of those impacts; knowledge of environmental issues that arise from human conflicts about environmental problems and solutions, including the causes and effects of those conflicts; multiple solutions to environmental issues including knowledge of past, ongoing, and current efforts, as well as the future alternatives, aimed at helping to solve environmental problems; and the legacy of efforts, and both success stories and failures, aimed at solving environmental problems using a number of dimensions from scientific and technical to economic, regulatory or educational efforts.

Natural Resource Management: students' understanding of the limited available natural resources and their classification; causes of natural resources degradation; the forms of citizen participation, action, and community service intended to preserve natural resources, or improve the environment including: restoration projects, consumer and economic action, effective communication strategies, political action, and collaborative solution seeking.

Sustainable Development: students' understanding of the various social, cultural, and political systems, as well as the historical and geographic contexts in which human populations have developed and function; civic participation and the beliefs/practices associated with environmental problem-solving; concepts of development, sustainable development and Gross National Happiness and their measurement and indicators; and roles of environment in sustainable development and Gross National Happiness.

ii. Environmental Processes

Through the domain of environmental processes, students are assessed on the following:

- Identifying environmental issues including the ability to describe and provide evidences for the dimensions of the issue, human disagreements central to it, and factors that cause or contribute to it.
- Ask relevant questions about environmental problems as well as human dimensions and historical or geographical features of an issue. This also includes the ability to ask higher-order questions aimed at discovering conditions that have implications for the issue.
- Analyse environmental issues by interpretation and use of knowledge regarding physical, ecological and socio-political systems, and of information about stakeholders, their positions, beliefs and value perspectives. Also, this includes the ability to determine relevant factors to discern interactions among those factors, and to predict likely consequences of issues.
- Investigate environmental issues by gathering new information about an

issue as well as locating and using relevant sources of additional information, synthesizing, and communicating the outcomes of the investigation.

- Evaluate and make personal judgments about environmental issues by constructing dispassionate evaluations and explanations based on available information and the beliefs and values of stakeholders, and by articulating views about actions that may be warranted. Critical thinking is at the core of this competency.
- Use evidence and experience to defend positions and resolve issues by constructing and defending a sound evidence-based argument about what it will take to resolve or help resolve an issue.
- Create and evaluate plans to resolve environmental issues by assuming the responsibility for acting, frequently with others, and engaging in planning based on the environmental conditions, available resources, and socio-political contexts to resolve or help resolve issues.

iii. Environmental values and attitudes

Through the domain of environmental values and attitudes, students will be assessed on the following attributes:

- Sensitivity, caring and positive feelings towards the environment.
- Attitudes, concern, and world view by responding in a favourable or unfavourable manner towards objects, events, and other referents.
- Personal responsibility, commitment and thoughtful processes that lead individuals to avoid or reduce behaviours that contribute significantly to negative environmental impacts as well as undertake behaviours that contribute significantly to positive impacts.
- The belief and/or feeling that an individual or collectively will be able to influence or bring about the environmental change.
- Motivation, intentions, willingness and verbal commitment to act based on beliefs or attitudes

II. Types of Assessment

The achievement and performance of students in environmental science are assessed through the following schemes of assessment.

Continuous Formative Assessment (CFA)

Formative assessment provides feedback to teachers and students on a continual basis, so that teaching and learning improves through the provision of feedback, and remedial learning opportunities for the needy learners as identified from the assessment. It also enables teachers to understand, which teaching methods and materials work best.

CFA facilitates teachers to diagnose the learning needs of the students, and recognize and understand students' individual differences in learning. The feedback encourages students to reflect on their achievement and performance, by which they are able to understand their strengths and weaknesses.

CFA should happen daily throughout the teaching-learning processes of the academic year. It is not graded, therefore, not reflected in promotion forms and reports to the next level, as it is used only to give continuous feedback to the students.

The techniques and tools for CFA can be seen in the Assessment Matrix, wherein the identified techniques of CFA for each domain are as follows:

Content knowledge: Interview, home work, class work, etc.

Environmental Processes: Class work, observations, project work, etc.

Environmental values and attitudes: Observations of students' conduct guided by environmental and social values.

The tools identified for CFA are **observation checklists** and **anecdotal records**. The sample checklists provided in this book under the assessment tools are only suggestive. Teachers must develop their own checklists for every lesson. Checklist must be maintained for each topic and recorded for future references.

Continuous Summative Assessment (CSA)

Continuous Summative Assessment is another form of continuous assessment. Unlike the CFA, the CSA is to grade student's performance on a continual basis and provide feedback at the same time. It helps in determining the students' achievement and performance and the effectiveness of the classroom instructions. The feedback from this assessment is to help them to improve their learning, and mandates teachers to incorporate varied teaching strategies and resources in ensuring quality teaching and learning in environmental science classes.

The CSA grades students' performances and achievements. This ensures students' active participations in the learning processes.

The techniques and tools for CSA can be seen in the Assessment Matrix, wherein the identified techniques of CSA for each domain are as follows:

Content knowledge:

Teacher is required to check all the home works assigned. Although the home works are given regularly, teacher grades only one of the learners' homework for every chapter using the rubrics. This records the students' achievements at frequent intervals. Chapter-end test is conducted upon the completion of every chapter.

Environmental Processes:

Project work begins at the beginning of the academic year from class 11. It must be assessed at different stages using the rubric. The summative marks for project work should be credited at the end of each academic year. This is to ensure that students undergo all the required processes of the project work and project work is a continual and progressive, not one time activity of each learner as a personal enterprise.

Environmental values and attitudes:

Environmental Profile must be maintained from the beginning of the academic year. It must be assessed at different stages using the rubric. The summative marks for Environmental Profile should be credited at the end of each term. It is a continual and progressive, not one time activity of each learner as a personal enterprise.

The main tools for CSA are: rubrics for homework, Environmental Profile and project work; and pencil paper tests for class test. The scores from the rubrics and paper pencil tests should be converted to the weighting prescribed for each technique for each domain in each term as prescribed in the **Assessment Matrix.**

Summative Assessment

Summative assessment is conducted at the end of a term and at the end of the year to determine the level of learning outcomes achieved by students. The information gathered is used by teachers to grade students for promotion, and to report to parents and other stakeholders.

The identified tools and techniques for SA can be seen in the Assessment Matrix. The questions for the term examinations should cover all the three domains of environmental science learning objectives using the Bloom's taxonomy. Therefore, it mandates teachers to prepare the test **blue print** prior to the setting of questions for the term examinations.

Reprint 2022

<table>
<tr><th colspan="9">Assessment Matrix</th></tr>
<tr><th>Types of assessment</th><th colspan="3">CFA</th><th colspan="3">CSA</th><th colspan="2">SA</th></tr>
<tr><td>Definition</td><td colspan="3">It is a continuous process of assessing student's problems and learning needs; provide feedbacks and to identify the needs for the remedial measures to improve student's learning. It also enables teachers to understand what teaching methods and materials work best.</td><td colspan="3">It is a continuous process of grading student's performances and achievements. Based on their performance, teachers provide feedbacks for improvement. It also enables teachers to understand what teaching methods and materials work best.</td><td colspan="2">Assesses student's cumulative performances and achievements at the end of each term.</td></tr>
<tr><td>Domains</td><td>Content knowledge (CK)</td><td>Environmental Processes (EP)</td><td>Environmental values and attitudes (EV)</td><td>Content knowledge (CK)</td><td>Environmental Processes (EP)</td><td>Environmental values and attitudes (EV)</td><td>CK, EP & EV</td><td>CK, EP & EV</td></tr>
<tr><td>Techniques</td><td>Quiz & debate, self & peer assessment, class presentation, homework, class work, immediate interaction with students.</td><td>Immediate interaction with students, class work, home work, experiments, exhibition, case studies</td><td>Observation of student's conduct, group work, field trip, excursion, self & peer assessment ,immediate interaction with students.</td><td>Class Test.</td><td>Project Work(PW)</td><td>Environmental Profile(EP)</td><td>Term exam.</td><td>Term exam</td></tr>
<tr><td>Assessment Tools</td><td>Q&A, checklist and anecdotal records.</td><td>Checklist and anecdotal records.</td><td>Checklist and anecdotal records.</td><td>paper pencil test (chapter end test).</td><td>Rubrics</td><td>Rubrics</td><td>Paper pencil test</td><td>Paper pencil test with:</td></tr>
<tr><td>Frequency interval (when &how)</td><td colspan="3">Checklists and anecdotal records must be maintained for each topic throughout the academic year.</td><td>Chapter end test – for every chapter.</td><td>Project Work -Single PW for Classes 11 &12 but assessed each year</td><td>Environmental Profile -assessed two times (half yearly)</td><td>Once in a term.</td><td>Once in a year.</td></tr>
<tr><td>Format in Progress Report</td><td colspan="3"></td><td>CK</td><td>EP</td><td>EV</td><td>Mid-Term</td><td>Annual Exam</td></tr>
<tr><td>Weightings</td><td colspan="3"></td><td>T1= 2.5
T2= 2.5</td><td>T1= 5
T2= 5</td><td>T1= 2.5
T2= 2.5</td><td>T1=30</td><td>T2=50</td></tr>
<tr><td>NB:</td><td colspan="8">1. Same mode of assessment will be followed in Mid Term and Trial Examination for class 12.
2. The marks for the Project Work for class 12 is the sum total of Class 11 and 12, which is out of 20 (10+10)marks. It is assessed internally and will be submitted to BCSEA.
3. The Question paper for the BHSCE board examinations for class 12 will be out of 100 marks(Weigthage = 80 marks).</td></tr>
</table>

III. Assessment Techniques and Tools

The following section describes the techniques and tools that are to be used to assess student's performance and achievement.

1. Continuous Formative Assessment (CFA)

The assessment through the CFA is purely to facilitate teachers to take corrective measures in their teaching and use of materials, and provide feedback on the students' learning. No scores are provided like in the CSA. Therefore, it must be continuously used in the regular teaching and learning process by using the suggested tools stated in the Assessment Matrix.

The suggested techniques to assess learners through CFA are as follows:

i. Classwork and Homework

Regular class work and homework given to students to assess their content knowledge, skills, and environmental values and attitudes. Class work is a planned learning activity related to the lesson taught, and is carried out by students in the classroom during the teaching period under the supervision and guidance of the teacher.

Homework is a task given to students to be completed at home. Homework includes problems to be solved, reading to be carried out, writings to be completed or other skills to be practiced. The work given to the students is done on their own. No classroom learning activities should be assigned as a homework.

ii. Quiz and debate

Quiz and debate can be conducted on specific topic to assess student's conceptual knowledge and understanding of environmental issues and concerns and to improve communication. It can be conducted as formal or informal activities.

Quiz and debate as an assessment technique are conducted to:

i. check student's general knowledge in environmental science.
ii. assess students communication and interaction skills.
iii. assess critical and analytical thinking skills.

iii. Group work presentation

Students working in groups provide a context in which individuals help each other to achieve a common goal. Group work provides students a constructive experience of membership in a group and develop to an individual who is able to contribute to the life of the community.

The group work and classroom presentation, as an assessment technique, is prescribed to:

i. assess student's progress in the development of social skills to work as a team.

ii. evaluate their abilities to share responsibilities in carrying out the learning activities.

iii. assess student's ability to respect others views and opinions.

iv. assess student's ability to manage resources in completing the assigned task.

iv. Immediate interaction with students

The teachers' interaction with students is an integral part of the teaching and learning process. It helps in understanding the progress of the students in learning; identify their learning needs; and enhance rapport between teacher and students, crucial in building trust and confidence of learners with teachers.

Immediate interaction with students must be carried out to:

i. assess progress in students' learning and to provide immediate feedback.

ii. assess students' communication skills.

iii. assess students' display of integrity, honesty, critical thinking, and attitudes towards environmental science.

iv. check students' abilities to follow verbal and written instructions.

v. Experiments and exhibition

Environmental science experiment is a scientific procedure undertaken by students to make a discovery, test a hypothesis, or demonstrate a known facts. The environmental science exhibition is a public display or demonstration of scientific skills to enhance learning and as well create awareness on environment. Experiments and exhibition must be carried out to:

i. assess the display of environmental science ideas and concepts of students in the form of models, charts and posters.

ii. assess student's ability to demonstrate the use of environmental processes.

iii. assess student's abilities to relate the environmental science concepts to their life and immediate environment.

iv. assess student's ability to handle equipment with accuracy and safety.

vi. Observation of student's conduct

Observing students carefully helps teacher to know them better. The information derived help teacher to plan, implement, assess and evaluate the teaching and learning process. In the environmental science curriculum, this technique is vital to assess the students' ability to demonstrate the essence of environmental processes and the display of environmental values of critical thinking, honesty, integrity, curiosity, team spirit and intellectual drive in students whether inside or outside the classroom.

Observation of student's conduct, as an assessment technique, is important to:

i. assess student's level of participation in learning activities.
ii. assess student's behavioural conduct with teacher, friends and community.
iii. assess student's ability to handle equipment safely.
iv. check the demonstration of concerns towards oneself, others and environment.

vii. Field trip or excursion

Field trip or excursion is a trip taken by a group of students to a place away from their normal classroom environment. The purpose of the field trip is usually for observation of natural phenomena in the real field for gaining first hand experiences. Field trip or excursion must be conducted as an integral part of environmental teaching and learning process to:

i. assess student's ability to use different tools, conventional or non conventional, to gather information.
ii. assess student's ability to explain the natural phenomena based on the environmental science concepts and ideas.
iii. assess student's level of participation in learning and social activities.
iv. check the demonstration of concerns for oneself, others and environment.
v. assess student's ability to explore and investigate environmental issues and concerns.
vi. assess student's ability to interpret and communicate the field trip findings to their colleagues.

The following suggested tools can be used to assess students, while using the above techniques.

a. Checklist

Checklist is a tool for recording the presence or absence of a characteristic, whether an action is taken or not, or whether learning has taken place or not with 'Yes' or 'No' judgment. In teaching environmental science, teacher makes a listing of environmental concepts that the learners would have learnt; skills that they would have developed; and environmental science values and attitudes that they should exhibit at the end of every topic teaching. Since there is no standard checklist developed, teacher has to develop his/her own checklists for the three domains - Content Knowledge (CK), Environmental Processes (EP), and Environmental science Values and attitudes (EV), as per the topic's learning objectives and learner's learning needs. Therefore, only a sample checklist is provided in this book.

Checklist for continuous formative assessment (CFA) on three assessment domains in environmental science

Sample checklists: Content Knowledge (CK)

Sl no	Class:	Content knowledge (CK) Topic: Ecosystem - organisation and types					
	Key: √- Yes X- No Learning objectives Name:	Explains ecosystem	Describes biome, niche and ecology	Describes levels of ecosystem	Explains the role of components and interactions in an ecosystem	Recognizes habitats, dominant plants and animals	Comments
1	Tshering						
2	Wangmo						

Sample checklists: Environmental Processes(EP)

Sl no	Class:	Environmental processes (EP) Topic: Ecosystem - organisation and types							
	Key: √- Yes X- No Learning objectives Name:	Follows the activity instructions correctly.	Participates actively in group activities.	Records the observation appropriately.	Identifies the raw materials needed for exploring ecosystem	Records all the biotic and abiotic components of ecosystem	Has a ability to use observations to answer the questions in the learning activities	Displays ability to collect relevant photographs, notes and information experiments.	Comment
1	Choeki								
2	Jigme								

Sample checklists: Environmental science values and attitudes (EV)

Sl no	Class :	Scientific values and attitudes (SV) Topic: Ecosystem - organisation and types						
	Key: √- Yes X- No Learning Objectives Name:	Respects others views in the group discussion.	Shares responsibilities in carrying out activity.	Shows cooperation in group discussion and activities.	Demonstrates willingness to learn and try new things.	Exhibits concerns for self, others and environment.	Demonstrates curiosity to learn more on the topic.	Comments
1	Tashi							
2	Zomba							

b. Anecdotal records

Anecdotal records are used to assess student's learning, which is not identified by other assessment tools. Anecdotal records are written descriptions of casual, or focused observations made on students. They are a brief description of incidents and behaviours that offer the teacher a way of assessing and recording the aspects of student's learning. It can be used in a more directed way when teachers want to collect information on particular areas such as social development, work habits, aspects of language use, and the children's development as environmental science learners.

Anecdotal records are usually collected in an exercise book or a folder. Record should include the following entries:

- Name of the student observed, class, and the date and time.
- Observation areas may include individual student's behaviours, skills, and attitudes in relation to outcomes of the study programmes.
- Setting can be either in group or individual.
- Record the observations with comments to share with students and parents.

c. Questions and answer

Asking question is a natural feature of teacher's interaction with students in the class in assessing mainly the content knowledge of the students. Therefore, questioning is crucial to the way teachers manage the class, and engage students in content learning, encourage students participation in enhancing their understanding. Asking question is widely used as an assessment tool in the teaching and learning process. Questioning may be in the form of:

i. verbal questioning
ii. written question
iii. interviews
iv. self assessment questionnaires

2. Continuous Summative Assessment (CSA)

The techniques to assess students through CSA are as follows:

i. Chapter end test

A pencil and paper test is conducted at the end of each chapter. This is mainly to assess the student's conceptual understanding of the topic. It is important to balance the items selected for the test to include questions involving concepts, skills, values and attitudes.

The chapter end test must be conducted for every chapter, and necessary feedback provided for students to improve their learning. The teacher should maintain the record of marks obtained by individual student for every chapter end test conducted. The cumulative marks of the chapter end test are then converted to actual marks assigned to chapter end test at the end of each term and reflected in the student's progress report.

ii. Environmental profiles (EP)

An environmental profiles is a formal written record of facts of phenomenon and incidents that occurred, local or global, along with personal thoughts, experiences, observations and critical analysis of the situation. Environmental profile entries can be about natural disaster or hazards, environmental degradation, mining, campaigns, climate change, green movements and policies, etc. The entries should contain adequate photographs, illustrations, facts and figures to supplement and strengthen the entries. Student's personal thoughts, opinions and conclusions should also find a place in the entries. This type of writing tends to be insightful in nature, allowing students to reflect on the content, as well as make a critical analysis of the situation of the events as in, "Thinking is the method of intelligent learning". Environmental profile will eventually be the archive of past, containing the events of present and global future goals on environment.

Why keep an environmental profile?

The use of environmental profile is important for many reasons. Through this, students are provided with opportunity to model the data collection forms that researchers use. Secondly, it is to provide means of reference and resource for students throughout the year. Thirdly, the environmental profiles are also a great communication tool of students with teachers to create awareness on environment. Lastly, it provides student the opportunity to "expand minds" as opposed to "training minds" through critical analysis experiences.

Therefore, the environmental profiles expect students to document their observations about the environmental science concepts, events and phenomenon that have occurred or may occur in the locality, country, region or in the world. It also serves as an informal assessment to determine what the students have understood. Environmental profile provides a meaningful writing assignment for children, allowing them to improve their writing skills.

Although there are no rules or limits to environmental profiles, below are some useful tips that can help student get the most out of keeping an environmental profiles.

Reprint 2022

Student:

i. uses a blank notebook that is acid-free for long-life.

ii. writes whatever he or she feels most comfortable with – a favourite pen, pencil, marker, coloured pencils, or other writing instrument.

iii. writes down the date on the top of the page.

iv. records and describes any event or incident which have relevance to environmental science that he or she has heard or watched television, radio, or read in books, Internet, journals or magazines. Such as, earthquake in Japan, Forest fires in Mongar , Rio Summit, introduction of electric vehicles in Bhutan, Protect White Bellied Heron Project, etc. Description may include facts and figures, causes, measures taken, response capacity and policies in place.

v. makes sure he or she has conducted further research of the event, and ensures that there is enough and reliable information, data, evidences and materials before making any entry.

vi. writes the significance of the entry of his or her thoughts, critical analysis and conclusion with evidences drawn from information of the entry, and proposes recommendations.

vii. focuses entries on environmental concepts and skills for real life events or phenomena and incidents.

viii. adds variety to entries and avoid long textual information, rather considers drawing, illustrations, charts, tables, photographs to convey message more effectively.

The maintenance of environmental profiles can facilitate teachers to assess the display of scientific skills and values and attitudes by students. Therefore, teacher must ask students to maintain environmental profiles from the beginning of the year. But, teacher should have a schedule to collect them periodically to provide regular feedback to ensure that students make entries throughout the year rather than filling up at the end of the year. Environmental profiles should be assessed by using the rubrics suggested here.

Criteria for the Environmental profile

Name	Criteria					Total marks (20)
	Format (4)	Background research on the event (4)	Analysis(4)	Critical and creative thinking skills (4)	Presentation & Content (4)	
Yeshi						

Rubric for Environmental profile

Criteria	Scoring				Total score	Tr.'s remarks
	4	3	2	1		
Format	Proper format has been followed for all of the entries.	Proper format has been followed for most of the entries.	Proper format has been followed for few of the entries.	Proper format has not been followed for any of the entries.		
Background research on the event	Research is thorough and specific. All the ideas are clearly explained	Research is thorough but not specific. Most ideas are explained.	Research is not thorough and not specific. Few ideas are explained..	Research not thorough and ideas are not explained.		
Analysis	Conclusion and recommendations are supported by data & evidences. Reflection of why event happened and how we could prevent are explicitly explained	Conclusion and recommendations are supported by limited data & evidences. Reflection of why event happened and how we could prevent are well explained	Conclusion and recommendations are not supported by data & evidences. Reflection of why event happened and how we could prevent are explained	Conclusion and recommendations are not supported by data & evidences. Reflection of why event happened and how we could prevent are poorly explained		
Critical and creative thinking skills	Uses critical and creative thinking skills with a high degree of effectiveness	Uses critical and creative thinking skills with considerable effectiveness	Uses critical and creative thinking skills with moderate effectiveness	Uses critical and creative thinking skills with limited effectiveness		
Presentation & Content	Work is thorough, clear, and legible for all entries. Student has included all relevant illustrations, data and ideas	Work shows an adequate amount of work for each entry and is legible. Student has included some relevant data & illustrations.	Work shows some work, but it is inadequate. Student has not included relevant illustrations and data.	Work shows very poor work, poor handwriting, and no illustrations, data or ideas		

Teachers can adapt the above format to suit their needs, based on the learning objectives that the teacher wishes to pursue through different teaching and learning activities.

iii. Project Work

An environmental science project presents a study of a problem with an objective to find a solution to a problem. It involves defining the problem, making hypothesis, observation, collection of data through survey or experimentation, analysing and then arriving at a conclusion to find out the solution. An important aspect of this experimentation involves identifying variables and, where possible, controlling them. It is an adventure that takes time, planning research, preparation, and lots of hard work. However, during the process students discover a great deal about themselves, as well as, about environmental science.

Reprint 2022

An environmental science project is a unique way for students to pose questions for which they must seek answers to satisfy their own curiosity about the world around them. Curiosity begins with questions and when they have questions, they seek answers. It is also an adventure into the world of scientific research that goes beyond their classroom and books. An environmental science projects are one of the most interesting assignments at school.

Why do environmental science project work?

The reason to do a environmental science project is that it is fun and students learn something they did not know about before. Working on an environmental science project can be one of the most exciting adventures students will ever have, as it allows students to be the expert and demonstrate the results and findings of their investigations. They not only perform experiments and investigations with their chosen research area, but they also explore for new ideas, use of new equipment, handling of new techniques, and learn about the principles of environmental science. As they carry out the things, students learn about the world in which they live.

Creating a environmental science project helps students put into practice the concepts learnt in science, mathematics, economics, geography, etc. Most importantly, an environmental science project represents their efforts of investigation into some area they found interesting. Through the development of a project, students gain a first-hand appreciation of the work of environmentalists and the value of their contributions. Students also get opportunities to play the role of environmentalist in coming up with an experiment, execution, presenting it to their class and reporting on the results.

An environmental science project is one of the best opportunities to face the challenges that may be faced in real life when they want to start their own business or get a job. Environmental science project is not of inventing equipment, devices or gadgets. Students must gather as much information as they can, and get as much help as needed. Following are some of useful steps that students may follow.

1. Select a environmental science project

The first step in doing a environmental science project is selecting a topic or a subject. Teachers allow students select subject or topic of their interest; however, teachers guide and approve the topic before they start project. Make a list of the most probable project ideas and select one idea that might be the best and interesting.

Reprint 2022

2. Gather background information

Gather information about the topic from books, magazine, Internet, people and companies. Students keep notes from where they got the information.

3. Identify variables

When students think about what variables may be involved; think about ways to change one at a time. If students change more than one variables at a time, they will not know what variable is causing the observation. Sometimes variables are linked and work together to cause something. At first, students try to choose variables that they think act independently of each other.

4. Write hypothesis

Based on the gathered information, make an educated guess about what types of things affect the system. Identifying variables is necessary before students can make a hypothesis. Hypothesis must be in the form of statement. For example, vehicular pollution causes acid rain.

5. Design an experiment or observation method

Devise the method of the observation or design an experiment to test the hypothesis. Students make a systematic list of what they will do or observe to answer each question. This list is known as an experimental or observational procedure. For observations or an experiment to give answers an experimental "control" is set. A control is a neutral "reference point" for comparison of what changing variable does with the variables without any change. Dependable controls are sometimes very hard to develop. They can be the hardest part of a project. Without a control, one cannot be sure what variable causes observations.

6. Write a list of material

Make a list of materials useful to carry out the experiment or observations.

7. Write the experiment results

Experiments are often done in series. A series of experiments can be done by changing one variable at a time. A series of experiments is made up of separate experimental "runs." During each run, students make a measurement of how much the variable affected the system under the study. For each run, a different amount of change in the variable is used. This produces a different amount of response in the system. Students measure this response, or record data in a table for this purpose. A series of observations of natural phenomenon at different intervals and conditions gives a good data. The data from experiments and observations are considered as a "raw data" since it has not been processed or

Reprint 2022

interpreted yet. When raw data is processed mathematically, for example, it becomes results.

8. Write a summary of the results

Summarize what happened. This can be in the form of a table of processed numerical data, or graphs. It could also be a written statement of what occurred during experiments. It is from calculations using recorded data that tables and graphs are made. Studying tables and graphs, one can see trends that tell about how different variables vary observations. Based on these trends, one can draw conclusions about the system under the study. These conclusions help to confirm or deny the original hypothesis. Often, mathematical equations can be made from graphs. These equations allow to predict how a change will affect the system without the need to do additional experiments. Advanced levels of experimental science rely heavily on graphical and mathematical analysis of data. At this level, science becomes even more interesting and powerful.

9. Draw conclusions

Using the trends in the experimental data and experimental observations, students try to answer the original questions. Is the hypothesis correct? Now is the time to pull together what happened in the form of conclusion, and assess the experiments students did.

10. Write a report on the project

Having completed all the steps of experiment and investigation with appropriate results and conclusion drawn, the last thing is to write a report. The report should start with an introduction on the topic related to the hypothesis, purpose of the study, literature review, methods used, findings, and conclude with conclusions. Do not forget to acknowledge the support provided by all individuals and organizations. Write a bibliography to show references in any form. Such information includes the form of document, name of writer, publisher, and the year of publication.

Project work, therefore, is one of the best ways to practice the application of conceptual ideas and skills. The very purpose of including project work is to provide opportunity to explore and extend knowledge and skills beyond the classroom. Students learn to organize, plan and piece together many separate ideas and information into a coherent whole. Through project work, students learn various techniques and skills including data collection, analysis, experimentation, interpretation, evaluation and drawing conclusion. Thus, project work fosters positive attitude towards environment and its study.

Reprint 2022

Criteria for project work assessment

Name	Criteria						Bibliography (4)	Total scores (28)
	Problem and hypothesis (4)	Background research on the hypothesis (4)	Experimental design / materials / procedure (4)	Investigation (4)	Analysis (4)	Format and editing (4)		
Nima								
Dawa								

(Name & signature of HOD) (Name & signature of Subject Teacher)

Rubrics for project work assessment

Name:........................... Roll no:..................... Class/sec:.......................

Criteria	Scoring				Total Score (28)	Remarks
	4	3	2	1		
Problem and hypothesis	Problem is new, meaningful and well researched. Hypothesis is clearly stated in the "IF... THEN" format.	Problem is not new but meaningful. Hypothesis is clearly stated.	Problem is stated but not new and so meaningful. Hypothesis is not clearly stated.	Problem is not stated and Hypothesis is unclear.		Class 11
Background research on the hypothesis	Research is thorough and specific. All the ideas are clearly explained.	Research is thorough but not specific. Most ideas are explained.	Research is not thorough and not specific. Few ideas are explained.	Research not thorough and ideas are not explained.		
Experimental design / materials / procedure	Procedure is detailed and sequential. All materials are listed. Safety issues have been addressed.	Procedure is detailed but not sequential. Most materials are listed. Safety issues have been addressed.	Procedure is not detailed and not sequential. Few materials are listed. Few safety issues have been addressed.	A few steps of procedure are listed. No materials are listed. Safety issues were not addressed.		
(Name & signature of HOD)		(Name & signature of Subject Teacher)		Total Score for Class 11		
Investigation	Variables have been identified, controls are appropriate and explained. Sample size is appropriate and explained. Data collected from at least 4 sources.	Variables have been identified and controls are appropriate but not explained. Sample size is appropriate. Data collected from at least 3 sources	Variables have somewhat been identified, controls are somewhat known. Sample size is not appropriate. Data collected from at least 2 sources.	Missing two or more of the variables or the controls. Sample size is not considered. Data collected from only 1 source.		Class 12

Criteria	Scoring				Total Score (28)	Remarks
	4	3	2	1		
Analysis	Conclusion is supported by the data. Explanation is made for how or why the hypothesis was supported or rejected. Reflection of what was learned and how it could be made better is made.	Conclusions are supported by the data. Not enough explanation is made for how or why the hypothesis was supported or rejected. Reflection of what was learned and how it could be made better is made.	Conclusions are not supported by enough data. Not enough explanation is made for how or why the hypothesis was supported or rejected. Reflection of what was learned and how it could be made better is not clear.	Conclusions are not supported by data. Not enough explanation is made for how or why the hypothesis was supported or rejected. Reflection of what was learned and how it could be made better is not stated.		
Format and editing	Correct format followed throughout. Report is free of errors in grammar, spelling or punctuation.	Only one aspect of format is incorrectly done. Report contains a few errors in grammar, spelling, and punctuation.	Only two aspects of format are incorrectly done. Report contains some errors in grammar, spelling, punctuation	Three or more aspects of format are missing or incorrect. Report contains many errors in grammar, spelling, and punctuation.		
Bibliography	Five or more references are cited in APA format and referenced throughout the paper and presentation.	Three or four references are cited and referenced throughout the paper and presentation.	One or two references are cited and referenced throughout the paper and presentation.	No references made.		
(Name & signature of HOD)		(Name & signature of Subject Teacher)		Total Score for Class 12		
				Grand Total		

The suggested format for Project Work write-up (report) shall include the following aspects:

- The title of the project work.
- Acknowledgment: Show courtesy to thank the people and organisations for the help received.
- Table of content.
- Introduction: What is the topic about, and why was the topic chosen? Hypothesis, research question.
- Background information: Scientific concepts, principles, laws and information on the topic.
- Methodology: Methods of data collection – sampling, tools used, etc., data sorting.
- Data analysis: Data tabulation, data processing, findings, etc., presented in a logical order with illustrations, photographs, and drawings where appropriate and necessary to support the findings.
- Conclusion: Reflection of the findings, learner's experiences and opinions

regarding the project.

- Bibliography: List of the sources of the information

Teachers can adapt the above format to suit their needs based on the learning objectives teachers wish to pursue through different teaching learning activities

3. Summative assessment

The techniques and tools for assessment through summative assessment (SA) are the term examinations and the end of year examinations. In SA, students are graded and marks reflected in the student's progress report. The main purpose of the assessment through SA is to assess student's conceptual knowledge, understanding of the environmental processes, and the inculcation of values and attitudes in environmental science learning.

The tools used in SA are test blue print and pencil paper test. The pencil paper test may include variety of questions, such as multiple choice questions, fill in the blanks, matching, true or false, short answer questions, extended response questions, etc. These questions will test the competencies of students in the three domains of assessment. The questions cover varying levels of difficulty guided by the principle of Bloom's taxonomy.

Chapter-wise time allocation and weighting

Chapters	Chapter title	Maximum time required (mins)	Weighting (%)
Chapter 1	Structures and Functions of Ecosystem	437.5	7%
Chapter 2	Balance of Nature	625.0	10%
Chapter 3	People and Environment	375.0	6%
Chapter 4	Natural Resource Degradation	250.0	4%
Chapter 5	Pollution:	562.5	9%
Chapter 6	Climate Change:	687.5	11%
Chapter 7	Disaster and Environment	375.0	6%
Chapter 8	Biodiversity and its Measurement	625.0	10%
Chapter 9	Biodiversity Conservation	375.0	6%
Chapter 10	Water and Land Management	625.0	10%
Chapter 11	Energy Conservation	312.5	5%
Chapter 12	Development and Environment	375.0	6%
Chapter 13	Sustainable Development	625.0	10%
Total		6250.0	100%

The total time required to complete the topics is 6250 minutes or 125 periods of 50 minutes in a period.

Reprint 2022

CHAPTER 1

Structures and Functions of Ecosystem

Everything in the natural world is connected in a self-sustaining system called ecosystem. An ecosystem is a community of living and non-living things that continuously work together. Ecosystem can be as large as a forest, or as small as a tree or a log.

A healthy ecosystem is one that has a high species diversity supported by favourable physical conditions. Every species has a niche in its ecosystem that helps to keep the system healthy. Generally, a healthy ecosystem can endure anthropogenic activities and natural calamities.

1. Spheres of the Earth

Learning Objectives

On completion of this topic, you should be able to:

- explain the characteristic features of spheres of the Earth.
- explain the roles of the spheres on the health of the ecosystems.
- relate the health of an ecosystem to interactions within the Earth's spheres.

Earth is a complex system consisting of various interacting subsystems (spheres) namely, atmosphere, hydrosphere, lithosphere and biosphere (Figure 1.1). These spheres interact physically, chemically and biologically to support all life forms.

Figure 1.1. Spheres of the Earth

A. Atmosphere

The atmosphere is the blanket of gases that surrounds the Earth. The major constituents of atmosphere are nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_2) and water vapour (H_2O) as shown in Table 1.1. The atmosphere also contains traces of inert gases, such as helium (He), neon (Ne) and argon (Ar). The oxides of nitrogen (NOx), ammonia and methane are also present in the atmosphere.

Reprint 2022

Table 1.1. Composition of major constituents of the atmosphere and their roles.

Major Constituent of Atmosphere	% Composition by Volume	Roles in the Ecosystem
Nitrogen (N_2)	78.09	N_2 is important for protein synthesis. It reduces the harmful effects of pure oxygen (eg. combustion and breathing).
Oxygen (O_2)	20.98	Oxygen forms ozone that protects the Earth from harmful effects of ultraviolet radiation. It supports combustion or burning. Aerobic life forms use oxygen to carry out cellular respiration.
Water vapour (H_2O)	~ 4-0.2 (at 3^0C- 4^0C)	It regulates Earth's climate and weather conditions.
Carbon dioxide(CO_2)	0.032	Autotrophs use CO_2 as raw material for photosynthesis. CO_2 causes greenhouse effect that helps to maintain the average temperature of the Earth.

The earth's atmosphere is divided into four major layers based on the difference in temperature, pressure and density of gases present in it as shown in Figure 1.2 and Figure 1.3.

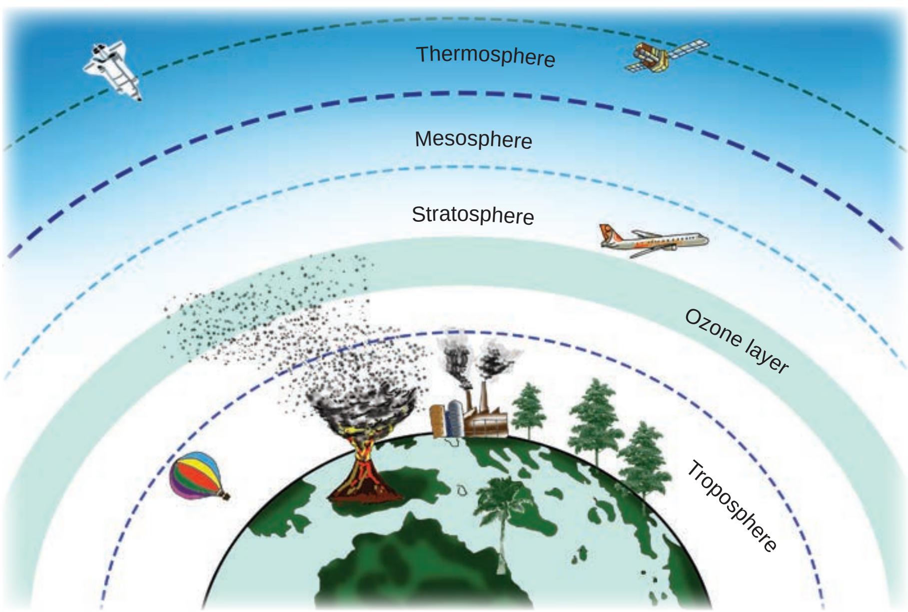


Figure 1.2. Four major layers of atmosphere

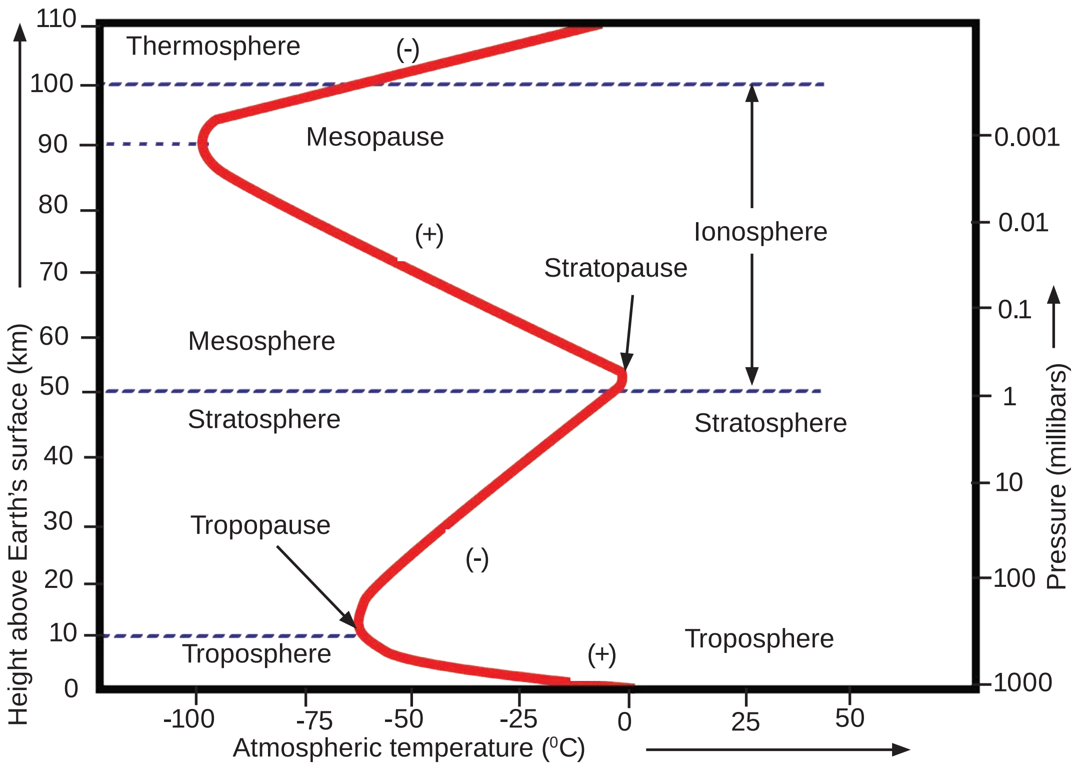


Figure 1.3. Atmospheric layers showing the change in temperature and pressure.

i. Troposphere

Troposphere is the layer nearest to the Earth, extending to a height of about 12 km from the surface. It is the region of strong air currents and cloud formation because of which it is also referred to as a turbulent zone. There is a thin "shock absorber" zone between the troposphere and the next layer (stratosphere) called the tropopause, a zone of transition between the two layers. Troposphere is the most important zone of the atmosphere for life since it contains oxygen and nitrogen. This region also consists of water vapour and clouds responsible for precipitation. The composition of air in the troposphere remains more or less constant, provided there is no significant air pollution. However, the amount of water vapour varies diurnally, seasonally and geographically. The air and water current influence the distribution of precipitation in space and determine the kinds of weather the place experiences.

The fall in pressure and density of the air causes the decrease in temperature in the troposphere. It steadily decreases from ground temperature of about 15°C to about -56°C. This change in temperature is known as lapse rate. The decrease of temperature with increasing height in the atmosphere is called positive lapse rate, while increase in temperature with increase in height is called negative lapse rate. The lapse rate is zero when the temperature is constant with change in height. Water vapour present in the troposphere regulates the air temperature because it absorbs radiation from the Sun and thermal radiation from the Earth's surface.

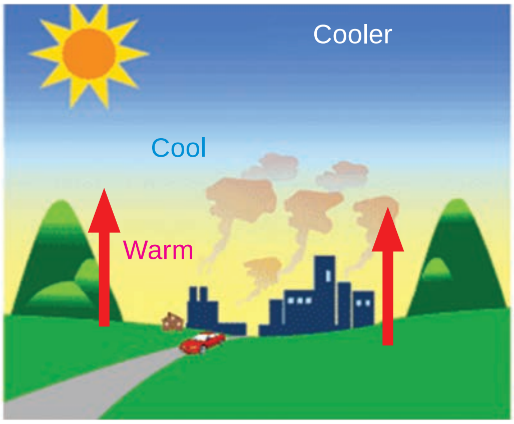


Figure 1.4 (a). Normal temperature pattern

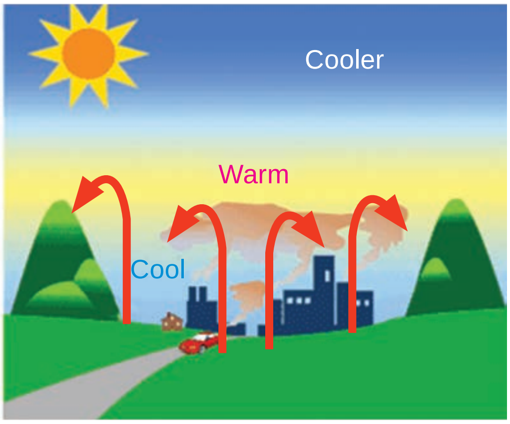


Figure 1.4 (b). Temperature inversion

The warmest sections of the troposphere are found at the lowest regions. This is because the Earth's surface absorbs the Sun's heat and radiates it back into the atmosphere. So, the temperature in tropospheric layer usually decreases with altitude, which is a normal pattern. However, depending on the wind current and the mountain ranges, there can be increase in temperature with altitude. This is called temperature inversion (Figure 1.4 (b)). Temperature inversion is defined as the reversal of the normal behaviour of temperature in the troposphere in which a layer of cool air at the surface is covered by a layer of warmer air.

ii. Stratosphere

The stratosphere is the second layer of Earth's atmosphere. It is located between the troposphere and the mesosphere and extends from about 12 km to 50 km. Stratosphere contains nitrogen, oxygen and small amount of water vapour. In stratosphere, the temperature ranges from -56°C to -2°C. This layer is rich in ozone (O_3).

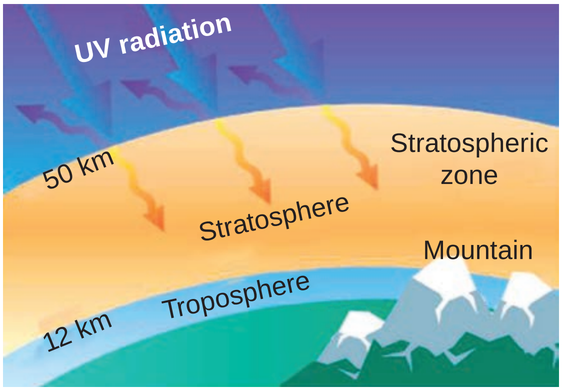


Figure 1.5. Stratosphere absorbs UV rays

Reprint 2022

Ozone (O_3) is a naturally formed colourless gas made up of three atoms of oxygen (O). It forms a thin shield which protects life on the Earth from the Sun's ultraviolet (UV) radiation. Thus, it is also referred to as the Earth's sunscreen.

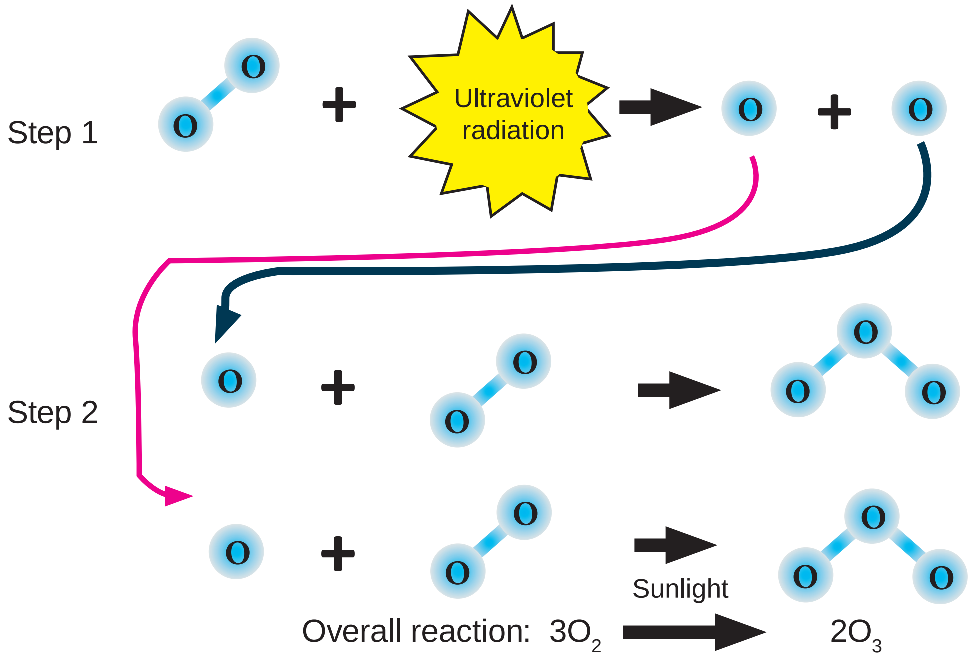


Figure 1.6. Formation of ozone

Ozone initiates chemical removal of many pollutants, such as carbon monoxide (CO), nitrogen oxides (NO_x) and greenhouse gas like methane (CH_4). The absorption of UV-B radiation by ozone is a natural source of heat in the stratosphere, causing temperatures to rise with altitude. This temperature affects the balance of ozone production and destruction processes and air motions in the stratosphere.

Ozone depletion is the destruction of the stratospheric ozone layer. Ozone gets depleted due to the presence of ozone-depleting substances (ODS), such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons, methyl bromide, carbon tetrachloride, and methyl chloroform. Decomposition of these ODS releases gases like chlorine, bromine and fluorine.

$$CFCl_3 + \text{UV Light} \longrightarrow CFCl_2 + Cl$$

Chlorine becomes actively involved in the process of destruction of ozone as shown in the given reaction:

$$Cl + O_3 \longrightarrow ClO + O_2$$
$$ClO + O \longrightarrow Cl + O_2$$

Ozone is converted to oxygen, leaving the chlorine atom free to repeat the process up to 100,000 times, resulting in a reduced level of ozone. Bromine compounds or halons can also destroy stratospheric ozone. Emissions of CFCs have accounted for roughly 80% of the total stratospheric ozone depletion.

Depletion of the ozone layer has serious negative consequences on humans, animals and plants.

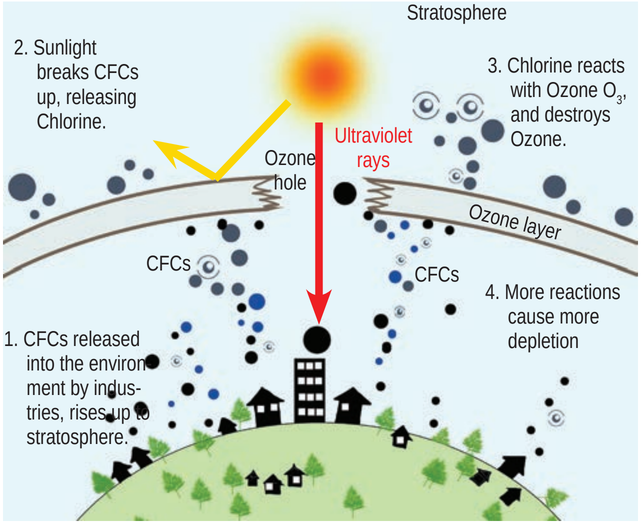


Figure 1.7. Depletion of ozone by the decomposition of CFC

a) Human**:** Exposure to the UV radiation causes skin cancer, cataracts, premature aging of the skin and it suppresses the immune system.

b) Plants: The exposure of plants to excessive UV radiation inhibits various physiological and developmental processes in plants. These include changes in plant forms, timing of development and growth, flowering, distribution of plant nutrients and metabolism, reduction in yield, etc. These changes in plants can have serious implications on the food chain, reduce global food supply and alter the biogeochemical cycles.

c) Marine Ecosystems: Phytoplankton are microscopic marine organisms capable of photosynthesis, which usually grow closer to the surface of water and form the foundation of aquatic food webs. Changes in UV levels affect the development and growth of phytoplankton and smaller fishes, which ultimately disturb the food chain.

d) Materials: Exposure to UV radiation progressively damages both the functional and aesthetic qualities of materials and products resulting to significant economic losses. Increased UV induced temperature accelerates the degradation of plastics and wood and thus, shortening their useful outdoor lifetime. Rubber, textile dyes, fibers and certain paints may be weakened or damaged by exposure to UV radiation.

iii. Mesosphere

Mesosphere is located above the stratosphere and extends from 50 km to 80 km. It is the coldest region of the atmosphere with an average temperature of -85ºC. This layer consists ofgases, such as atomic oxygen, molecular oxygen, atomic nitrogen, molecular nitrogen, helium, and hydrogen, but these gases become less abundant as the distance from the Earth increases.

iv. Thermosphere

It is the outer most layer of the atmosphere, which extends from 80 km to 500 km. The thermosphere is so named because of its high temperature range, reaching up to 1,982°C. The temperature variations in this layer are affected by high and low sun spot and solar flare activity. Extreme thermospheric temperatures are the result of UV radiation absorption. These radiations remove electrons from the free oxygen (O), molecular oxygen (O_2) and nitrogen oxide (NO), creating positively charged ions. This ionisation gives the thermosphere its other name, the ionosphere. Thermosphere absorbs a large portion of the ultraviolet and x-ray radiations emitted by the Sun before it reaches the Earth's surface. It supports and protects life on the Earth as it recycles water and helps to maintain moderate temperature of the Earth by shielding the Earth from the severely cold temperature of the space.

The atmosphere is a complex system in which physical and chemical reactions are constantly taking place. Each region of the atmosphere maintains a balance between solar energy entering and radiant energy leaving the Earth. The interaction between the atmosphere and solar radiation is responsible for determining the weather and climate on the Earth.

B. Lithosphere

The lithosphere is the solid outer section of the Earth, which includes the Earth's crust and the top part of the upper mantle as shown in Figure 1.8. Lithosphere is the coolest part of the Earth and acts as insulator over the active mantle. It extends from the surface of the Earth to a depth of about 70-100 km. Lithosphere is subdivided into Pedosphere and Tectonic plates.

Pedosphere is the uppermost layer of the Earth, composed of soil and soil formation processes. Pedosphere exists at the interface of the four spheres of the Earth. It develops when there is a dynamic interaction between the atmosphere, lithosphere, hydrosphere and biosphere. Pedogenesis (soil formation) occurs due to continued weathering of rocks and minerals. Biological reaction also significantly quickens the soil formation process.

Lithosphere is fragmented into a dozen or more large and small solid slabs called tectonic plates. These plates move relatively to one another as they float in hot, molten mantle called asthenosphere. Earthquakes, volcanic activity, mountain-building and oceanic trench formation occur along the boundaries of tectonic plates.

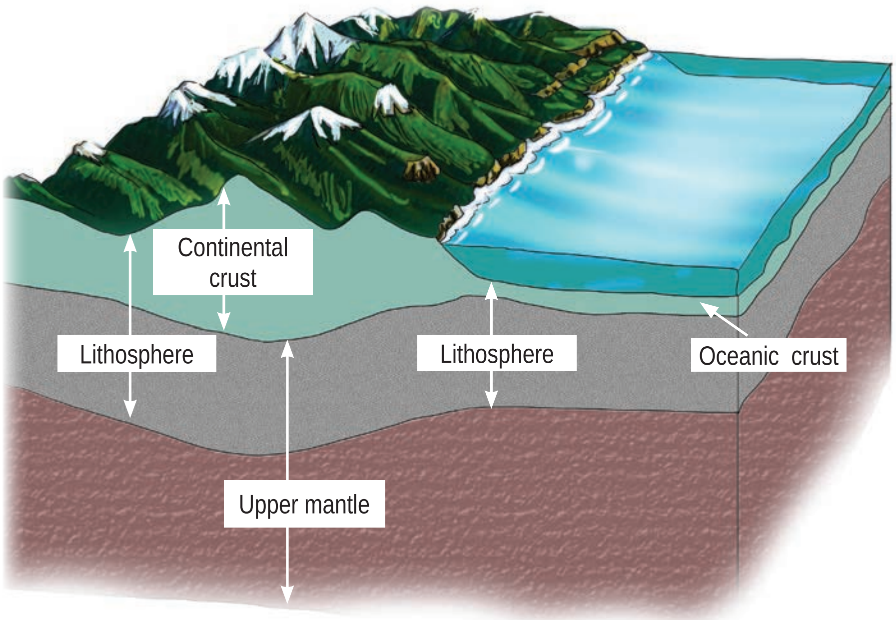


Figure 1.8. Cross section of lithosphere

Lithosphere is one of the abiotic components of the terrestrial ecosystem. It plays an important role in the metabolic processes of organisms because it contains soil for providing most of the necessary mineral nutrition required by plants. It also provides water and gases to plants and other life forms. The nutrient elements used by the biotic components of an ecosystem are restored into the lithosphere when they die and decompose.

C. Hydrosphere

The hydrosphere comprises all the water bodies on the Earth. It includes the oceans, seas, glaciers, lakes, ponds, rivers, streams and underground water (Figure 1.9). It covers about 70% of the surface of the Earth and is a habitat for many aquatic organisms. Many life forms exist in varieties of water habitats, such as freshwater, marine or wetland ecosystems. The freshwater ecosystem is further classified into two types: lentic and lotic ecosystems. Lentic ecosystem includes the static water habitats like ponds, lakes, swamps and marshes or relatively still water. Lotic ecosystem includes flowing water such as rivers, streams and brooks. Marine ecosystems are the largest aquatic ecosystem that includes seas and oceans. It is one of the largest reservoirs of water, living things and essential nutrients needed by both marine and terrestrial organisms.

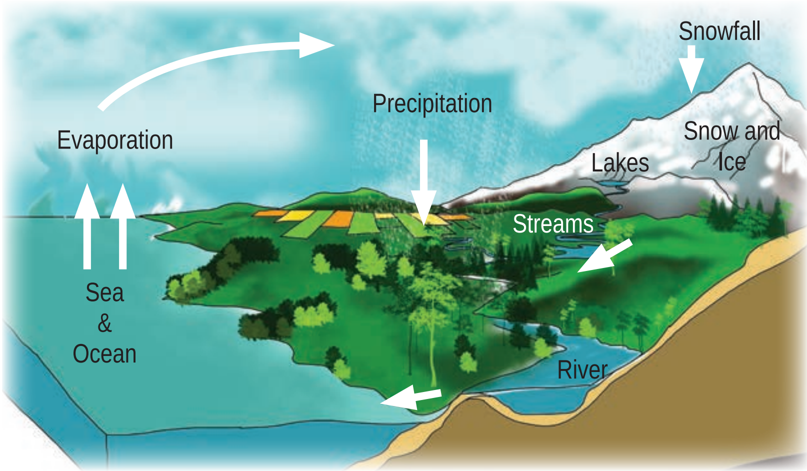


Figure 1.9. Hydrosphere and its cycle

A wetland is an area saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem. In their natural condition, wetlands supply numerous ecological, economic and cultural benefits to local communities. It provides habitat for several species of amphibians, fishes and variety of aquatic plants.

The hydrosphere interacts with the atmosphere and lithosphere mainly through the hydrological cycle (Figure 1.9). It outlines the Earth's surface and moderates the climate of a place. The hydrosphere is essential to life because water is the medium in which all living processes occur. Water dissolves nutrients and distributes them to cells, regulates body temperature, supports structures, and removes waste products. About 60 percent of human body contains water. Water is needed for various human-related activities, such as agriculture, industry, transportation, and for other uses like recreation and aesthetic inspiration.

D. Biosphere

The biosphere includes parts of the lithosphere, hydrosphere and atmosphere in which life forms can survive (Figure 1.10). Biosphere extends from the floor of the ocean, some 11,000 m below the surface of the Earth, to the top of the highest mountain, or about 9,000 m above the sea level. The life in biosphere is densely populated with species between 600 m below the surface of the ocean and about 6000 m above the sea level.

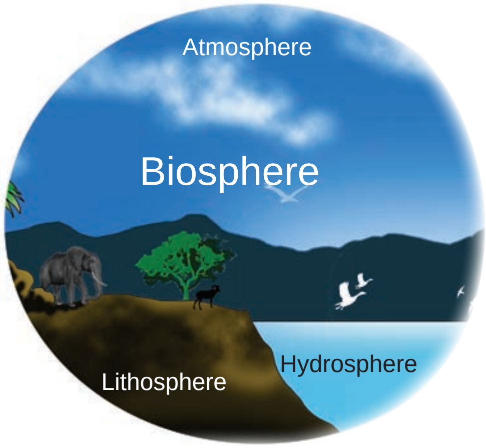


Figure 1.10. Biosphere

Biosphere is the biotic component of all types of ecosystem. The biotic community of an ecosystem inhabits spheres of the Earth that have favourable conditions of air, water, temperature, nutrients and supply of energy.

The physical and chemical conditions of the biosphere become suitable for varieties of life forms through the dynamic biogeochemical cycles. However, the natural processes of the biosphere are disturbed by anthropogenic activities, such as pollution and land degradation. In such cases, biotic components of an ecosystem tend to recover through ecological succession.

Ecological succession is the gradual and sequential replacement in the composition of a community over a period of time. For instance, when a fire destroys a forest, seeds and roots that remain in the soil grow into herbaceous plants and grasses. Gradually, small bushes and trees begin to colonise the area and restore the ecosystem.

Questions

1. Which layer of the stratosphere is considered as the "sun screen of the Earth'? Why?
2. Construct a concept map to illustrate the interaction of lithosphere, hydrosphere and atmosphere to support biosphere.

Reprint 2022

2. Biomes and Ecosystems

Learning Objectives

On completion of this topic, you should be able to:

- explain the characteristics of biomes.
- discuss the factors that determine the distribution of biomes.
- compare the flora and fauna in various biomes.
- describe ecosystems in Bhutan and their characteristics.
- differentiate between biome and an ecosystem.
- describe adaptation in plants and animals.

Look at the two pictures in Figure 1.11(a) and 1.11(b). What differences do you see? What do these differences indicate?

Figure 1.11. (a) Sahara Desert in Northern Africa (b)Rain Forest in Northern Australia.

A. Biomes

Many places on the Earth have similar climatic conditions, vegetation types and growth patterns of flora and fauna though they are located in different geographical areas. Large geographical areas with the similar climatic conditions and vegetation, usually classified based on the dominant flora and fauna found in the area, is termed as biome. Biomes form the largest divisions of the biosphere which consist of broad types of biological communities. The large regions within biomes have similar biotic and abiotic components. The interaction of these components determines the characteristics of the biomes.

Reprint 2022

The Earth's biomes can be grouped into two broad categories, namely terrestrial biomes and aquatic biomes. Terrestrial biomes are found on land, such as deserts and forests, while aquatic biomes are found in ocean and freshwater. However, in this chapter, only the terrestrial biome is discussed.

Terrestrial biomes

The geographical distribution of biomes is determined primarily by the climatic variables such as precipitation and temperature. The average temperature and precipitation in different regions of the world determines the different climatic conditions. For instance, the equatorial regions are continuously warm with high rainfall and no distinct seasons. In regions above and below the equator, temperatures become increasingly seasonal, characterised by warm or hot summers and cool or cold winters. Towards the poles, the winters become colder and longer and at the poles, it is perpetually icy cold. Likewise, places at higher elevations experience colder temperature and hence, there are snow-capped mountains even on or near the equator.

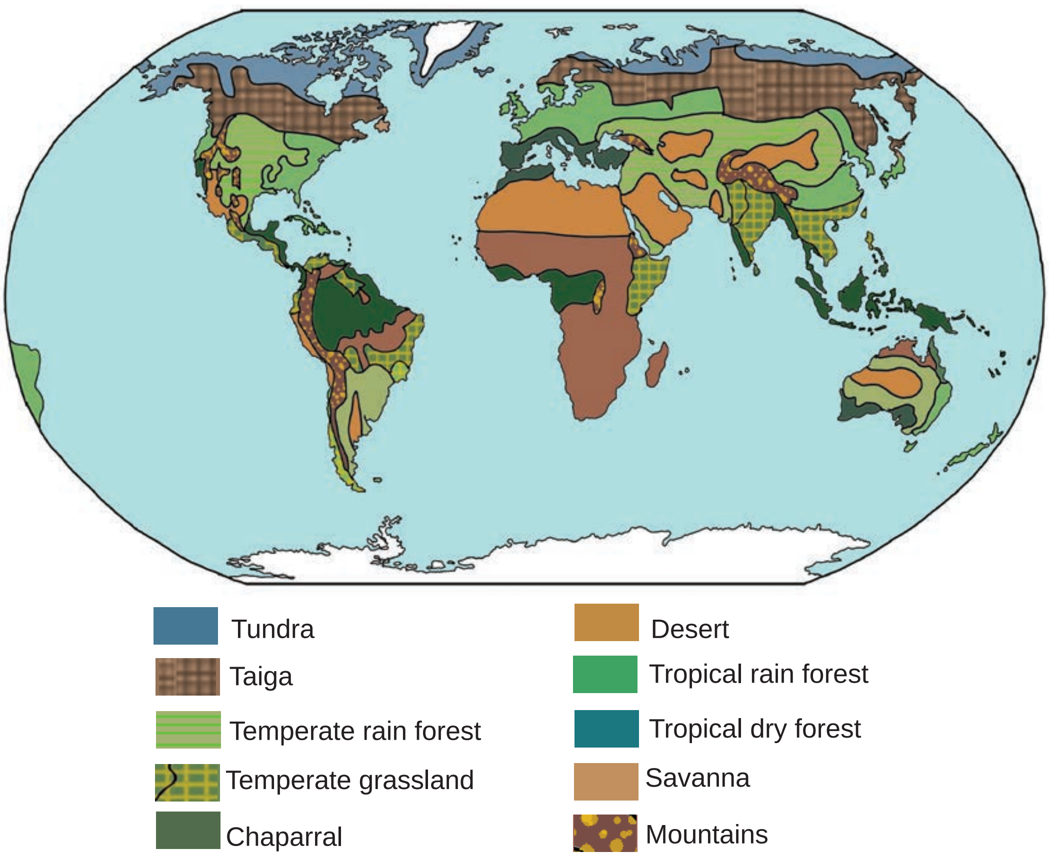


Figure 1.12. Locations of the world's major terrestrial biomes.

A given climatic condition supports only those species that find the temperature and precipitation levels within their ranges of tolerance. This results in the formation of a particular type of biome. An important characteristic of each biome is its biodiversity, or the number and variety of different biological species that live in the particular place.

Other important factors that influence the biomes are ocean currents, variation in latitude, elevations and prevailing winds in the area.

Globally, ecologists have identified major biomes which are shown in Figure 1.12. However, the number of biomes vary depending on the type and number of factors considered for the classification by the ecologists.

The boundaries between the biomes may appear to be sharp on the map. On the ground, however, there are often transitional areas between the biomes. In these areas, one biome's plants and animals gradually become less seen, while the organisms of the adjacent biome become more frequent. The community structure of a particular biome may also differ slightly depending on the location and elevation.

a. Tropical rainforests

Tropical rainforests are home to greater species diversity than all other biomes combined. In this biome, temperature ranges from 20°C to 34°C and the annual rainfall ranges from 125 cm to 660 cm, which keeps the region hot and wet year-round. This range of temperature and precipitation provide an ideal climatic condition for the growth of plants and thus, it is a host for a high diversity of species. It is estimated that one-half to two-thirds of all species of terrestrial plants and insects live in tropical forests. Tall trees form a dense covering called canopy, while the shorter trees and vines form the second layer called understory (Figure 1.13). The soil is thin and acidic. Though there is rapid decay of organisms, the soil is generally nutrient-poor due to fast absorption of nutrients by plants.

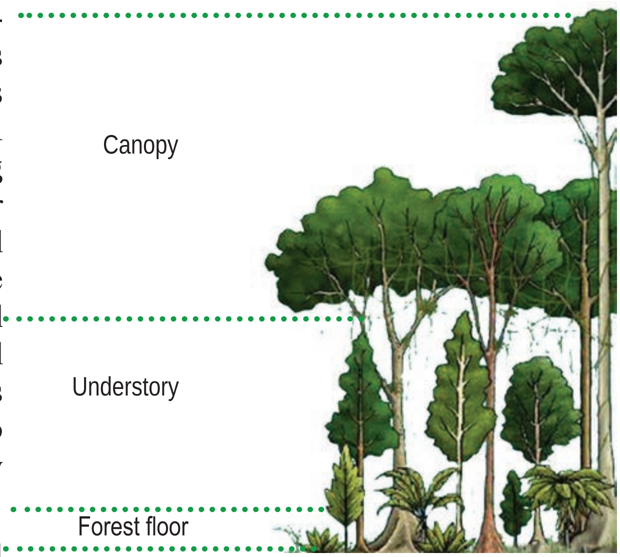


Figure 1.13. Tropical Rain Forest

The dominant plants found in this biome are broadleaved evergreen trees, ferns, large woody vines and climbing plants, orchids and bromeliads. Among the wildlife are herbivores, such as sloths, tapirs, and capybaras; predators, such as jaguars, anteaters, monkeys; birds, such as toucans, parrots and parakeets; insects, such as butterflies, ants, and beetles; piranhas and other freshwater fishes; reptiles, such as frogs, caimans, boa constrictors and anacondas.

This type of biome is distributed in parts of south and central America, south-east Asia, parts of Africa, southern India, and northeastern Australia.

b. Tropical dry forests

Tropical dry forests receive seasonal rainfall of about 50 cm to 200 cm, rather than year-round. The tropical dry forests receive seasonal rainfall and has an annual average temperature over 20^{0}C. The tress shed their leaves during the dry season to conserve water. Such trees are called deciduous trees. The tall deciduous trees form canopy, while the shorter evergreen plants form understory. Soil in these forests have higher nutrient contents and are more productive for agricultural activities than the tropical rain forest.

Figure 1.14. Tropical Dry Forest

Some dominant animals found in this biome include herbivores, such as elephants, Indian rhinoceros, hog deer; birds, such as great pied hornbill, pied harrier and spot-billed pelican; insects, such as termites; reptiles, such as snakes and monitor lizards.

This type of biome is distributed in parts of Africa, south and central America, Mexico, India, Australia and tropical islands.

c. Tropical Savanna

Tropical Savannas or grasslands receive more seasonal rainfall than deserts, but less than tropical dry forests. With annual rainfall of about 50 cm to 150 cm and temperature ranging from 24^{o}C to 29^{o}C, it remains extensively dry and hot. This biome is characterised by an open tree canopy (i.e., scattered trees) above a continuous tall grass understory. The soil is compact and poor in nutrient contents. This biome is frequently set on fire by lightning during dry season. The plants in this biome are adapted to survive drought, heat and fires. They have deep, long-lived roots that seek groundwater, and persist even when leaves and stems die. After fire or drought, fresh green shoots grow from the roots.

Figure 1.15. Tropical Savanna

The vegetation includes tall, perennial grasses with thorns and sharp leaves to protect against predation. The wildlife includes predators, such as lions, leopards, cheetahs, hyenas, and jackals; herbivores, such as elephants, giraffes, antelopes, and zebras; baboons; birds, such as eagles, ostriches, weaver birds, and storks; and insects, such as termites and beetles.

This biome covers a large part of eastern Africa, southern Brazil and northern Australia.

d. Desert

The biome which receives an annual precipitation of less than 25 cm is defined as desert. Though all deserts are said to be dry, they vary greatly depending on elevation and latitude. The temperature in desert ranges between 10°C to 43°C. In many deserts, temperature during the day varies extremely between hot and cold. The soil is bare and dry, rich in minerals, but poor in organic material. This leads to poor ability of the soil to retain water and thus, the land becomes progressively drier and bare.

Figure 1.16. Desert

The plants in deserts are highly

adapted to tolerate heat and dry condition with water-storing leaves and stems, thick epidermal layers and spines to reduce water loss. They are also salt tolerant as the soil in the desert contain high level of salts due to very low precipitation. They have salt bladders on their leaf surface and store large amount of water within their bodies to minimise salt toxicity. Some common plants found in the desert are cacti and other succulents; creosote bushes; and other plants with short growth cycles. The common wildlife that inhabit the desert are predators, such as mountain lions, gray foxes, and bobcats; herbivores, such as mule deer, pronghorn antelope, desert bighorn sheep, and kangaroo cats; bats; birds, such as owls, hawks, and roadrunners; insects, such as ants, beetles, butterflies, flies, and wasps; and reptiles, such as tortoises, rattlesnakes, and lizards.

Desert biomes are found in Africa, Asia, the Middle East, the United States, Mexico, south America, and Australia.

e. Temperate forests

Temperate forests occupy a wide range of precipitation conditions, which ranges from 75 cm to 150 cm throughout the year. Temperature ranges between -30°C to 30°C, with cold to moderate winters and warm summers. The cold winters usually halt plant growth for several months and sprout again as spring falls. Soils of temperate forests are often rich in humus due to the thick layer of leaf litter on forest floors. This makes the soil fertile for plant growth.

Figure 1.17. Temperate forests

The biome consists of mixture of coniferous trees, flowering shrubs, herbs and ground layer of mosses and ferns, dominated by deciduous trees. Some of the dominant wildlife includes deer, black bears, bobcats; nut and acorn feeders, such as squirrels; omnivores, such as raccoons and skunks; and numerous songbirds and turkeys.

Temperate forests biomes are found in eastern United States, south-eastern Canada, most of Europe, and parts of Japan, China and Australia.

f. Temperate grassland

Temperate grasslands are found in those regions of the world where annual rainfall is between 25 cm to 75 cm. In Europe and Asia, temperate grassland is named as Steppes; Prairies in north America. This biome experiences wide range of temperature with over 38°C in summer and as low as -40°C in winter. The biome is characterised by high rates of evaporation, periodic severe droughts and frequent fire. The soil is dark brown with thick layers of humus. The mild leaching and high organic content makes the soil fertile. Large parts of these grasslands have been converted into agriculture and pasture lands because of its high fertility.

Figure 1.18. Temperate grassland

The vegetation in this biome consists of abundant perennial grasses and herbs, which are resistant to drought, fire and cold. Some species of grasses include purple needlegrass, blue grama, buffalo grass and galleta. Though large trees and shrubs are largely absent, a few trees, such as cottonwoods, oaks and willows grow in some river valleys. The dominant animals that inhabit this biome are predators, such as coyotes, badgers, wolves and grizzly bears; herbivores, such as mule deer, pronghorn antelope, rabbits, prairie dogs and bison; birds, such as hawks, owls, bobwhite, prairie chicken, mountain plover; reptiles, such as snakes; and insects, such as ants and grasshoppers.

The regions where this biome is found are central Asia, north America, Australia, central Europe, and upland plateaus of south America.

g. Mediterranean shrublands

The Mediterranean shrubland or Chaparral is the biome found in regions which have moderately hot and dry summers, while the winters are cool and moist. The annual rainfall in this biome ranges from 65 cm to 75 cm, and most rainfall occurs in winter. The average temperature ranges from 10°C to 12°C in winter and 30° C to 40°C in summer. This biome often forms the transitional zone between areas of forests and shrublands. The dense shrubs that grow in this biome produce certain flammable oils which make fire a constant threat. The soil is thin with very poor nutrient content.

The dominant plants that grow in this region are woody evergreen shrubs with small, leathery leaves, and fragrant, oily herbs that grow during winter and die in summer. The biome is a home for animals like predators, such as coyotes, foxes, bobcats and leopards; herbivores, such as black tailed deer, rabbits, squirrels, and mice; birds, such as hawks, California quail, western scrub jay, warblers and other songbirds; reptiles, such as lizards and snakes; and insects, such as butterflies and spiders.

Figure 1.19. Mediterranean Shrub lands

Some regions of the world where this biome exists are western coasts of north and south America, areas around the Mediterranean Sea, South Africa, and Australia.

h. Taiga Forest

Taiga forest is also known as Coniferous or Boreal forest. The Taiga forest lies within the regions of sub-Arctic and cold continental climate. It has long, cold, dry winters extending up to six months with an average temperature of -30°C. Summer is short, moist and moderately warm for three to five months with an average temperature of 20°C. The annual precipitation in this biome ranges between 40 cm to 100 cm, which mostly occurs in summer. The soils are characterized by a deep layer of litter derived from the conifer needles that decay slowly in cold temperatures, and are generally acidic, poor in nutrient contents.

The dominant trees of taiga forest are: needle leaf coniferous trees, such as spruce and fir, some broadleaf deciduous trees, and small, berry-bearing shrubs. Some dominant animals of this biome are predators like lynx and timber wolves; herbivorous mammals, such as moose, elk, deer; birds, such as songbirds and migratory birds.

Figure 1.20. Boreal forest

Taiga forests can be found in Eurasia, North America, Siberia, Scandinavia, Alaska and Canada.

i. Tundra

Among all the terrestrial biomes, tundra is considered the simplest biome in terms of species composition. This is due to its very harsh environmental conditions like extremely low temperature, low precipitation, poor nutrients and a short growing season. It is a treeless land with desert-like conditions that lies between the polar ice caps to the north and forests to the south in the Arctic region. Thus, Tundra can be divided into two types: Arctic Tundra and Alpine Tundra.

Figure 1.21. Arctic Tundra

The Arctic Tundra is very cold with average temperatures of -34° C in winter and about 12°C in summer. The annual precipitation ranges between 15 cm to 25 cm, which allows the vegetation to grow for a short period of 50 to 60 days. This biome is characterised by a layer of permanently frozen soil, called permafrost. Though this biome receives very less rainfall, many of its low-lying areas remain moist throughout the growing season because the permafrost prevents the proper drainage of water. The soil is usually acidic due to high organic matter content and poor in nutrients because the very slow process of decomposition inhibits the recycling of nutrients. The plants that can survive through such harsh conditions of this biome are low shrubs, sedges, mosses, grasses, lichens, and some varieties of flowering herbs. The animals in this biome are cold-blooded, have thick plumage and layer of fat to overcome the extreme climatic conditions. Some of the animals found are migratory waterfowls, shore bird, musk deer, Arctic fox, polar bear, caribou, lemming and small rodent. Arctic Tundra stretches across northern America, northern Europe and Siberia.

Alpine Tundra falls on the mountain regions throughout the world at high altitude where trees cannot grow. The temperature in this biome goes below freezing point in winter and rises to approximately 10°C in the summer, which is too low to support the growth of trees.

This biome is similar to Arctic Tundra in many features except that it lacks permafrost in the sub-soil. Soil is usually acidic due to high organic matter content and poor in nutrients because the slow decomposition delays the recycling of nutrients.

Figure 1.22. Alpine Tundra

Alpine Tundra has higher species diversity than the Arctic Tundra. Vegetation in this biome varies greatly from place to place and is adapted to both high altitude and extreme climates. Some common plants that survive in such harsh condition are lichens, mosses, sedges, dwarf willows and grasses. Among animals are pikas, mooses, marmots, mountain sheep, mountain goats, elk, yak, snow leopard, vole, pocket gopher and ground squirrels. It also hosts varieties of insects, such as springtail, beetles, grasshoppers, bugs, butterflies, ants, bumblebees and mites.

Alpine Tundra is found in the Rocky Mountains of North America, the Alps of Europe and the Plateau of Tibet in central Asia.

Activity 1.1. *Identifying features of terrestrial biomes*

Instruction:

1. Students work in groups and each group is assigned one or more type of terrestrial biomes.
2. Discuss and complete the Table 1.2.

Table 1.2.

Biome	Climate and soil types	Dominant flora	Dominant fauna	Geographical distribution

3. Present your work to the whole class.

Questions

1. Why do you think different terrestrial biomes have different climatic conditions?

2. Illustrate the change of vegetation that could be observed as one moves from southern belt of Bhutan to the northern mountains.
3. Which terrestrial biome do you think is more vulnerable to human exploitation? Why?

B. Ecosystem

An ecosystem is a combination of biotic community and the abiotic components in which organisms live. The grouping of plants, animals and microbes we observe in a forest, a grassland, a pond, a coral reef, or some other natural area is referred to as the area's biota (bio-living) or biotic community. The plant portion of the biotic community includes all vegetation, from large trees to microscopic algae. Likewise, the animal portion includes large mammals, birds, reptiles, amphibians, earthworms, tiny insects and mites. Microbes consist of large array of bacteria, fungi and protozoans.

Figure 1.23. Forest ecosystem

The particular kind of biotic community found in a given area largely depends on abiotic factors. Abiotic factors include temperature, amount of water or moisture, soil type, air quality, pH of the soil and salinity. The degree to which each abiotic factor is present or absent profoundly affects the ability of organisms to survive. Each species responds differently to each factor. This difference in response to the abiotic factors determines which species may or may not occupy a given region or a particular area within a region. In turn, the organisms that do or do not survive determine the nature of a given ecosystem. Thus, ecosystem is defined as a dynamic complex plant, animal, and microorganism communities and the non-living environment interacting as a functional unit within a definite space. The study of ecosystems and the interactions that occur among organisms, and between organisms and their environment is called ecology.

While it is convenient to divide the living world into different ecosystems, there are rarely distinct boundaries between ecosystems, and they are never totally isolated from one another. Many species occupy two or more ecosystems, or they may move from one ecosystem to another at different times, as in the case of migrating birds and animals. The transitional area between the two different

Reprint 2022

ecosystems, such as forest and grassland, is termed as ecotone. An ecotone shares many of the species and characteristics of both the ecosystems.

Figure 1.24. Ecotone between a meadow and forest

Ecosystems in Bhutan

Ecosystems in Bhutan have been classified into forest ecosystems, aquatic ecosystems and agricultural ecosystems.

a. Forest ecosystem

Forest ecosystem is the most dominant ecosystem in Bhutan. Our country has a wide range of forest types and vegetation zones due to variation in climatic conditions and altitude. It can be divided into three distinct eco-floristic zones with different forest types as shown in Table 1.3.

Table 1.3. Eco-Floristic Zones of Bhutan

Eco–floristic Zone	Main forest types and dominant flora (plants)	Main fauna (animals)
Alpine Zone Altitude: (4000 + masl)	Alpine meadows and scrubs dominated by rhododendron scrubs, juniper and medicinal plants and herb species such as *Ophiocordyceps sinensis, Picorrhiza, Fritillaria.*	Snow leopard, Lynx, Blue sheep, Malayan marmot, Tibetan wolf, Takin, Musk deer.

Temperate Zone Altitude: (2000-4000 masl)	**Fir Forest – 3000 masl+** Fir forest consists either of *Abies densa* or mixed with other species such as *Juniperus, Taxus* and *Larix.* **Mixed Conifer Forest – 2500- 3500 masl** Mixed conifer forest includes mixed stands of spruce, hemlock, juniper, fir, larch, *taxus***.** Some broadleaf are also common particularly *Quercus semecarpifolia, Quercus griffithii, Rhododendron spp., Acer spp., Betula sp.* **Blue Pine Forest- 1500- 3200 masl** Blue pine forest consists of pure or dominant stands of blue pine. It is sometimes mixed with *Quercus semecarpifolia, Populus rotundifolia* and *Rhododendron spp.* **Broadleaf mixed with Conifer – 2000-2500 masl** Consists of blue pine mixed with poplar, and other species such as *Castanopsis, Quercus, Persea, Litsea, Populus ciliate.*	Goral, Serow, Black bear, Grey langur, Red panda, Assamese macaque, Leopard.
Sub Tropical Zone Altitude : *(150-2000 masl)*	**Broadleaf Forest – 1000-2000 masl** Represented by species of *Castanopsis, Lithocarpus, Schima,* and *Quercus.* **Chir pine Forest – 700- 2000 masl** Pure stands of Chir pine or in association with *Quercus lanata, Quercus griffithii, Quercus glauca* and *Alnus nepalensis* along water courses. **Tropical Lowland Forest - <700 masl** Broadly classified as semi-evergreen but varies from almost totally deciduous on exposed dry slopes to almost evergreen in the moist valleys. Floristic composition consists of tropical species like *Shorea robusta, Terminalia myriocarpa, Bombax ceiba, Daubanga grandifolia, Sterculia villosa, Acacia catechu, Terminalia nudiflora.*	Water buffalo, Golden langur, Sambar deer, Tiger, Golden cat, Clouded leopard, Capped langur, Gaur.

(Adapted from Ohsawa (1987) and LCMP (2010))

b. Aquatic ecosystems

The aquatic ecosystems of Bhutan consist mainly of rivers, lakes, marshlands and hot springs. Bhutan has many inland water resources in the form of rivers, rivulets, springs and streams due to the presence of large number of glaciers and glacial lakes, relatively well-preserved forests and watersheds. The four major river basins are Amo Chhu (Torsa), Drangme Chhu (Manas), Puna Tsang Chhu (Sunkosh) and Wang Chhu (Raidak). Drangme Chhu is the largest river basin in the country. There are numerous small and medium-sized lakes spread across the country. An inventory of High Altitude Wetlands by the Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER) reports that Bhutan has about 2,963 lakes and 63 marshes, with sizes varying from the smallest at about 35 square metre to the largest at about 1.5 square kilometre, covering 0.26 per cent of the country's total land cover. According to the Aquatic Biodiversity Assessment, about 93 freshwater fish species have been discovered in the rivers and lakes of Bhutan. Some examples are Gray's stone loach, Common snowtrout, Tibetan stone loach, Brown trout, Golden mahseer and Common carp. Insect species inhabiting rivers and lakes are found in larval form along with some semi aquatic-adults like Aquatic worm, Caddis fly larva, May fly larva, Riffle beetle and Water spider. There are also records of migratory birds like Great Cormorant, Ruddy Shelduck, Brown-headed Gull and Red-crested Pochard; and aquatic plants like Watershield, Roundleaf pondweed, Sphagnum mosses and watercress.

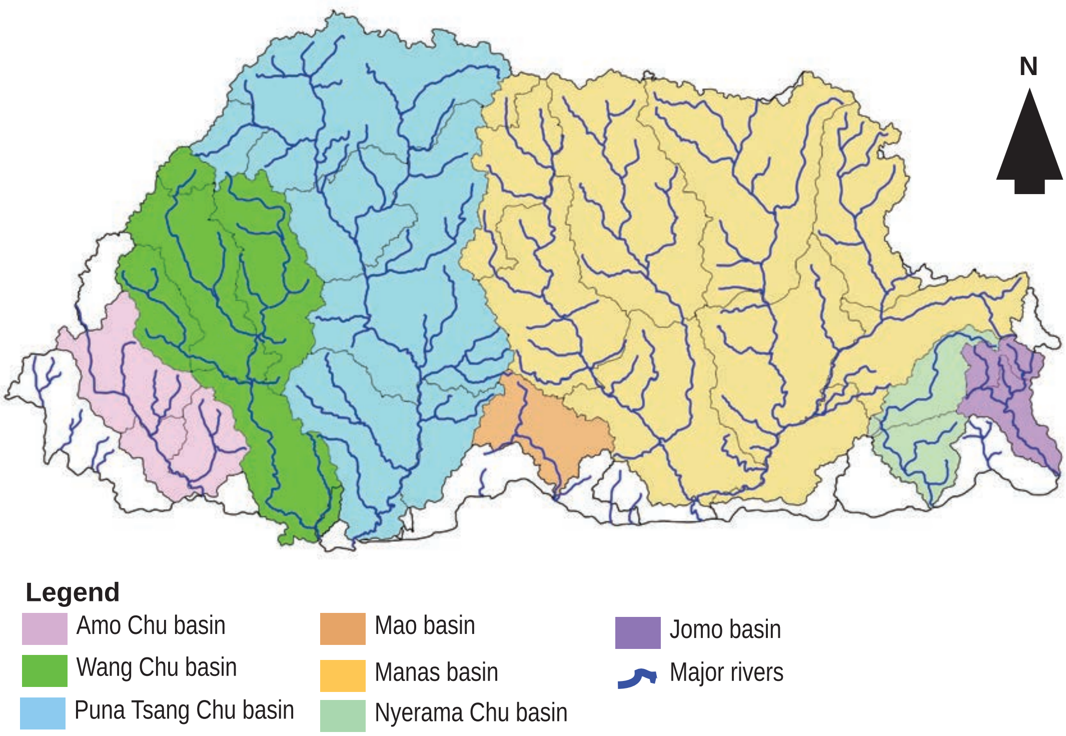


Figure 1.25. River systems and river basins of Bhutan

In addition to rivers and lakes, marshlands are major part of the aquatic ecosystem in the country. Marshlands are generally known to be rich in biota and are habitats for resident as well as migratory birds, reptiles, amphibians and fishes. The best known marshland in the country is the Phobjikha valley, where the globally threatened Black-necked Cranes roost in large numbers during winter. Other important marshlands recognised as wetlands of international importance are Bumdeling (Ramsar site No. 2032) and Khotokha (Ramsar site No. 2033).

Hot springs, also known as '**tshachu**' in Dzongkha, are very popular in Bhutan. There are several hot springs in the country. Some of these are Gelephu '**tshachu**' in Sarpang, and Chu Boog '**tshachu**' in Punakha. People mainly visit hot springs for healing various ailments. These hot springs are habitat to many thermophilic and hyperthermophilic bacteria, fungi, micro and macro algae, and archea. *Thermus aquaticus*, *Synechococcus*, *Chloroflexus*, *Methanobacterium thermoautotrophicus*, and *Thermocrinis rubber* are some examples of heat-loving bacteria found in most of the hot springs of the world.

c. Agricultural ecosystem

The country has six major agro-ecological zones corresponding with altitudinal range and climatic conditions. Table 1.4 gives an overview of the major agro-ecological zones along with characteristic features of these zones.

Table 1.4. Agro-ecological Zones of Bhutan

Agro-ecological zone	Altitude (Metres above sea level [masl])	Rainfall (mm/annum)	Farming systems, major crops and agriculture produce
Alpine	3600-4600	*< 650*	Semi-nomadic people, yak herding, dairy products, barley, buckwheat, mustard and vegetables.
Cool Temperate	2600-3600	650-850	Yaks, cattle, sheep &horses, dairy products, barley, wheat & potatoes on dryland, buckwheat & mustard under shifting cultivation; temperate fruits and vegetables
Warm Temperate	1800-2600	650-850	Rice on irrigated land, double cropping with wheat and mustard, barley and potatoes on dryland, temperate fruit trees, vegetables, cattle for draft and manure, some machinery & fertilisers used.
Dry sub-tropical	*1200-1800*	850-1200	Maize, rice, millet, pulses, fruit trees and vegetables, wild lemon grass, cattle, pigs & poultry.
Humid sub-tropical	*600-1200*	1200-2500	Irrigated rice rotated with mustard, wheat, pulses and vegetables, tropical fruit trees.
Wet sub-tropical	150-600	2500-5500	Humid zones-irrigated rice rotated with mustard, wheat, pulses and vegetables, tropical fruit trees.

(Adapted from MoAF 9th FYP and BAP III, 2009)

Activity 1.2. *Studying interactions in an ecosystem*

Instruction:

Study the concept map shown in Figure 1.26 and answer the questions that follow:

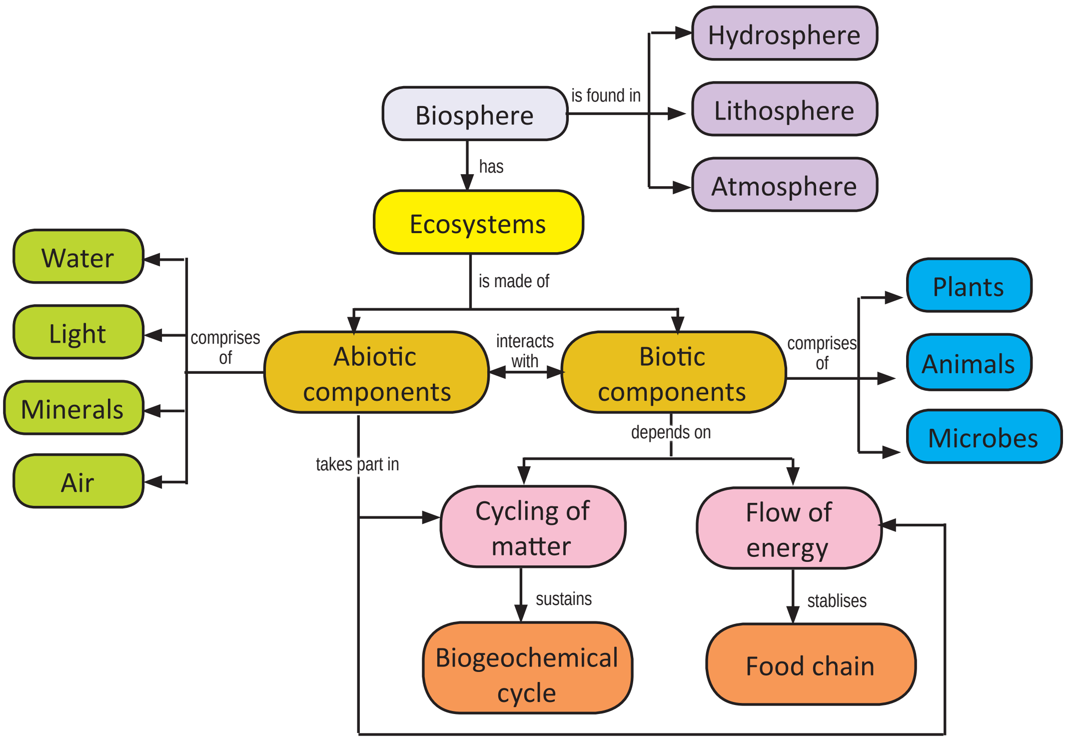


Figure 1.26.

Questions:

1. In what ways do abiotic components support the survival of biotic components within the biosphere?
2. Discuss the impact(s) of removal of any one biotic component from the ecosystem.
3. Explain the factors that influence abiotic components of ecosystem.
4. How can organisms survive if biosphere consist of hydrosphere and lithosphere only?
5. What is the role of abiotic components in the flow of energy?

C. Adaptations in plants and animals

Activity 1.3. *Exploring adaptive features and their benefits*

Instruction:

1. Visit your library or browse internet to complete the Table 1.5.

Table 1.5.

Group of organisms	Name of Organism	Adaptive Features	Purpose
Hydrophytes	1.Hydrilla 2.Water hyacinth		
Mesophytes	1.Rose 2.Blue Poppy		
Xerophytes	1.Opuntia 2.Nerium		
Halophytes	1.Rhizophora 2.Sonneratia		
Hydrocoles	1.Jellyfish 2.Shellfish		
Mesocoles	1.Earthworm 2.Fire salamander		
Xerocoles	1.Desert tortoise 2.Kangaroo rat		

Questions

1. What are the differences and similarities between xerophytes and halophytes?
2. How do predators affect the adaptation of their prey?
3. Identify a few plants and animals in your local ecosystem and list their adaptive features.

Reprint 2022

Types of adaptation

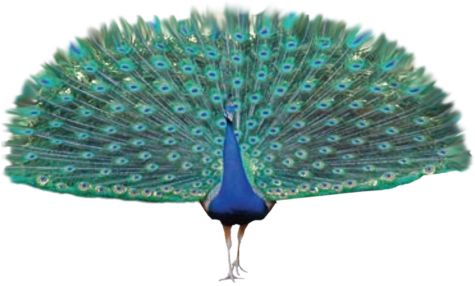


Figure 1.27. Exotic plumage in peacock

Adaptation is the ability of living things to adjust to different conditions in their environment. It enhances the fitness of organisms and helps them survive in their ecological niche or habitat. Adaptations can be physical, biological and chemical. Most adaptations have emerged through evolution while a few adaptations are learnt.

Physical adaptation is when the body of the animal or plant changes in response to a change in its physical environment or conditions within its environment. For instance, polar bear has a layer of fat under its skin and thick layer of fur, which help it stay warm. Their wide, large paws help them to walk in the snow. In plants, pine trees have needle-like leaves which are thick and waxy to reduce transpiration. Camouflage and mimicry are other examples of physical adaptation.

Figure 1.28. Venus flytrap

Figure 1.29. Poison dart frog

Biological adaptation is the adjustment brought about by an organism according to its biological needs like finding mate, feeding and caring of the young ones. For example, the exotic plumage in peacock attracts the peahen. In plants, various flowers attract specific insects or birds as pollinator by their beautiful colour, sweet fragrance and nectar. In carnivores, the sharp claws and sharp teeth aid them in predation.

Chemical adaptation is when an organism adapts to changes in the chemical make-up of its environment. For example, carnivorous plants like Venus flytrap generally grow in nitrogen poor environment. It supplements its nitrogen through the ingestion of prey. Preys are digested with the help of enzymes, or bacteria that co-inhabit the carnivorous plants. In animals, an example is the poison dart frog which has poison glands scattered all over its body to protect it from the predators.

a. Adaptation to drought

Plants that live in very dry conditions have made adaptations to survive in a climate with minimum water availability. Such plants are called xerophytes. The desert plants such as cactus have spines rather than leaves to reduce water loss and protect themselves from animals. They are succulent in nature and store water in their stems and leaves. They have deep and wide root systems to collect as much water as possible.

Figure 1.30. Cactus

Figure 1.31. Camel

Figure 1.32. Fennec fox

Desert animals are also adapted to conserve moisture and escape the scorching heat of the Sun. These animals are called xerocoles. For example, the camel accumulates its fat in the hump which helps it to survive longer without food and water. The fennec fox can also survive in the deserts as it has large ears to dissipate excess body heat on hot days, its kidneys are adapted to restrict water loss, its thick fur helps insulate it from the cold desert nights, and it also has thick fur on the soles of its feet, which insulates against the hot sand of the desert.

b. Adaptation to water abundance

Plants that live in aquatic environment are called hydrophytes. Hydrophytes can either be fully submerged in water, or partly submerged. Hydrophytes must be flexible to withstand the pressure of moving water. Roots are either absent as in Wolffia or poorly developed as in Hydrilla. In hydrophytes, stomata are present on the upper epidermis for gaseous exchange as the lower surface is in touch with water. Hydrophytes like water lilies have special air spaces in the leaves and stem called aerenchyma, which provides buoyancy and allow increased gaseous exchange.

Figure 1.33. Water lily

Hydrocoles are aquatic animals that generally have streamlined and flexible bodies. They have structures like flagella, antennae or fins which help them in movement. Aquatic animals have to use the oxygen dissolved in water; hence, they have some special organs called gills for the exchange of gases. They have slimy skin to reduce friction for easy movement and protection. Hydrocoles are adapted to the changing temperature of water because they are cold-blooded organisms.

Figure 1.34. Fish

c. Adaptation to moderate amount of water

Plants that live in an environment that has adequate water supply are termed as mesophytes. Most of the plants found in forest, shrubland and cropland are generally mesophytes. They usually have broad, flat and green leaves and extensive fibrous root system for absorption of water.

Figure 1.35. Pansy

Mesocoles are terrestrial animals requiring moderate amount of water. Some animals, such as land planarians, earthworms and amphibians, have sensitive epithelium, which functions as a respiratory membrane. The drying of the membrane injures the cells permanently. Therefore, these animals must always remain in humid conditions to maintain moist body surfaces by secreting mucus coating. In unusually dry situations, they may resort to behavioural adaptations such as burrowing, coiling or forming aggregates.

Figure 1.36. Earthworm

d. Adaptation to saline environment

Halophytes are plants that grow in saline environment, where there is a high salt concentration which makes water osmotically unavailable to them. Succulent halophytes are able to store water in the cells of leaves and stem and thus, dilute the ionic concentration. Halophytes tolerate higher salt concentration

Figure 1.37. Sonneratia

in their cell sap because they have means of getting rid of excess salt. Several mangroves (*Rhizophora* spp. and *Sonneratia* spp.) have salt glands to excrete salts through the surface of the leaves.

Halophytes accelerate their growth after heavy rains when the salt concentration is at its lowest, and this is also the most favorable time for germination of seeds. Some halophytes are obligates, requiring a saline habitat, while halophytes of coastal marshes and swamps (salt marsh grass, mangroves) grow best at low salinity. Glassworts (*Salicornia*) grow best at moderate salinity.

Most of the mangrove halophytes produce negatively geotropic roots that come out of the soil to take oxygen (O_2) directly. Such roots are called pneumatophores, which possess pores for gaseous exchange.

Questions

1. Why do you think the tropical rain forest contains the maximum biodiversity than any other terrestrial biomes?
2. Compare camouflage and mimicry in living organisms with examples.
3. How do people adapt to changing environment? List adaptive features of human beings which differentiate them from other animals.

Reprint 2022

Exercise

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

   i. What key role does the troposphere play in maintaining life on the Earth?

      A. Regulates weather

      B. Absorbs UV radiation

      C. Regulates ozone formation

      D. Regulates ionisation of gaseous molecules

   ii. The sum of all ecosystem is classified as

      A. biosphere.

      B. atmosphere.

      C. lithosphere.

      D. hydrosphere.

   iii. The characteristics of biomes are affected by different biotic and abiotic factors of an ecosystem. Which statement describes the two main factors that predominantly control the distribution of biomes?

      A. Plants and animals can survive in dry and high altitude conditions.

      B. Plants and animals depend on temperature and water availability.

      C. Plants and animals need flora and fauna for interaction.

      D. Plants and animals have regenerative and resilience capability.

   iv. Bhutan is perceived as a tourist attraction as it is a part of the 10 hot-spots of biodiversity. The main type of ecosystem of Bhutan is terrestrial ecosystem, because Bhutan is

      A. rich in flora and fauna.

      B. covered with large area of forest only.

      C. deprived of oceans and seas.

      D. located in the Himalayas.

v. Hydrophytes are adapted to abundance of water. One of the adaptive features to provide buoyancy to the plants is

A. collenchyma that is abundant in vegetative parts.

B. aerenchyma that is extensive almost in all vegetative parts.

C. sclerenchyma that supports plant's body.

D. parenchyma that is found in leaves.

2. ***Fill in the blanks with the correct form of word(s).***

i. Using aerosol sprays, air-conditioners, refrigerators and pesticides increases the concentration of .... in the atmosphere.

ii. The four main layers of the atmosphere are classified according to changes in …………….. and temperature of air.

iii. Some mesocoles always need to keep their skin moist which is an adaptaion for…………………

iv. The biome that contains a mixture of deciduous and coniferous trees, the cold winters usually halt plant growth and the soil is rich in humus is ……………..

v. If an imaginary line is to be drawn on the map of Bhutan from North to South to show agro-ecological zones, it must be based on climatic conditions and ……………….

3. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.***

i. Some primitive aquatic animals can be found in deep seas and oceans forming a lotic ecosystem.

ii. The atmospheric temperature becomes 0°C near stratopause.

iii. Tundra biome has the highest diversity of flora and fauna.

iv. Webbed feet in penguins is an example of physical adaptation.

v. Yak herding is practiced in the humid-subtropical agro-ecological zone of Bhutan.

Reprint 2022

4. ***Answer the following questions.***

   i. What is the difference between ecosystem and biosphere?

   ii. Even though thermosphere lies further away from the mesosphere, it is the hottest. Explain.

   iii. How does adaptation lead to speciation?

   iv. Study Figure 1.38 and describe as many adaptive features as possible of the plant.

Figure 1.38

   v. How do wetlands protect shoreline from erosion and provide habitat for wildlife?

   vi. Why is it important for trees in a boreal forest to conserve water?

   vii. Study Figure 1.39 and answer the following questions:

Figure 1.39

      a. List down the spheres of the Earth that you observe in the figure.

b. The spheres of the Earth do not exist in isolation in nature. Justify the statement with reference to Figure 1.39.

c. What type of biome do you see in Figure 1.39? Mention few characteristics of this biome.

Explore:

https://prezi.com/khpnr-llvg42/mesophytes-xerophytes-and-hydrophytes/
http://www.shareyouressays.com/121233/essay-on-ecological-groups-of-organisms-and-ecological-adaptations
http://www.eoearth.org/
http://d43fweuh3sg51.cloudfront.net/media/assets/wgbh/tdc02/tdc02_doc_biomesummary/tdc02_doc_biomesummary.pdf
http://d43fweuh3sg51.cloudfront.net/media/assets/wgbh/tdc02/tdc02_doc_biomesummary/tdc02_doc_biomesummary.pdf

Reprint 2022

CHAPTER 2

Balance in Nature

Balance in nature is a concept that describes natural systems which are in the state of equilibrium. This means that the disturbance of one element affects the entire system. When the ecosystem maintains equilibrium among the biotic and abiotic components, it is said to be in the state of homeostasis. Homeostasis is regulated through different interactions among the organisms and with their environmental changes in the ecosystem. When considered at all levels of the ecosystem, a food web governs the flux of energy and nutrients throughout our natural world.

Ecosystems recycle nutrients, decompose wastes, and produce primary and secondary biomass through various processes to maintain the equilibrium.

1. Energy Flow in an Ecosystem

Learning Objectives

On completion of this topic, you should be able to:

- distinguish between grazing and detritus food chains.
- explain the energy flow across the trophic levels in an ecosystem.
- differentiate between different types of ecological pyramids.
- relate energy flow and self-sustenance of an ecosystem.

All organisms require energy for growth, maintenance, reproduction, and locomotion. The energy and nutrients are passed from one organism to another through food chains and decomposers remove the last energy from the remains of organisms. Inorganic nutrients are cycled through various biogeochemical cycles, whereas energy flows in a linear fashion.

A. Feeding relationship

The overall structure of ecosystems is characterised by the organisms' feeding relationships. The main components of an ecosystem such as energy, nutrients and organisms, are linked by nutrient recycling and the flow of energy from the sun, through organisms, and then into the environment. This linkage is the feeding relationship represented by food chains and food webs in an ecosystem.

The solar energy from the sun enters the food chain through the plants and is passed to other organisms in sequence depending on their feeding habits. Each step in the flow of energy is referred as 'trophic level' (Figure 2.1). The major categories of trophic level are producers, consumers, and decomposers. All ecosystems have the same three basic categories of trophic levels that interact in similar ways. The consumers are further categorised into different types on the basis of their feeding habits and their position in food chain. For instance, herbivores, carnivores and omnivores have different positions in a trophic level (Figure 2.1).

An ecosystem has two types of food chain, i.e., grazing food chain and detritus food chain. A grazing food chain starts with green plants followed by various levels of consumers while a detritus food chain starts with dead organic matter consumed by the decomposers. Detritus refers to dead plant materials, such as fallen leaves, bark, flowers, the fecal matters and animal dead bodies. The organisms that feed on detritus or organic matter are called decomposers.

Reprint 2022

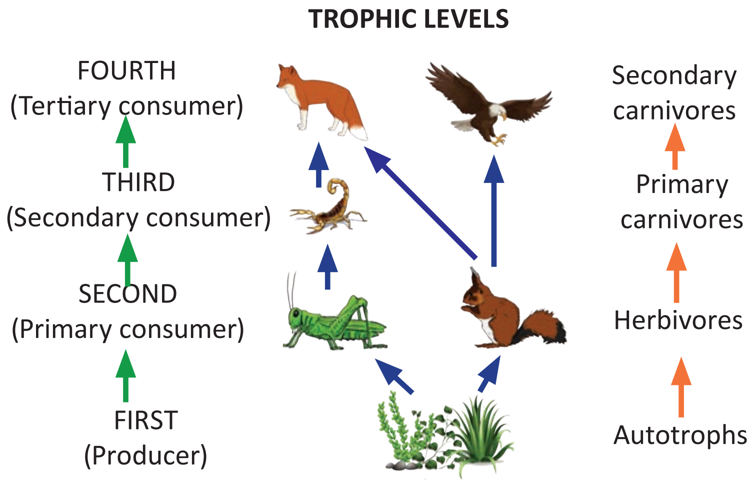


Figure 2.1. Trophic levels

There are two categories of decomposers: detritivores and saprophytes. Detritivores obtain their nourishment by feeding on detritus. Earthworms, millipedes, fiddler crabs, termites, ants, and wooden beetles are some of the detritivores. They consume lumps of organic matter and digestion occurs internally. Saprophytes like bacteria and fungi feed on the detritus for their nourishment. Unlike detritivores, saprophytes digest the food externally by releasing the enzymes on the detritus and absorb the chemically digested food. Detritivores break down the organic matter (detritus) into smaller particles, which increases the surface area that makes it easier for the saprophytes to feed on it.

Activity 2.1. *Identifying the trophic level and types of consumers*

Instruction:

Study the food web given in Figure 2.2 and answer the questions that follow:

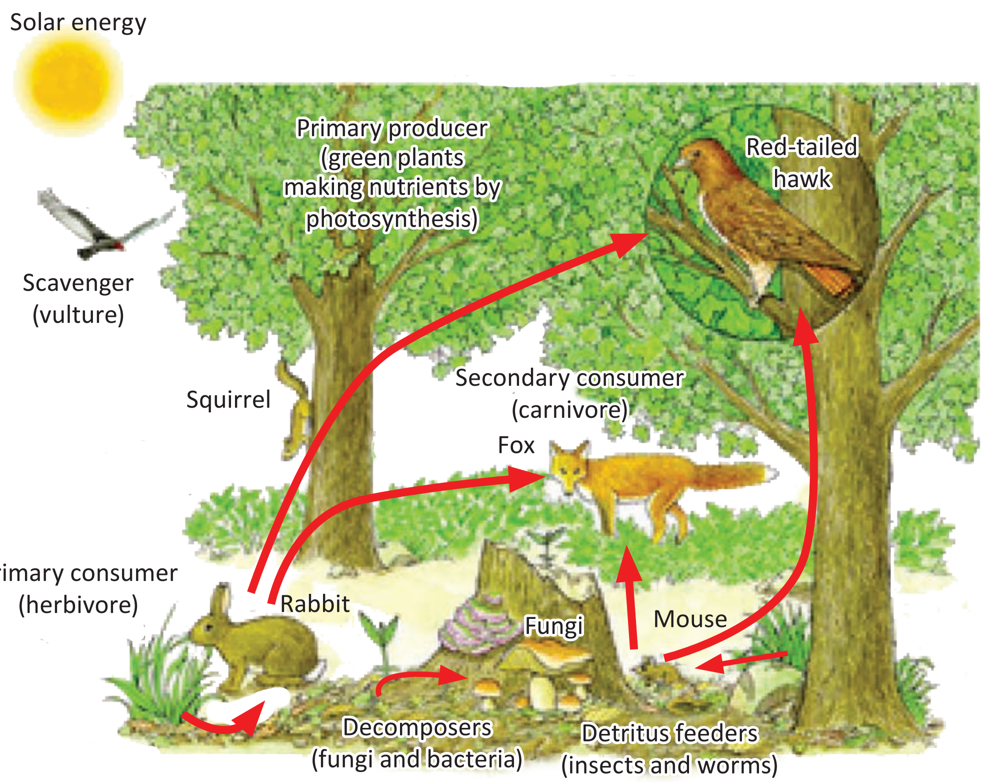


Figure 2.2. A forest food web (Source: www.thinglink.com)

Questions

1. Identify the animals in the diagrams and explain their roles as:
   a) Producer
   b) Herbivore
   c) Carnivore
   d) Detritivore
   e) Saprophyte
   f) Scavenger

2. Draw a food chain from the food web and label the different trophic levels.
3. How will the removal of primary consumer affect an ecosystem?
4. Why is food chain of an ecosystem generally limited to 3-4 trophic levels?
5. What are the differences between a detritivore and a saprophyte?

Food chains are typically short, consisting of two to four trophic levels. When a herbivore eats plants, only a fraction of the energy that it gets from the plant becomes new body mass, while the rest of the energy is lost as waste, or used up to carry out its various life activities. In a food chain, the energy decreases by about 10% at each trophic level because some amount of energy is lost as heat as shown in Figure 2.3. Thus, there cannot be too many links in a single food chain, because the animals at the end of the chain do not get enough food and energy to survive.

In an ecosystem, when one species becomes extinct or is removed, it can affect the entire chain of other species and have unpredictable consequences. For instance, when the number of carnivores increases, the number of herbivore decreases. It becomes harder for carnivores to find food, and the population of carnivores decreases. In the process, carnivores and herbivores stay in a relatively stable equilibrium, each limiting the other's population.

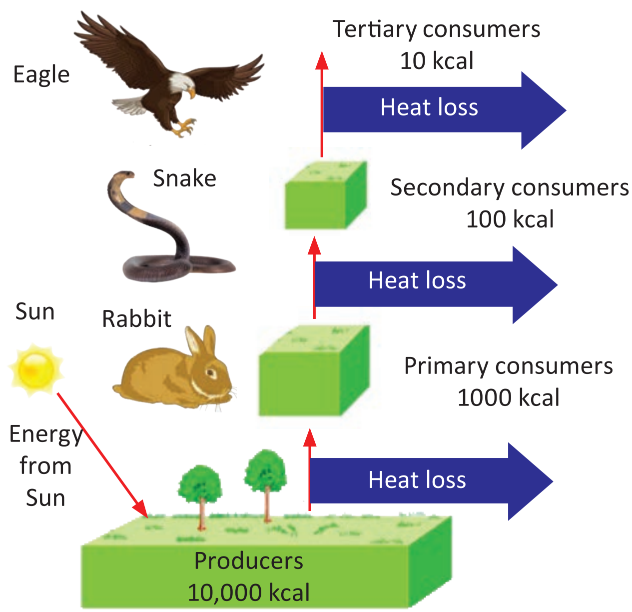


Figure 2.3. Energy flow through trophic levels

Reprint 2022

B. Ecological pyramids

The concept of ecological pyramid was developed by Charles Elton in 1927, hence, pyramid is also known as Eltonian pyramid. The pyramids are a graphical representation which depicts the number of organisms, biomass and productivity at each trophic level. All ecological pyramids begin at the bottom with the producer and proceed through different trophic levels. There are three types of ecological pyramids: pyramid of number, pyramid of biomass and pyramid of energy.

Activity 2.2. *Identifying the trophic level and types of consumers*

Instruction:

Use the hypothetical data given in Table 2.1 and construct pyramid of number, pyramid of biomass and pyramid of energy.

Table 2.1.

Trophic level	Numbers	Biomass (kg/m²)	Energy (kcal)
1st (rose, corn, rice)	50, 1000,2000	10, 30, 70	20, 35, 45
2nd (cow, mouse, rabbit)	10,13,17	5, 9, 15	2, 3, 5
3rd (fox, leopard, martin)	5,4,7	3, 2, 5	0.3, 0.3, 0.4
4th (tiger, lion)	2,3	1,1	0.05,0.05

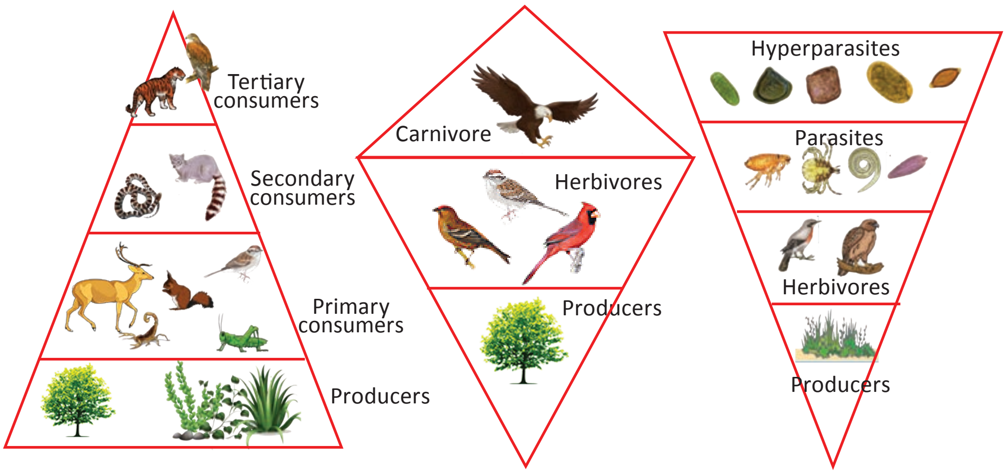
Questions

1. What is the shape of each pyramid?
2. Can there be more carnivores than herbivores in an ecosystem? Explain why?
3. Can the amount of available energy on a given trophic level be higher than the available energy on lower trophic levels? Why?

Reprint 2022

a. Pyramid of number

Pyramid of number shows the relationship between producers, herbivores and carnivores at successive trophic levels in terms of their number. There are three types of pyramid of numbers: upright pyramid of number, partly upright pyramid of number and inverted pyramid of number.



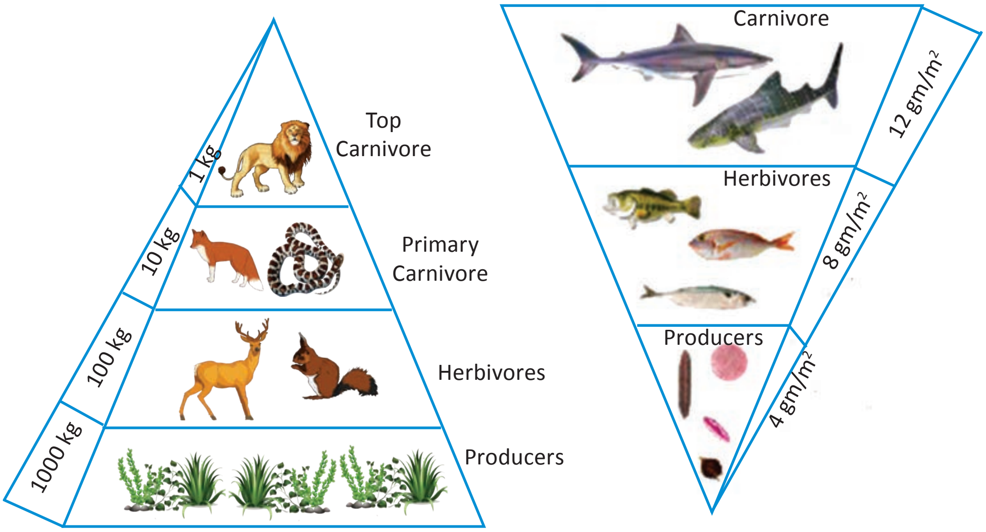
(a) Upright pyramid (b) Partially upright pyramid (c) Inverted pyramid

Figure 2.4. Pyramid of number

Upright pyramid of number is seen in the aquatic and grassland ecosystems. The base of the pyramid has numerous small producers which support lesser primary consumers which in turn support a smaller number of secondary and tertiary consumers (Figure 2.4a). Forest ecosystem shows partly upright pyramid of numbers (Figure 2.4b). The producers, which are mainly large-sized trees are lesser in number and form the base of the pyramid. This supports a greater number of herbivores which in turn support a fewer number of carnivores. The inverted pyramid of number is seen in the parasitic food chain as shown in Figure 2.4c. In this type of ecological relationship, a single plant may support the growth of many organisms and each organism, in turn, may provide nutrition to several parasites, which support many other parasites.

b. Pyramid of biomass

Pyramid of biomass is the graphical representation of the mass of living things present per unit area at different trophic levels, with producers at the base and carnivores at the apex. Pyramid of biomass can be upright as in a grassland ecosystem shown in Figure 2.5a or inverted, as in an aquatic ecosystem as shown in Figure 2.5b where the smaller weight of producers supports the consumers of larger weight.



(a) Upright pyramid of biomass (b) Inverted pyramid of biomass

Figure 2.5. Pyramid of biomass

c. Pyramid of energy

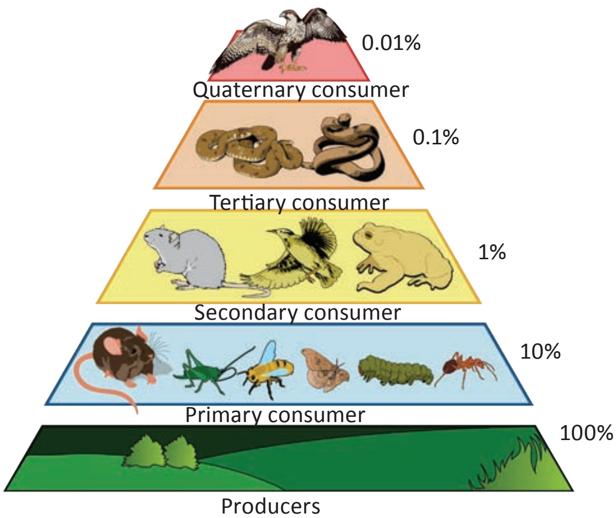


Figure 2.6. Pyramid of energy

An energy pyramid is a model that graphically represents the energy flow in a community. The different levels in the energy pyramid represent different groups of organisms present in a food chain at different levels. An energy pyramid's shape shows decrease in the amount of useful chemical energy in the form of food at each level as it is used by the organisms in that level. During the flow of energy from one organism to the other, there is considerable loss of energy in the form of heat. At each level, there is about 10% less energy available to put on the new biomass. Thus, pyramid of energy is always upright.

C. Organism relationships

All organisms in an ecosystem are connected through food chains and food webs. Ecological relationships help better describe how they are connected. Some of the ecological relationships are explained below:

Producers and consumers: Producers are organisms that produce their own food, and consumers are those that depend on producers for their food. Consumers in turn enrich the soil through the decomposition of their metabolic wastes and dead remains which help plants to grow.

Predation: It is a relationship wherein one organism hunts and eats the other organism. The organism that hunts is called predator, while the organism being hunted is prey.

Parasitism: It is a relationship in which one organism benefits, while the other one (host) is harmed. Based on where they are found, parasites are either ectoparasites or endoparasites. Fleas, lice, and leech are ectoparasites, while tapeworm, roundworm and flat worm are examples of endoparasites.

Commensalism: It is an association between two organisms in which one benefits and the other derives neither benefit nor is harmed. For example, orchids obtain their nutrition by growing on the branches of trees. There are four types of commensalism: chemical commensalism, phoresy, inquilinism and metabiosis.

Mutualism: It is a relationship in which both the organisms of different species interacting with each other are benefitted from the association. For example, ox peckers get food such as ticks and other parasites, from the body of zebras, while the zebras get rid of parasites. There are three types of mutualism: defensive, dispersive and trophic mutualism.

The nutrient elements used by the biotic components of an ecosystem are restored into the lithosphere when they die and decompose.

The interactions amongst the living organisms are crucial to maintain the balance in the ecosystem. If any one of the interaction fails to function, the health of the entire ecosystem is affected.

Activity 2.3. *Identifying the relationship of organisms*

Instruction:

Study Figure 2.7 carefully and identify the type of relationship between organisms and answer the following questions:

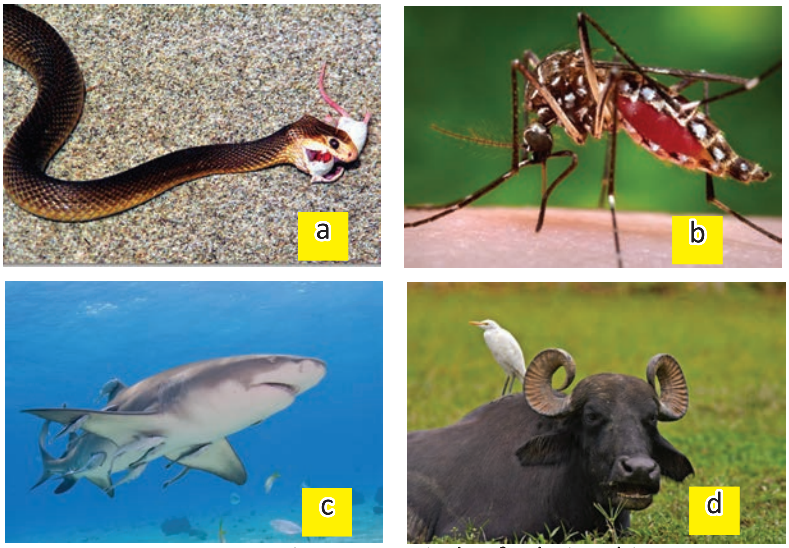


Figure 2.7. Kinds of relationship

Questions

1. Identify and describe the kinds of relationship depicted in Figure 2.7a, Figure 2.7b, Figure 2.7c, and Figure 2.7d.
2. What is the main difference between the relationship depicted in Figure 2.7c and Figure 2.7d.
3. How do these relationships shown by Figure 2.7 help in maintaining homeostasis in the ecosystem?
4. Give one example for each relationship evident in your locality.
5. Carry out a short project to find out more information about the types of commensalism and mutualism. Support your findings with appropriate examples.

Reprint 2022

Questions

Study the Figure 2.8 and answer the following questions:

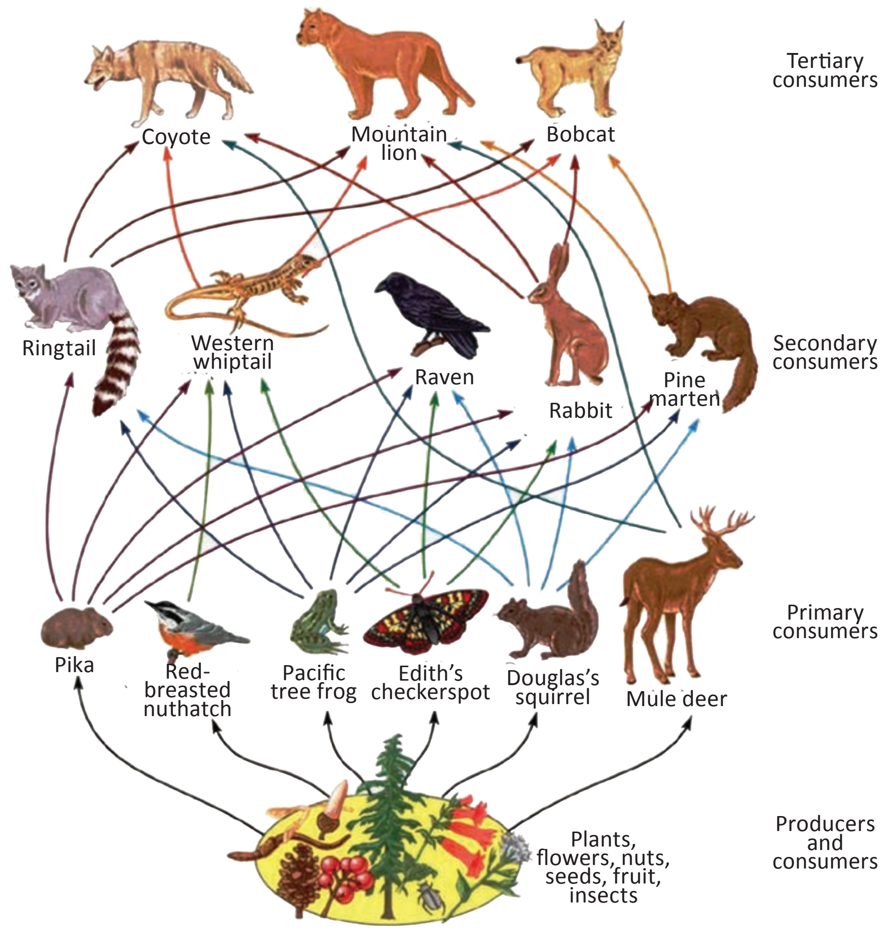


Figure 2.8.

1. Explain the significance of decomposers in the food web?
2. What anthropogenic activities would cause imbalance in the food web given in the Figure?
3. What could be the consequences in the food web if we remove pacific tree frogs?
4. Mention at least three types of relationships that you observe in the given food web.
5. Why does the number of organisms go on decreasing as we move from the producers and decomposer to the tertiary consumers in the food web?

2. Biogeochemical cycles

Learning Objectives

On completion of this topic, you should be able to:

- explain biogeochemical cycles with illustrations.
- explain that the biogeochemical cycles are affected by anthropogenic activities.
- explain how each component of the Earth's global system is involved in the biogeochemical cycle.

Earth is a complex system made up of many smaller systems through which nutrients are continuously cycled. Nutrients flow through the Earth's four spheres: the lithosphere, atmosphere, hydrosphere, and biosphere, under the influence of different natural processes. The natural processes like biological, geological, and chemical cycle facilitate the circulation of nutrients and elements throughout the biosphere. This process is known as biogeochemical cycle. It involves the movement of elements and compounds continuously between the Earth and its organisms. The biogeochemical cycles are divided into atmospheric and edaphic cycles

A. Atmospheric cycles

Some nutrients and elements are cycled through the atmosphere. Some of the most important cycles in the Earth system are hydrologic, carbon and oxygen cycles.

a. Hydrologic cycle (Water cycle)

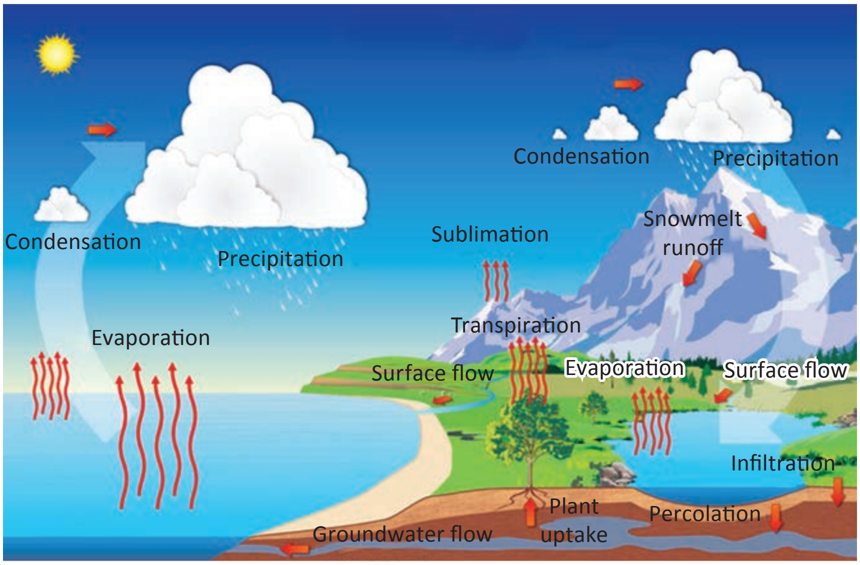


Figure 2.9. Hydrologic cycle

Reprint 2022

Hydrologic cycle is a natural process of water transfer that consists of three important phases as evapotranspiration, precipitation and runoff. It starts with evaporation from the surfaces of lakes, ponds, oceans, and transpiration from vegetation. The vapours rise and are transported to different places by wind and storm where they condense to form clouds. The clouds precipitate in the form of rain, snow, hail, mist, and frost. A part of this precipitation flows over the land as runoff, and part of it filters into the soil which builds up the ground water table. The surface runoff joins the streams and flows to the larger water bodies. Again, evapotranspiration starts from the surfaces of the water bodies and vegetation, and the cycle repeats.

b. Carbon cycle

Activity 2.4. ***Analysing of Carbon cycle***

Instruction:

Study Figure 2.9. Based on your earlier knowledge, complete the diagram by using the given keywords in the box, and answer the following questions.

respiration, sedimentation, combustion, dissolution, photosynthesis, decomposition, human activities

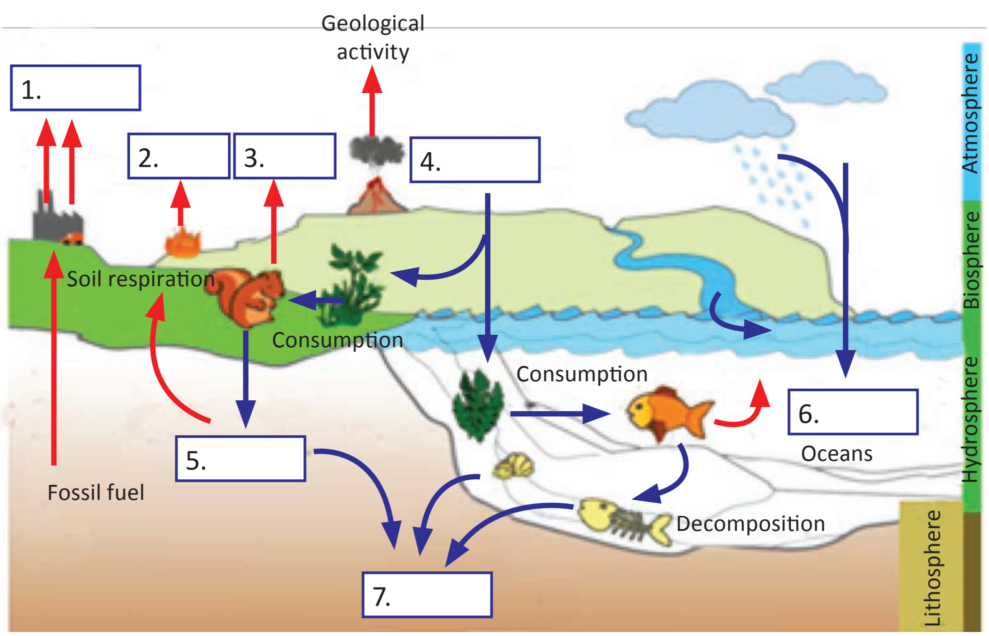


Figure 2.10. Carbon cycle

Questions

1. How is carbon released into the atmosphere?
2. What is the process by which fishes obtain carbon?
3. Identify the four main reservoirs of carbon on the Earth from Figure 2.10.
4. Why is cycling of carbon important for the plants?

c. Oxygen cycle

The atmospheric concentration of oxygen is one of the contributing factors for the existence of life on the Earth. The bulk of the atmospheric oxygen is in the gaseous state, which represents about 21% of the atmosphere.

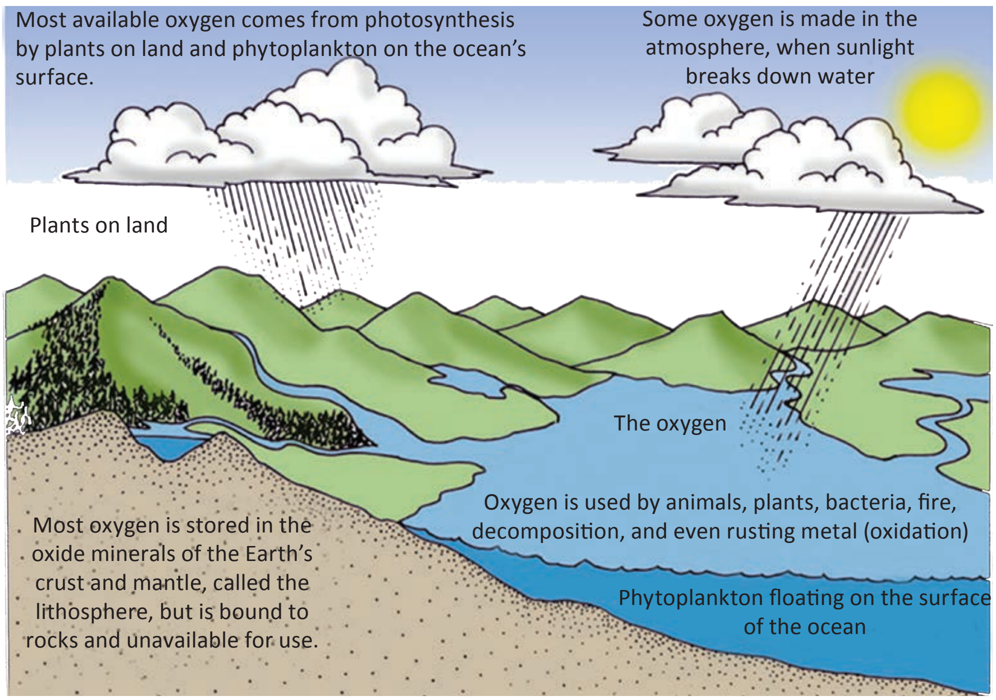


Figure 2.11. Oxygen cycle

The oxygen cycle is the biogeochemical cycle that describes the movement of oxygen within and between its three main reservoirs: atmosphere, biosphere, and lithosphere. The main driving factor of the oxygen cycle is photosynthesis. So, the oxygen cycle and carbon cycle are closely related because photosynthesis is also an intrinsic process in the carbon cycle. The overall reaction of photosynthesis shows that carbon dioxide and water reacts to produce oxygen and carbohydrate.

$$6CO_2 + 12H_2O \longrightarrow 6O_2 + C_6H_{12}O_6 + 6H_2O$$

Photolysis is an additional source of free atmospheric oxygen, whereby high-energy ultraviolet radiation from the Sun breaks down the atmospheric water and nitrous oxide into their component atoms. The free H and N atoms escape into the space, leaving O_2 in the atmosphere.

$$H_2O + \text{energy} \longrightarrow 4H + O_2$$

$$2N_2O + \text{energy} \longrightarrow 4N + O_2$$

The free oxygen is lost from the atmosphere through respiration and decay. They are the mechanism in which animals and bacteria take in oxygen and release carbon dioxide. The lithosphere also uses free oxygen in chemical weathering and surface reactions. For example, oxygen is used during rusting of iron.

$$4FeO + O_2 \longrightarrow 2Fe_2O_3$$

Oxygen is also cycled between the biosphere and lithosphere. Marine organisms in the biosphere create calcium carbonate shell material ($CaCO_3$) that is rich in oxygen. When the organism dies, its shell is deposited on the shallow sea floor and buried over time to create the limestone sedimentary rock of the lithosphere. Weathering processes initiated by organisms can free oxygen from the lithosphere. Plants and animals extract nutrient minerals from rocks and release oxygen in the process.

Due to increased human developmental activities, the concentration of oxygen in the atmosphere is changing. For instance, for every molecule of CO_2 formed through combustion of hydrocarbons, one molecule of O_2 is lost from the atmosphere. The rampant deforestation occurring throughout the world is reducing the capacity to absorb carbon dioxide, thereby increases the amount of carbon dioxide in the atmosphere.

B. Edaphic nutrient cycles

In edaphic nutrient cycles, nutrients are mainly cycled through the soil in the form of different compounds.

a. Nitrogen Cycle

Nitrogen is an important constituent of amino acids and proteins in plants and animals. Nitrogen is the most abundant gas in the atmosphere as it constitutes about 78% of the atmosphere. However, the atmospheric nitrogen cannot be used by most of the living organisms. Plants can use nitrogen either as nitrates or ammonia in the form of salts. This is achieved by the fixation of atmospheric nitrogen either by a natural process or by a synthetic process.

The natural process of nitrogen fixation can occur either by lightning and thunderstorms or by microorganisms. During periodic thunderstorms and lightning, the gaseous nitrogen is converted into nitric oxide, which gets oxidised into nitrogen dioxide. Both the oxides of nitrogen get dissolved in rain and reach the soil, where the nitric acid formed combines with salts in the soil to form the corresponding nitrates.

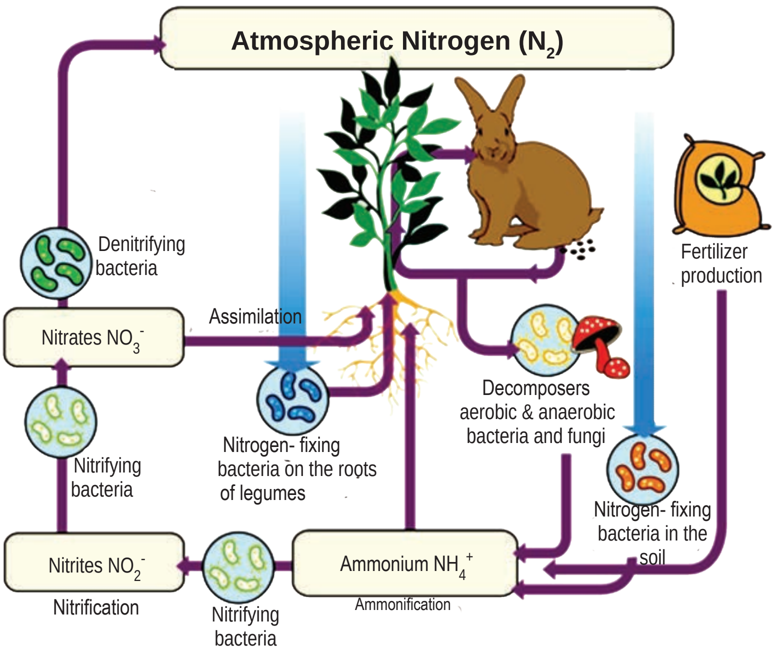


Figure 2.12. Nitrogen cycle

Nitrogen fixation by microorganisms is an alternate natural process. Microorganisms fix atmospheric nitrogen by converting it into ammonium ions. This is carried out by nitrifying bacteria such as aerobic *Acetobacter* and anaerobic *Clostridium* and symbiotic nitrifying bacteria, *Rhizobium*, living in association with leguminous plants as shown in Figure 2.12.

The decomposition of dead plants and animals, and their wastes releases ammonia into the soil. The ammonium ions and ammonia are oxidized into nitrites or nitrates by specialised bacteria. For example, *Nitrosomonas* bacteria can promote oxidation of ammonia into nitrite, which is further oxidized into nitrate by the bacteria *Nitrobacter*. The nitrates, thus obtained in the soil are actively absorbed across root hairs by the plants and converted into amino acids.

The denitrifying bacteria, e.g. *Pseudomonas* present in soil as well as in oceans convert the nitrates into nitrogen gas which diffuses out of the soil back into the atmosphere; thus, completing the cycle.

Human activities like burning of fossil fuels and application of nitrogen-based fertilisers can alter the amount of biologically available nitrogen in an ecosystem. Excessive use of nitrogenous fertilisers can lead to growth of massive plants leading to eutrophication, which affects the aquatic ecosystem. Release of nitrogen oxides from burning of fuels, decomposition of livestock wastes and chemical fertilisers form acid rain. Acid rain damages the aquatic and terrestrial ecosystems.

b. Phosphorus cycle

Activity 2.5. ***Understanding the phosphorus cycle***

Instruction:

1. Work in pairs.
2. Study Figure 2.13 and answer the following questions:

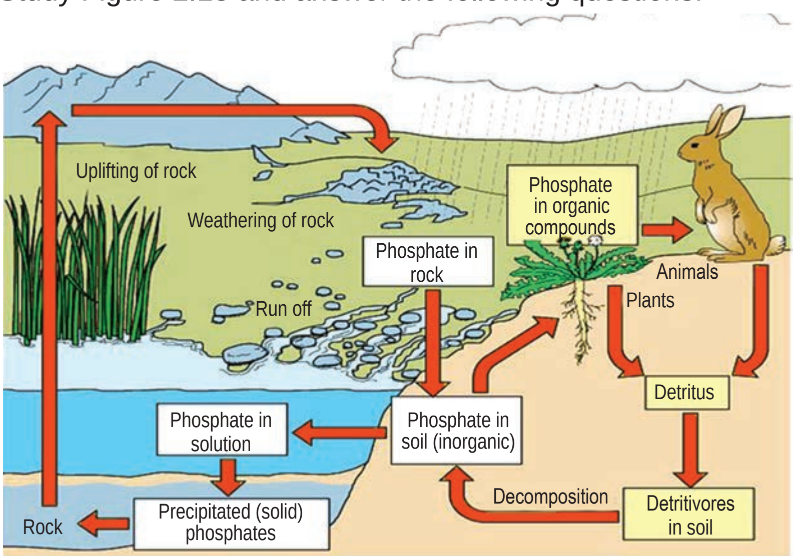


Figure 2.13. Phosphorus cycle

Questions:

1. Explain the phosphorus cycle given in Figure 2.13.
2. What role does phosphorus cycle play in maintaining the balance in nature?
3. How is phosphorus cycle related to eutrophication?
4. What are some of the human activities that alter the phosphorus cycle?

c. Sulphur Cycle

Sulphur plays a vital role in organisms as an essential component of proteins, though needed in small quantity. Sulphur circulates through the biosphere in the sulphur cycle. Much of the Earth's sulphur is stored underground in rocks and minerals, including sulphate salts buried deep under ocean sediments. It is released from the sedimentary rocks by weathering and decomposition of organic matter by bacteria and fungi.

Sulphur enters the atmosphere in the form of hydrogen sulphide and sulphur dioxide. Hydrogen sulphide is released from active volcanoes and by the putrefaction of organic matter by bacteria and fungi as shown in Figure 2.14.

Sulphur dioxide is added through volcanic eruptions, hot springs, combustion of fossil fuels and from metallurgical operations.

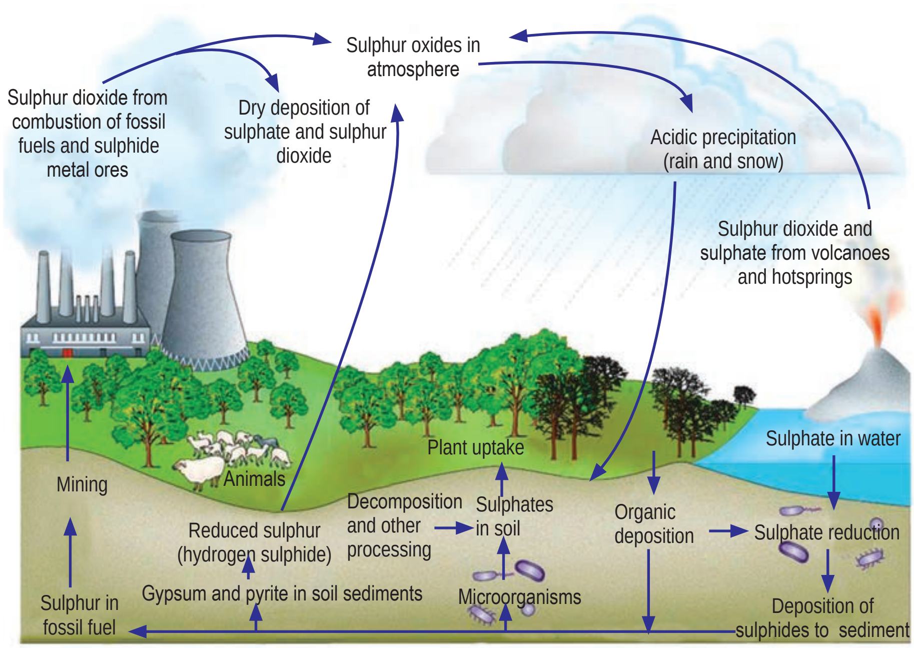


Figure 2.14. Sulphur cycle

In the atmosphere, sulphur dioxide is oxidised into sulphur trioxide gas which reacts with water droplets to produce sulphuric acid. Sulphur dioxide also reacts with other chemicals in the atmosphere such as ammonia to produce tiny particles of sulphate salts. These droplets and particles fall to the Earth as acidic sulphate deposition, which is absorbed by the plants for making amino acids and proteins.

In anaerobic soils and sediments, sulphate is reduced to hydrogen sulphide by sulphate reducing bacteria like *Desulfavibrio*. Certain species of *Beggiatoa* and green and purple sulphur photosynthetic bacteria oxidise hydrogen sulphide to elemental sulphur. (Figure 2.13)

Questions

1. How do the activities shown in the pictures in Figure 2.15a and Figure 2.15b affect the carbon and oxygen cycles?

(a) (b)

Figure 2.15.

2. In the biosphere, nutrients follow circular pathways, while energy flows in a linear manner. Explain.
3. How do developmental activities affect the hydrologic cycle?
4. Aeration of a grass lawn is an important activity. Justify the statement in relation to the biogeochemical cycle.
5. Human activities can alter the sulphur cycle. Suggest some ways to minimise the effects.

3. Carrying Capacity of the Ecosystem

Learning Objectives

On completion of this topic, you should be able to:

- explain carrying capacity of the ecosystem.
- relate carrying capacity with the availability of resources.
- explain the influence of symbiotic relationships among the species on the carrying capacity.

In an ecosystem, organisms depend on each other as well as compete amongst themselves for food, shelter and mate. These interrelationships and interdependencies of organisms generate stable ecosystems. The population of organisms can go on increasing, however, the resources in the environment do not have the capacity to match the increasing population. This can affect the interactions amongst organisms.

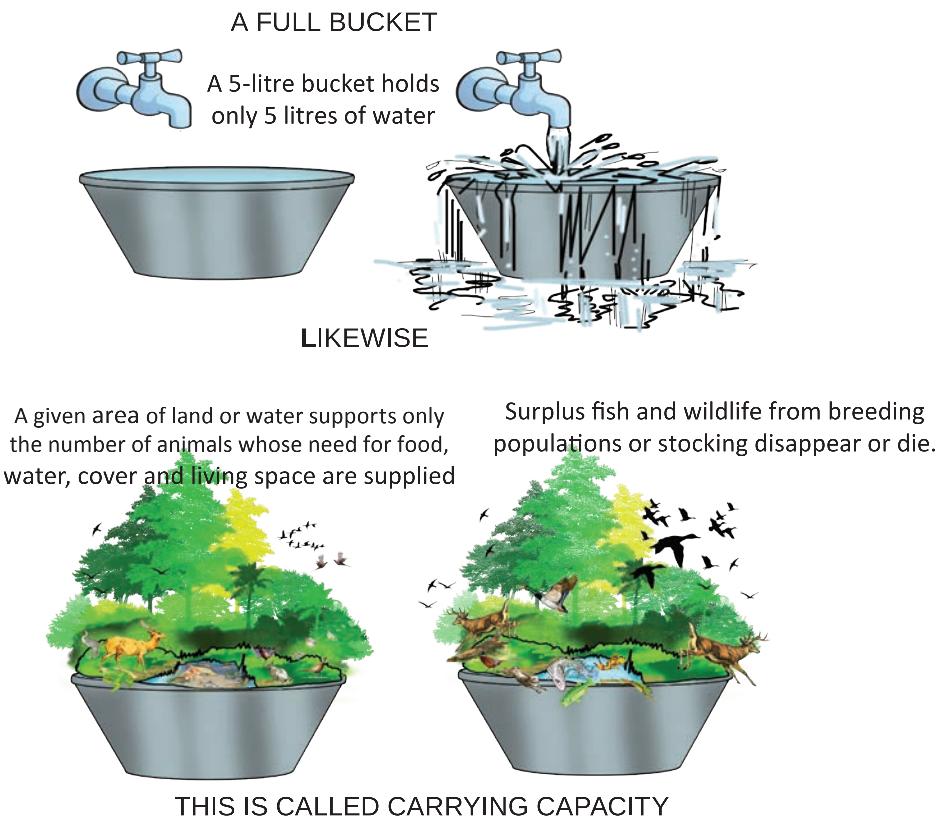


Figure 2.16. Analogy of carrying capacity

Reprint 2022

A. Interaction among species and the carrying capacity

The size of a population that can be supported indefinitely by the resources and services of a given ecosystem is called carrying capacity. No additional individuals can be supported beyond this carrying capacity for long. When a population is within its carrying capacity, the size of the population is at equilibrium.

Activity 2.6. *Interpreting carrying capacity graphs*

Instruction:

1. Use the data from Table 2.2 to plot population growth curve.
2. Plot two separate line graphs for bacteria and paramecium with X-axis for time and Y-axis for population.

Table 2.2.

Time (hours)	A. Population size (number of bacteria)	B. Population size (number of paramecium)
0	1	1
1	2	3
2	4	5
3	8	7
4	16	9
5	32	11
6	64	13
7	128	17
8	256	19
9	512	20
10	1024	20

Questions:

1. Identify and interpret the shape of graphs of carrying capacity.
2. Which graph represents a stable ecosystem? Why?
3. What is the importance of the idea of carrying capacity to an ecologist?
4. Explain the relevance of this knowledge for a cow herder.

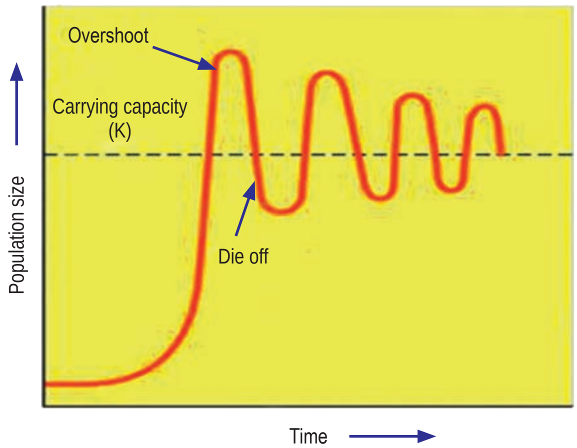


Figure 2.17. Logistic population growth

When resources are unlimited, populations exhibit exponential growth, resulting in a J-shaped curve. However, when resources are limited, populations exhibit logistic growth. In logistic growth, when the population exceeds the carrying capacity of the environment, it is termed as overshoot. However, population expansion decreases as resources become scarce; this is called a crash or die-off. As a result, there is levelling off of the population, leading to an S-shaped curve as shown in Figure 2.17.

A symbiotic relationship exists when there is a close, long-term relationship between two organisms of different species. Interactions among different species influence the carrying capacity of ecosystem. Carrying capacity increases when species derive a mutual benefit or decreases when their interactions are antagonistic. For instance, lichens show a symbiotic relationship between a phycobiont (algal) and a mycobiont (fungal) partner. Existence of lichens in an ecosystem improves the soil formation making water and minerals available for the plants. This improves the net primary productivity of the ecosystem which ultimately leads to an increase in the carrying capacity.

However, some of the symbiotic interaction like parasitism shows the antagonistic symbiotic relationship as a pathogenic plant parasite hampers the plant growth and development, which can decrease the net primary productivity of the ecosystem thereby decreasing the carrying capacity.

B. Limiting factors for carrying capacity

The actual population size of a species is normally either above or below the carrying capacity. If the population size gets much larger than the carrying capacity, some limiting factors regulate the population size. For instance, limiting factors can lower birth rates, increase death rates, or lead to emigration.

The carrying capacity of an ecosystem or an organism can be affected by the following limiting factors:

(i) Water and energy

Animals need water for their metabolic processes of digestion, homeostasis, excretion, etc. Similarly, plants need water for various physiological processes like photosynthesis, transpiration, transportation and growth. Where water becomes scarce, food may also become scarce resulting to decrease in population. The scarcities of food and water resources compel species to compete amongst themselves. The more energy an organism spends on competing, the less energy it has for growth and reproduction.

(ii) Predation

The predator-prey relationship is important in shaping the species communities. Predators determine the size of prey populations and determine the places prey can live and feed. If the population of prey grows too large, the increase in the predation controls the population growth of the prey. Therefore, the predator and prey populations oscillate in synchrony with each other.

(iii) Competition

As the population becomes denser, individuals compete to obtain the resources they need. When resources become scarce, members of a population fight for resources to survive. For example, tiger and leopard compete for hog, and different plants in the forest compete for nutrients and sunlight. Often competition results in the reduction or complete elimination of one species from the area due to competitive exclusion.

(iv) Space

Organisms require space for growth, shelter and reproduction. Sufficient space within a habitat allows organisms to find adequate food and water. Without space, animals cannot ensure a place to hide and raise their young ones or to nest. Crowded populations often exhibit increase in aggression and infant mortality.

Some other factors that limit the size of population are pollution and destruction of habitat due to human activities and natural calamities.

Questions

Study Figure 2.18 and answer the following questions:

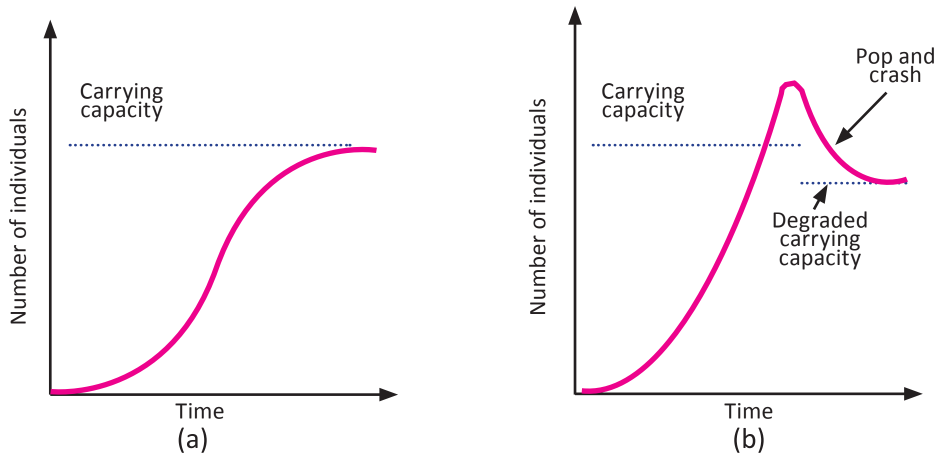


Figure 2.18.

1. What relationship do you observe between the population growth and the carrying capacity in Figure 2.18?
2. Compare and contrast Figure 2.18a and Figure 2.18b based on population growth and resource consumption.
3. In Figure 2.18b, population rises beyond the carrying capacity (over shoot) and gradually falls back to crash/die off state.
   a) Why do you think the population does not increase continuously?
   b) What would happen once the carrying capacity is upset?
3. Which Figure shows the existence of good interrelationships and interdependencies among the organisms to generate stable ecosystem? Why?

Exercise

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

   i. When deforestation occurs in an area, what immediate effect does this have on the water cycle?

      A. There is more runoff water.
      B. There is less runoff water.
      C. More water is returned to the atmosphere.
      D. Less water returned to the atmosphere.

   ii. All of the following statements concerning characteristics of predator-prey relationships are correct EXCEPT

      A. A rise in the population of prey is often followed by a rise in the population of predators.
      B. A rise in the population of predators is followed by a decrease in the population of prey.
      C. The production of large numbers of offspring within very short period of time ensures the survival of some prey populations.
      D. The population of predators is influenced by the population of the prey.

   iii. Addition of oxides of nitrogen and oxides of sulphur to the atmosphere leads to the formation of acid rain. Some of the deleterious effects of acid rain on ecosystem are given below. Which of the following statement is not TRUE about acid rain?

      A. The acid rain causes excessive leaching of labile minerals from the soil reducing its fertility.
      B. The lichen populations are sensitive to acid rain and their population will be eliminated.
      C. The acid rain destroys the symbiotic association of Rhizobium and legumes which may have serious consequences on the soil nitrogen content.
      D. Acid rain helps in the decomposition of litter by increasing the microbial population

   iv. Which of the following organisms in the food web shown in Figure 2.19 is most likely to be located at the apex of the pyramid of biomass?

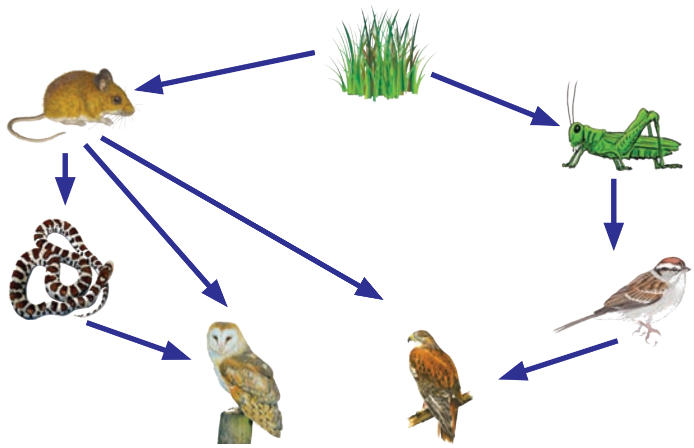


Figure 2.19.

A. grass
B. grasshopper
C. snake
D. hawk

v. Photosynthesis is equally important for both oxygen cycle and carbon cycle. The best reason that support the statement is

A. Plants are the only organisms that provide food for the animals.
B. Photosynthesis cannot occur without carbon dioxide.
C. Carbon dioxide is formed when carbon combines with oxygen.
D. Carbon dioxide is used and oxygen is released during photosynthesis.

2. ***Fill in the blanks with the correct form of word/s.***

i. The absorption and downward movement of water into the soil layer is called…………………

ii. The ……………….are the organisms that help return the nutrients to the abiotic part of ecosystem.

iii. A clownfish lives in a sea anemone. The anemone is not hurt, but the clownfish can live in its safety. This is an example of …………………

iv. The process in which living things in water bodies are suffocated due to pollution by fertilizers is called ……………………

v. The excessive degradation of the natural resources is an indication of increase in population beyond its…………………..

Reprint 2022

3. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.***

   i. In different trophic levels, primary consumers have the most energy available to them.
   ii. The breaking of water and nitrous oxide molecules by ultra violet radiation from the sun contributes to addition of oxygen in the atmosphere.
   iii. Number pyramid of desert ecosystem is always upright, whereas the number pyramid of forest ecosystem is inverted.
   iv. Elemental nitrogen cannot be directly used by the plants; however, it can be fixed by microorganisms into soluble nitrous oxides which are absorbed by the plants.
   v. The limiting factors of carrying capacity will always decrease the population.

4. ***Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.***

Column A	Column B
1. Scavenger	a. Bacteria
2. Detritivore	b. Wolf
3. Saprophyte	c. Vulture
4. Primary consumer	d. Lichens
5. Secondary consumer	e. Wooden beetle
	f. Squirrel

5. ***Answer the following questions.***

   i. Describe how the carbon compounds in plants end up in animals such as foxes.
   ii. Why are there more insects than tigers in the world?
   iii. Ecologists discovered that trout were dying in a stream that ran through some farmland where nitrogen fertilizer was used on the crops. Explain what might happen? Formulate a hypothesis in order to test your idea.
   iv. Why do farmers not apply carbon in their field to grow their crops but often need to add fertilizer containing nitrogen and phosphorus?
   v. Explain how limiting factors affect populations in ecosystems.

vi. How does the understanding of carbon cycle help scientists prepare and prevent the global climate changes?

vii. Humans should all be vegetarians. Justify the statement.

viii. Figure 2.20 shows the flow of energy (red arrows) and nutrients (blue arrows) in an ecosystem. Study the figure and answer the questions:

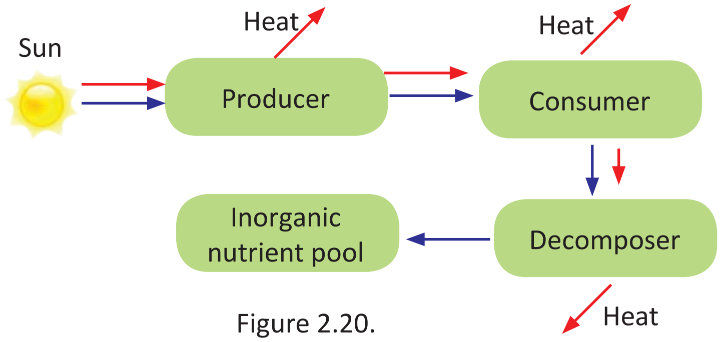


Figure 2.20.

a. Identify the direction in which the energy and nutrients follow in an ecosystem.

b. Justify your answers in question (a).

c. Relate the concept of the figure to the balance in ecosystem.

ix. Study the context given based on Figure 2.21 and answer the following questions:

Students have investigated a food chain in a garden.

The students found 650 aphids feeding on one bean plant.

Five ladybirds were feeding on the aphids

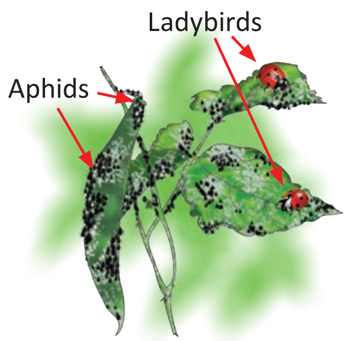


Figure 2.21.

a. Draw a pyramid of biomass for this food chain. Label the pyramid.

b. The biomass in the five ladybirds is less than the biomass in the bean plant. Give two reasons why.

c. The carbon in dead bean plants is returned to the atmosphere via the carbon cycle. Describe this part of the carbon cycle.

Reprint 2022

3

CHAPTER

People and Environment

The environment of an organism is its surrounding comprising of biotic and abiotic components. The environment provides resources that ensure the well-being of each species in an ecosystem. The factors like changing lifestyles of humans, industrialisation and urbanisation have increased pressure on the environment leading to degradation of natural resources. For instance, humans depend excessively on natural resources to fulfil their socio-economic demands. Therefore, it is necessary to understand how humans depend and interact with the environment.

Reprint 2022

1. Dependency on Natural Resources

Learning Objectives

On completion of this topic, you should be able to:

- describe the types of natural resources and their uses.
- describe the dependency of livelihood of communities on natural resources in Bhutan.
- analyse the impacts of human interactions on natural resources.

Nature provides all resources necessary for humans' survival. With modernisation and increase in human population, the demands on the natural resources are on the rise, degrading the health of the environment. The environmental degradation ultimately affects the well-being of all living organisms in an ecosystem. Therefore, it is crucial for us to understand about our interactions with the environment for the sustainable use and management of the natural resources.

A. Types of natural resources and their benefits

Natural resources include all the resources that exist in natural state and all systems that are or can be indispensable to man in the actual technological, economical and social circumstances. The natural resources can be categorised broadly as renewable resources and non-renewable resources. Renewable resources are those that are constantly available or can be replenished by natural processes, for example, solar, water and wind. Non-renewable resources are those that cannot be easily replaced once they are depleted. Fossil fuels and minerals are examples of non-renewable resources.

Natural resources can have a direct economic consumption values, or can have values as input factors in production of other consumables. For instance, they are the primary inputs in the production of all manufactured goods. The benefits derived by humans from the natural resources are broadly categorised as provisioning, regulating, cultural and spiritual supporting services as shown in Figure 3.1.

Figure 3.1. Benefits and services of natural resources

Activity 3.1. *Studying the dependency on natural resources*

Instruction:

Work in small groups. Read the extract and answer the questions that follow:

Community based natural resource management

Wamrong and Kangpara Gewog under Wamrong and Thrimshing Dungkhags respectively, are located in Trashigang dzongkhag in eastern Bhutan. With altitudes ranging from 1900-2108 meters above sea level, the areas consist largely of broadleaf forests with potentially high diversity of faunal and floral species. These two gewogs consist of 64 villages with 949 households, home to more than 10,000 subsistence farmers. About 85% of the households depend on agriculture activities for rural livelihood and they cultivate various cereals and vegetables while 15 % of the households engage in development of handicrafts such as bamboo weaving and wood carving. The villagers almost entirely depend on the natural resources for water, wood, timber, fodder, and non-timber forest products such as cane and bamboo.

Most of the villages in Wamrong and Kangpara are scattered amidst forest areas and lack modern infrastructural facilities. The increasing aspirations of the inhabitants of Wamrong and Kangpara for economic development and expanding access to market will potentially lead to degradation of the natural resources. With support from the Embassy of Finland in New Delhi, RSPN began work on initiation of community based natural resource management program in the area. A Field Office was set up in Wamrong in September

2007 to coordinate the program and its activities. Socio-economic and biodiversity surveys have been carried out in four representative villages i.e., Passangphu, Maduwa in Kangpara and Moshi and Khaimanma in Wamrong. Survey results indicate that deforestation due to increasing human population and uncontrolled exploitation of forests, dwindling water sources, decrease in soil fertility, low food productivity, soil erosion, and landslide are some of the common threats to human livelihood in these areas. The community based natural resource management program is expected to be ecologically and economically beneficial to the local population. Heavy dependence of the local population on natural resources call for continued efforts to strengthen community involvement in natural resource management. Communities in Wamrong and Kangpara represent the difficulties commonly faced by rural communities in Bhutan. Successful and appropriate interventions in enhancing both environmental conservation and socio-economic welfare of the local people will provide the basis for up-scaling and replication in other communities.

(Source: http://www.rspnbhutan.org/programs/sustainable-livelihoods/wamrong-kangpara.html)

Questions

1. Identify two main natural resources on which the livelihood of people of Kangpara and Wamrong village depend.
2. Describe the potential threats to the natural resources in these villages.
3. Community based natural resource management is one of the initiatives carried out in the villages. Why do you think such initiative is essential for the community?
4. Construct a concept map to show the dependency of Bhutanese on the natural environment.

Reprint 2022

B. Human activities and their impacts on the environment

Human activities pose considerable threats to the environment in several ways. Some of the damaging activities are: producing waste, damaging habitats, removing too many species from the ecosystem, etc. Sometimes, such activities are so severe that the ecosystems do not get time to regenerate their losses. This phenomena is generally termed as 'ecocide' which refers to the destructive impact of human activities on their own natural environment.

One of the earliest attempts to describe the role of multiple factors in determining environmental degradation was calculated by I = PAT equation, which was first proposed by two scientists named Paul Ehrlich and John Holdren in the early 1970s. It describes the multiplicative contribution of population (P), affluence (A) and technology (T) to environmental impact (I).The impact of human activities on the environment is a function of three variables, in which an increase in anyone of them results in an increase in the impact.

a. Population

Although the growth rate of the human population varies from nation to nation, the overall environmental effects of the rapidly growing human population are global. An increase in population makes extreme demands to expand living areas, which results in the clearing of more land for housing. The growing need for resources, such as water, food and fuel increases human dependency on natural resources. Providing the basic needs to the growing population results in the depletion of natural resources and an increase in greenhouse gas emissions that are detrimental to the environment. In other words, as the population increases, so does the environmental impact.

b. Affluence

It represents the average consumption of resources by each person in the population. As the consumption of each person increases, the ecological footprint increases, ultimately increasing the environmental impact. GDP per capita is an important statistic which can be used as a common proxy for measuring the average consumption. Increased consumption significantly increases the human environmental impact because each product consumed has wide ranging effects on the environment.

c. Technology

The technology represents the environmental impact due to creating, transporting and disposing of the technological goods, services and amenities used. Although improvements in efficiency of technologies can reduce the extent and intensiveness of resource uses, the increase in P and A can contribute to environmental degradation. Since technology can affect environmental impacts in many ways, the unit for T is often tailored for the situation I=PAT, the equation is being applied to. For example, for a situation where the human impact on climate change is being measured, an appropriate unit for T might be greenhouse gas emissions per unit of GDP.

Activity 3.2. *Identifying environmental impacts due to human activities*

Instruction:

1. Work in groups to complete Table 3.1.
2. Assign each group the following objects like notebook, shoe, classroom desk, window pane glass, pen, blackboard chalk, etc.
3. The group traces the types and sources of raw materials used in producing the object, and how the object reaches humans from the production point.
4. Discuss and identify the impacts on the environment due to production and transport of object to humans.

Table 3.1. Production of goods vs environmental impacts

Sl. no	Type and source of raw materials used in producing the object	Impact(s) on the Environment
1	Notebook	
2	Shoe	
3	Classroom desk	
4	Window pane glass	
5	Pen	
6	Blackboard chalk	

Reprint 2022

Questions

1. What are the ultimate sources to make these objects?
2. How does the production of these objects affect the environment?
3. Relate production of any one of the object in the table to exploitation of natural resources.

Questions

1. Study Figure 3.2 and answer the following questions:

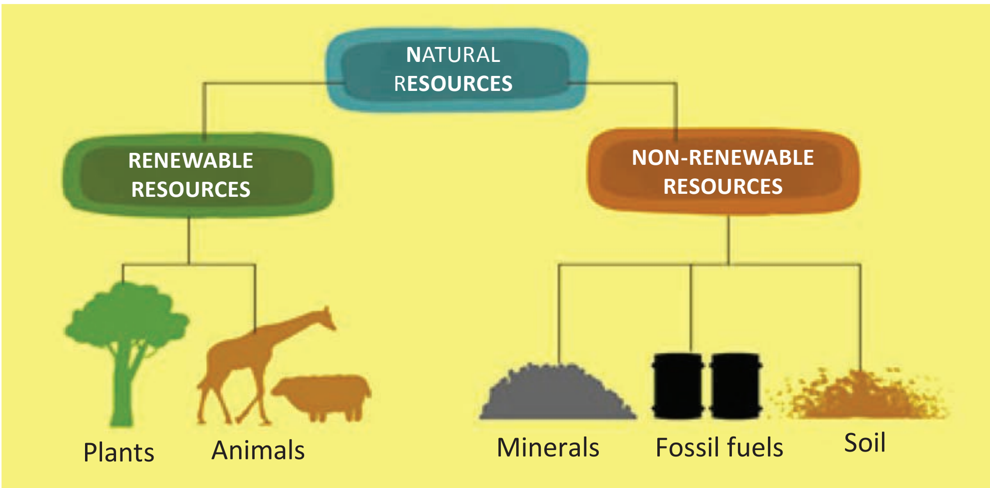


Figure 3.2. Types of natural resources

   a) Why do you think plants and animals are categorised into renewable natural resources?
   b) Suggest the basis on which the classification of resources is done.
   c) What are some of the important benefits derived by human from the nature?

2. In Bhutan, the use of natural resources, especially forest resources, are essential component of livelihood and culture. Narrate some of the significant impacts of these practices on the environment.
3. Why is affluence considered one of the variables in the measurement of impact of human activities on environment?

2. Interdependency of Humans and Environment

Learning Objectives

On completion of this topic, you should be able to:

- explain coevolution and coadaptation.
- analyse how human interactions modify ecosystems and environment.
- evaluate the changing relationship of humans with the environment.

The natural world and its driving forces are critical for the well-being and sustenance of the gene flow through the time. Humans depend on the environment for all their basic necessities. The environment, therefore, influences the lives of human and other living organisms in the natural world. The natural world in its normal state coexists with humans and other living things. Humans respond to changing environment through the biological processes of coadaptation and coevolution.

A. Coadaptation and coevolution

The plants, animals and microorganisms of an ecosystem are organised in a food chain, each functioning as part of a food web. Some of the functional ways are coadaptation and coevolution. Coadaptation and coevolution are integral part of an ecosystem. Coadaptation refers to a process wherein organisms adapt to the changing environment, or a process in which two or more interacting species adapt to each other mutually for their survival through natural selection. While adaptation can take any form of relationship that enhances survival, the most conspicuous forms of coadaptation are associated with the ways in which animals and microorganisms obtain nutrition from other living organisms in the food web. Species that have lived together in the same ecosystem for thousands of years have coadapted to each other through biological evolution.

Figure. 3.3. Coadaptation

For example, a caterpillar (larva) of lycaenid butterfly and the ant formica fusca illustrate a good coadaptation as shown in Figure 3.3. These ants normally feed on lycaenid butterfly larva. However, lycaenid larve have evolved with specialised glands that secrete a substance (honeydew) on which the ants feed. Thus, the larvae are instead

Reprint 2022

protected from being eaten by the ants or other predators.

Coadaptation between different organisms in the food web results in coevolution. Coevolution occurs when two or more organisms evolve together in adaptation to their environments. For example, coevolution occurring between predator and prey, predators evolve effective ways like higher speed, stealth, and camouflage to hide while approaching the prey and capture them. They also develop a good sense of smell, sight, or hearing to find the prey and the right kind of mouth parts or digestive system. Likewise, the prey responds by evolving speed, camouflage to hide from the predator, develops a good sense of smell, sight, or hearing to detect the predator and thorns, toxins to spray to avoid the capture. Similarly, coevolution can happen between humans and the ecosystem.

a. Coadaptation in traditional social system

Traditional societies are a rich source to exemplify coadaptation between the social systems and ecosystems. Centuries of trial-and-error cultural evolution have fine-tuned many aspects of traditional social systems to their environment.

Human social systems and ecosystems show complex adaptive systems. As shown in Figure 3.4, ecosystems and human social systems have many of their components connected. They also adapt to ecosystem through feedback structures to promote survival in a constantly changing environment. For example, according to the Food and Agriculture Organisation of the United Nations, at least one-third of

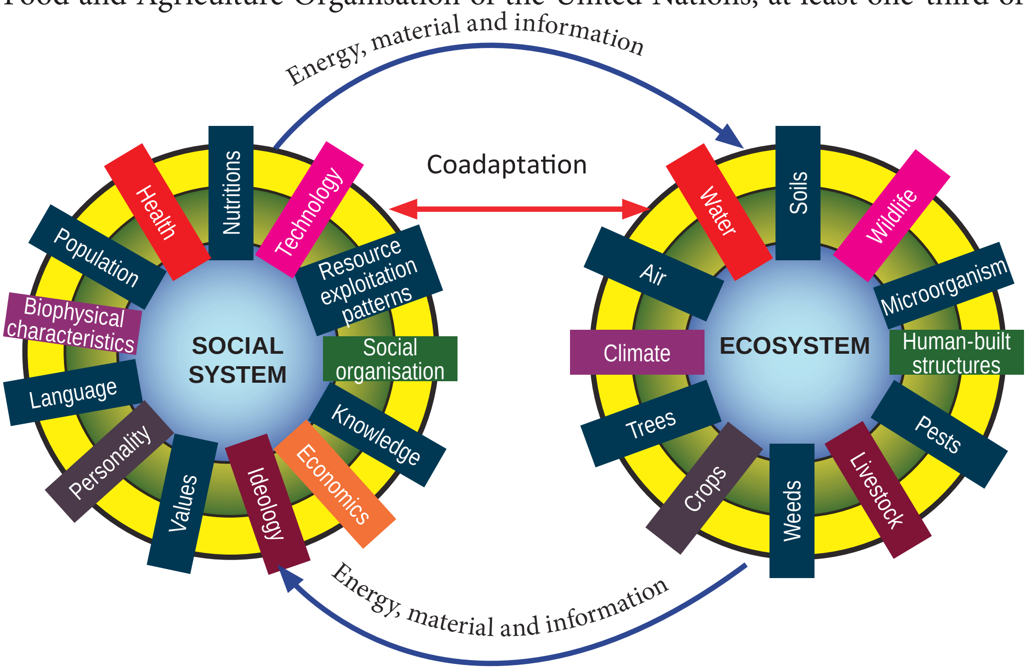


Figure 3.4. Interaction, coevolution and coadaptation of the human social system with the ecosystem

the world's agricultural crops depend upon pollination provided by insects and other animals. So, if something happens to those pollinators, it has an impact on the amount of food available to everyone in the world.

Activity 3.3. *Analysing coevolution of people and ecosystem*

Instruction:

Read the following extract and answer the questions that follow:

Approximately 100 years ago, the French moved large numbers of people from the lowlands to the mountains to work on rubber plantations and work at tin mines in colonial Vietnam. Unfortunately, many lowland people died of malaria transmitted by mosquitoes in the mountains. Although the mountains have malaria-transmitting mosquito species, the disease was never a serious problem for the mountain people. This is because mountain people build their houses raised above the ground, keep their animals below the house and have their cooking fire inside the house. Mosquitoes fly close to the ground, bite animals instead of people and are repelled by smoke. The mountain people were protected from malaria without realizing that mosquitoes transmit the disease. However, lowland people build their houses right on the ground, keep their animals away from the house and cook outside. This lowland house design worked well in the lowlands but was not adapted to the mountain ecosystem.

If mountain people were asked why they built their houses in a specific way, they would say it is tradition. In fact their house design was a product of centuries of cultural evolution that adapted their buildings to all of their needs, including health.

In 1940, scientists invented DDT, an effective insecticide against mosquitoes that transmit malaria. Malaria almost disappeared by the end of the 1960s. However, mosquitoes returned during the 1970s because they evolved resistance to DDT. A few mosquitoes had a genetic mutation that protected them from DDT. There was also a behavioural mutation in some regions. The mosquitoes started to rest on vegetation outside the houses instead of house walls sprayed with DDT. DDT was not a sustainable technology for malaria control. The mosquito example illustrates how natural ecosystems reorganise themselves.

In a similar way, the natural components of agricultural and urban ecosystems also adapt to human actions by reorganizing themselves. People make agricultural and urban ecosystems to fit their social system, and people adjust their social system to fit with their agricultural and urban ecosystems. The modernisation of agriculture after the Industrial Revolution illustrates coevolution of the social system with agricultural ecosystems.

Before the Industrial Revolution, people were very much aware of environmental limitations. Most people were small-scale subsistence farmers. Most families had a variety of farm animals and cultivated many different crops to meet the family's needs for food and clothing. Agricultural techniques were adapted to local environmental conditions. Most farmers used polyculture - a mixture of several crops together in the same field. One of the main changes in the ecosystem was from polyculture agriculture to monoculture. With mechanisation, farmers stopped mixing crops together because farm machines work best with single crops. The market economy also provided an incentive to change from polyculture to monoculture because producing and marketing a single crop was more convenient for farmers. However, monoculture did not protect the soil from erosion or maintain soil fertility. Risks of crop failure due to bad weather or pest attacks were greater with monoculture. As a result, it was important to make agriculture more independent of the environment by means of irrigation, chemical fertilizers and pesticides - all of which were possible with new developments in science and energy from fossil fuels.

Source: (http://gerrymarten.com/human-ecology/chapter07.html)

Questions

1. Culture has an important role in survival of humans through coadaptation. Explain it in the context of people and mosquito in the extract.
2. What were the reason(s) for farmers to shift from polyculture to monoculture farming?
3. Explain coadaptation and coevolution based on the two cases given in the extract.
4. How do coadaptation and coevoluation contribute in the maintenance of good health of an ecosystem?
5. Narrate a few examples of coadaptation and coevoluation and their benefit to humans in your locality.

B. Human-ecosystem dynamics

Environmental problems are not entirely new. Although most societies in the past have lived in harmony with the environment, there have been occasions when particular societies have had unsustainable interactions with the environment. Human-ecosystem interaction is sustainable when social system and ecosystem are coadapted. Sudden changes in the social system or ecosystem can disrupt the coadaptative relationships, thereby, reducing ecosystem's resilience and its ability to provide essential services. The main cause of unsustainable human-ecosystem interaction today is an expanding human population coupled with an expanding economy that places excessive pressure on ecosystem. Some of the factors leading to changing relations between human societies and ecosystem are:

(i) Human migration

Humans migrate to different places influenced by a combination of economical, social, political, or ecological factors, which are often interrelated. Migration of humans has resulted in unsustainable interaction between people and ecosystem.

Immigrants usually increase pressure on the environment and reduce the carrying capacity of the environment. Large population leads to over-exploitation of locally available resources. Further, with differences in culture and traditions, there lacks world-view of values, knowledge, technology and social institutions that are needed for sustainable interaction with their new environment.

Do You Know ?

Rural-urban migration is increasing in Bhutan and today, of 85,261 households in the country, 4,269 are registered as 'gung-tongs'.

-State of the nation report (2016)

(ii) New technologies

Humans benefit a lot from the development of technologies, but some technologies may bring about extensive environmental damages. For example, during early civilisation, the traditional hunting societies used weapons and tools such as spears, stone axes, bows and arrows or blow guns with poison darts, which did not cause over-exploitations of the available resources. However, the same resources can be over-exploited with the introduction of new technology like guns resulting in ecological imbalance.

Reprint 2022

(iii) Production and industrialisation

Industrialisation contributes in increasing the economies of modern societies and is indispensable feature of development of a nation. Industries extract raw materials from the natural resources to produce goods.

Due to industrialisation, the dependency of humans on natural resources increases, which in turn results in further degradation of environment.

(iv) Urbanisation and alienation from nature

As cities grow, vital habitat gets destroyed, species become endangered or even locally extinct as previously natural areas are replaced by the urban jungle. The shrinking natural environment and scarce resources weaken the connection between human and nature.

Humans who live in cities are deprived of natural environment and lack emotional feeling for the nature and its benefits. This emotional need for nature is termed as biophilia, which is generally developed in the childhood stage of a person when a child has access to nature. The attachment of humans with the nature enhances their knowledge of the environment which is necessary for sustainable interaction.

Questions

1. Explain the changing relationship between human and environment.
2. How does coadaptation lead to coevolution? Give an example.
3. How does the technological advancement change the relationship between human and environment?
4. Childhood contact with nature seems to be important for the knowledge and judgement that people need for sustainable interaction with ecosystems as adults. Justify the statement with appropriate examples.

Exercise:

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

    i. Natural resources which cannot be replaced once depleted are known as non-renewable resources. Which of the following is an example of non-renewable resources?

    A. Soil.

    B. Water.

    C. Wind.

    A. Forest.

    ii. Ecotourism in Bhutan is an example of

    A. supporting services.

    B. provisioning services.

    C. cultural and amenity services.

    D. regulating services.

    iii. All the following are results of indirect human activities on environment EXCEPT

    A. climate change.

    B. extinction of flora and fauna.

    C. biomagnification.

    D. deforestation.

    iv. Ladybirds live on plants, eating aphids for food, while the plant benefits by getting rid of the aphids. This is an example of

    A. adaptation.

    B. evolution.

    C. coadaptation.

    D. coevolution.

Reprint 2022

v. In an IPAT equation, I represents environmental impact which is a result of

A. increase in P but decrease in A and T.

B. increase in A but decrease in P and T.

C. increase in T and P but decrease in A.

D. increase in P, A and T.

2. ***Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.***

Column A	Column B
1. Destructive human activities	a. provisioning services
2. Energy outputs from ecosystem	b. carrying capacity
3. Organisation of species in a food web	c. ecocide
4. Human migration	d. coadaptation
5. GDP per capita	e. biophilia
	f. Affluence

3. ***Fill in the blanks with the correct word(s).***

i. If a large number of people migrate from rural to urban area, the carrying capacity of the rural area ___________.

ii. If climate regulation is an example of regulating services, nutrient regulation is an example of ___________.

iii. As human access to nature is limited due to urbanisation, it leads to the development of an emotion called___________.

iv. The process in which one of the organism develops adaptive abilities to live with other organism is called___________.

v. Migration usually reduces the ___________ of the environment.

4. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.***

i. The equation I=PAT is used to determine the the level of human dependence on the natural resources.

ii. Human-ecosystem interaction becomes unsustainable when coadaptation takes place.

iii. Coadaptation can be considered as changing together, while coevolution is fitting together.

iv. Increase in the average consumption of each person is directly proportional to environmental impact.

v. Cultural practice of revering forest and lakes in Bhutan is an example of coadaptation.

5. ***Answer the following questions.***

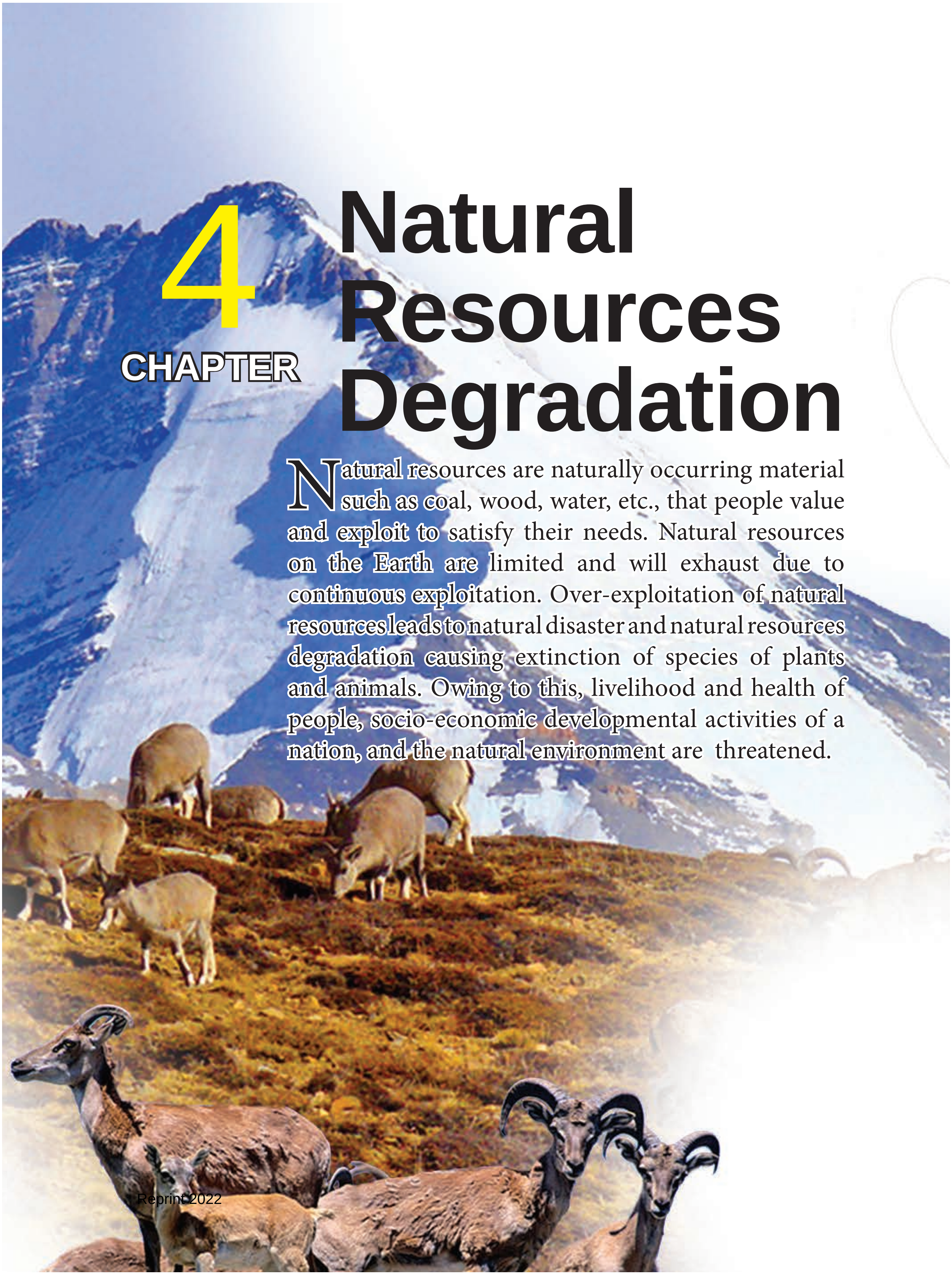
i. Explain how technological innovation affect the environment using the I=PAT equation.

ii. Analyse the importance of cultural and amenity services of nature in Bhutan.

iii. With development, the relationship between humans and the environment changes. How would you justify this statement?

iv. How does coadaptation take place between human society and the ecosystem? Give one relevant example.

Reprint 2022



CHAPTER 4

Natural Resources Degradation

Natural resources are naturally occurring material such as coal, wood, water, etc., that people value and exploit to satisfy their needs. Natural resources on the Earth are limited and will exhaust due to continuous exploitation. Over-exploitation of natural resources leads to natural disaster and natural resources degradation causing extinction of species of plants and animals. Owing to this, livelihood and health of people, socio-economic developmental activities of a nation, and the natural environment are threatened.

1. Natural Resources and its Exploitation

Learning Objectives

On completion of this topic, you should be able to:

- explain natural resource exploitation and its impacts.
- explain the factors that cause over-exploitation of natural resources.
- describe the impact of over-exploitation of natural resources on carrying capacity of the ecosystem.
- explain Ecological Footprint.
- evaluate the impacts of forest and forest products on economy, environment and society.

Natural resources on which organisms depend are provided by various spheres of the Earth: atmosphere, hydrosphere, lithosphere and biosphere. These spheres provide land, forest, water, food, minerals and energy resources. These resources can be either renewable or non-renewable. The resources that have the potential to be renewed through natural processes in one human life cycle are known as renewable resources. Forest is an example of a renewable resource as it can naturally regenerate upon its degradation. The resources that will exhaust and cannot be renewed in one human life cycle are known as non-renewable resources. Non-renewable resources exist in finite quantities. Every unit of resources consumed today will reduce the amount available for future consumption. For instance, the fossil fuels once used cannot be replenished in one human life time as it takes over millions of years to form.

The available natural resource begins to shrink when the rate of its exploitation exceeds the rate at which it is replenished. The deterioration in the quantity and quality of resources is known as natural resource degradation.

The natural resources are continuously exploited and at times, over-exploited to the point that the resource is completely degraded. Such over-exploitation exerts immense pressure on the natural resources and hence affects their availability.

A. Impacts of natural resource exploitation

Natural resource exploitation is the extraction of natural resources vital to the survival of people and development of economy. With the rising global population and industrialisation, there is an increasing pressure on the natural resources in terms of availability and quality. Hence, the consumption rates of the natural resources should be maintained within the regeneration capacity of the ecosystem.

Reprint 2022

The natural resource degradation is generally estimated by the following:

(i) Impact on water resources

The water use has been increasing about two times as fast as the population growth over the past century. The crisis of unavailability of fresh drinking water is expected to continue as more watersheds are disturbed. The fresh water sources are contaminated by leaching of pollutants from waste disposal sites, factories, sewage and farmland. The source of fresh water is also reduced due to irrigation for agricultural purposes.

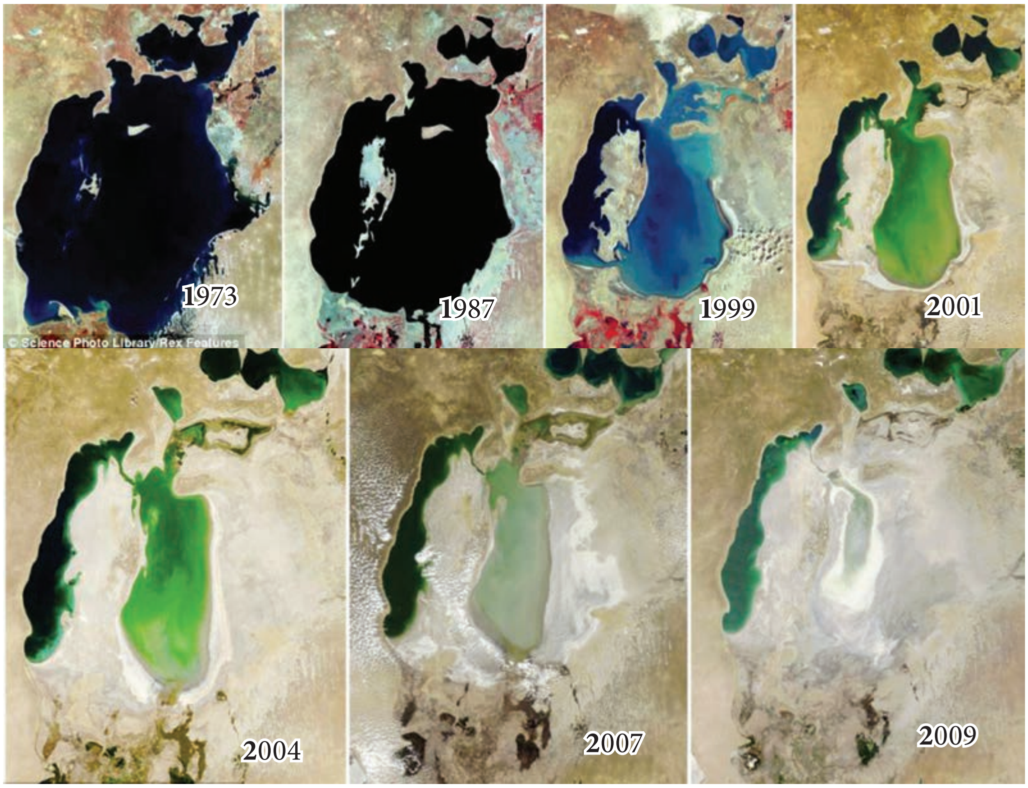


Figure 4.1. For nearly 40 years, rivers feeding the Aral Sea have been diverted to irrigate agriculture fields. The main body of the sea has lost more than 90 percent of its volume

(ii) Impact on land resources

Land resources include soil, rocks, minerals that are used for agriculture, mining, infrastructure building, roads and industries. Rising human population and economic development activities have increased the dependency on the land resource, ultimately increasing the pressure on land, which leads to degradation of land resources. Land degradation is the decline of land's capacity to support agro-forestry, biotic diversity and production of goods and services. Mining, industrialisation, infrastructural building, utilisation of chemical fertilisers and pesticides are the major causes of land degradation.

(iii) *Impact on forest resources*

Over half of the world's forests are exploited by humans for various purposes. Deforestation occurs primarily as a result of increase in settlements, agriculture, pasture-clearing for livestock, timber harvesting, mining, industrialisation, fuel use, and wildfire. This leads to loss of habitat, migration of species, erosion of topsoil, change in climate, human-wildlife conflict and wasteland. Deforestation also leads to scarcity of forest resources affecting the livelihood of people.

B. Over-exploitation of natural resources

The exploitation of natural resources at a rate faster than its rate of regeneration resulting in degradation or depletion of the resources is termed as over-exploitation of natural resources. Over-harvesting of wild species, unsustainable hunting, fishing and logging, and illegal trade of plants and animals are some examples of over-exploitation. Over-exploitation occurs as a result of direct and indirect exploitation. The causes of direct exploitation of natural resources include commercial activities, such as logging operations, trading of endangered species, mining, etc. Indirect exploitation is the occurrence of unintentional exploitation during the process of direct exploitation. For example, mining is the direct exploitation of the natural resources while destruction of vast area of forest cover in the process of mining is the indirect exploitation of natural resources.

Figure 4.2. Over-exploitation of minerals

Over-exploitation of natural resources results in intensive land degradation, floods, drought, desertification, extinction of species and disturbances to the stability of an ecosystem.

Figure 4.3. Over-exploitation of fish

Reprint 2022

Activity 4.1. *Examining factors affecting natural resources over-exploitation*

Instruction:

1. Work in four groups.
2. Each group will discuss on a topic and prepare a presentation on one of the causes of over-exploitation of natural resource and its consequences as represented in Figure 4.4.

Figure 4.4.

3. Make a presentation to the class.
4. When one group makes the presentation, members of other groups will record key information. While taking notes, remember the following:
   a. Concentrate and pay attention – Actively listen, analyse and think critically to understand the presentation.
   b. Do not try to write down everything – Be selective and do not transcribe the entire presentation. Recognise key concepts and identify main points and ignore repeated points. Focus on the concluding statements.
   c. You may use acronyms, symbols, personal abbreviations, tables, graphs, diagrams to note the key points and concepts.
5. After the completion of presentation, review your notes. Identify gaps and fill in the missing words, information and concepts. You may outline contradicting and coherent points made during the presentation.

Questions

1. What are the causes of over-exploitation of natural resources other than the ones mentioned in Figure 4.4?
2. Discuss the social and cultural ill effects of over-exploitation of natural resources.

a. Over-exploitation and carrying capacity

The over-exploitation of natural resources occurs due to an increase in human population, expanding markets and increasing demand for the resources. Over-exploitation results in environmental deterioration, pollution, disintegration of the population, scarcity of food and exhaustion of energy sources. These consequences create competition among organisms for resources, depletes soil nutrient, decrease food availability, water and living space, which eventually leads to decline in the carrying capacity of a particular area. For example, if an area is low in nutrients, few plants will be able to grow, which decrease the food availability for herbivores. Only a few herbivores can be sustained affecting the higher trophic levels. Therefore, nutrient concentration of the soil affects the carrying capacity of the entire ecosystem.

b. Ecological Footprint

The word 'footprint' generically refers to human impact on the Earth. The Ecological Footprint measures the area of biologically productive land and water required to produce the resources for the consumption and to absorb the waste produced by people.

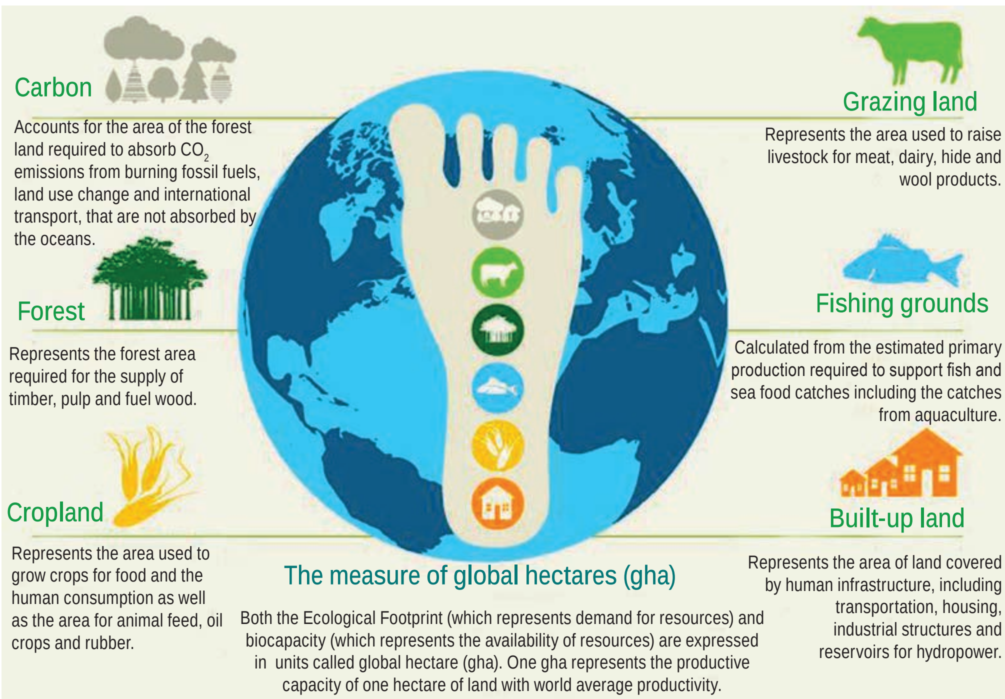


Figure 4.5. Components of Ecological Footprint

Biologically productive area includes land and water that support human demands for food, fibre, timber, energy and space for infrastructure and to absorb the

waste produced. The ability of this biologically productive land and water to generate resources required and absorb waste produced is called biocapacity. The components of Ecological Footprint are shown in Figure 4.5.
Ecological footprint is measured in terms of global hectares (gha) at global level. A global hectare is the average biological productivity of one hectare of land and water in a year. Global hectares measures productivities of different land types. For example, cropland would occupy smaller physical area than a pasture land. However, pasture land would be equal or less biologically productive than a crop land as more pasture is needed to provide same biocapacity of one hectare of cropland. The global hectare may vary every year due change in productivity of land use type.

Therefore, the Ecological Footprint in global hectares is calculated as:

$$\text{Ecological Footprint} = \frac{P}{YN} \times YF \times EQF$$

In this relation, P is the amount of a product harvested or waste emitted, YN is the national average yield, YF is yield factor and EQF is equivalence factor.

National average yield is the average of productivity of different land type in a year. For example, the productivity of grassland is 20 tonnes in year 2016, 10 tonnes in 2017 and 15 tonnes in 2018. Therefore, the national average yield for productivity of grassland is 15 tonnes.

Yield factor for a land type is the ratio between the national average yield and the world average yield on that type of land. World average yield is equated to 1.0 to compare with national average yield. Each country has yield factors for cropland, grazing land, forest and fisheries for each year. Yield differs due to factors such as precipitation, soil quality, management practices, etc. For example, if the world average yield of timber is 1.80 m3 in 2017, and national average yield for Bhutan is 0.60 m3, then the yield factor is 3. This means Bhutan's forest is on average 3 times less productive as world average forest yield.

Equivalence factor for a land type indicates how much higher or lower the productivity of a particular land type is compared to the world average productivity. In other words, it converts a specific land type (such as cropland, forest, etc.,) into a universal unit of biologically productive area, a global hectare. Equivalence factor is calculated for each year. For example, cropland with equivalence factor of 2.51 indicates that world average cropland productivity is more than two and half time the average productivity of all land combined. Similarly, the grazing land with equivalence factor of 0.46 shows that average grassland productivity is almost half as productive as the world average bioproductive hectare.

A grazing land of one hectare in Lunana produces fodder of 20 tonnes in a year and the required amount of fodder productivity for yaks to sustain in a hectare of grazing land in a year is 30 tonnes. If yield factor for production of fodder is 2.2 and equivalence factor 2.5, then the ecological footprint would be:

$$EF = \frac{P}{YN} \times YF \times EQF$$

$$EF = \frac{30}{20} \times 2.2 \times 2.5$$

$$EF = 8.25 \text{ gha}$$

The above value of ecological footprint states Lunana requires 8.25 global hectares of grazing land for growing fodder to produce 30 tonnes of fodder in a year to feed the yaks.

Activity 4.2. *Finding the largest ecological footprint*

Instruction:

Read the case study given below and answer the questions that follow:

China's New Affluent Consumers

More than a billion super-affluent consumers in developed countries are putting immense pressure on the earth's natural capital. Another billion consumers are attaining middle-class, affluent lifestyles in rapidly developing countries such as China, India, Brazil, South Korea, and Mexico. The 600 million middle-class consumers in China and India are twice the U.S. population, and the number is growing rapidly! In 2006, the World Bank projected that by 2030, the number of middle-class consumers living in today's developing nations will reach 1.2 billion – four times the current U.S. population.

China is now the world's leading consumer of wheat, rice, meat, coal, fertilizers, steel and cement, and it is the second largest consumer of oil after the United States. China leads the world in consumption of goods such as television sets, cells phones, refrigerators, and soon, personal computers. By 2020, China is projected to be the world's largest producer and consumer of cars and to have the world's leading economy in terms of GDP-PPP.

Suppose that China's economy continues growing exponentially at a rapid rate and its projected population size reaches 1.47 billion by 2031, then China will need two-thirds of the world's current grain harvest, twice the world's current paper consumption, and more than the current global production of oil.

According to environmental expert, Lester R. Brown, The western economic model–the fossil fuel based, automobile-centered, throwaway economy – is not going to work for China. Nor will it work for India, which by 2033 is projected to have a population even larger than China's, or for the other 3 billion people in developing countries who are also dreaming the "American dream."

Source: Living in the Environment: Principles, Connections, and Solutions (By G. Tyler Miller, Scott Spoolman)

Questions

1. Why is a country's rapid economic growth a concern?
2. How would the growing population impact the overall carrying capacity of the Earth?
3. Suggest some of the ways a country can adapt or adopt to control the environmental problems posed due to over-consumption of resources.

C. Forest and forest products

A forest is a natural self-sustaining biotic community, predominantly of trees, shrubs and other woody vegetation, which provides invaluable renewable natural resources. Forest plays a crucial role for the survival of all living organisms in many ways. Forest provides food, shelter and space for all living things, and it is the source of various kinds of wood and non-wood products that contribute to the economy of the country. Some of the forest products in Bhutan are shown in Table 4.1.

Table 4.1. Wood products and Non-wood products

Wood products	Non- wood products
Timber, firewood, shingles, board products, briquettes, etc	Natural dyes, plant exudates (resin, latex, gums, oil, tannin, lacquer, etc.), bamboo, cane, medicinal herbs, broom, fibres, lemon grass oil, ferns, mushrooms, wild fruits, ornamental plants, Cordyceps. Animal products such as skin, tusk, honey, wax, lac, etc.

Large number of population depends on forest and forest product for their livelihood. Figure 4.6 shows some of the products derived from the forest. Owing to this dependency, natural resources are excessively used and over-exploited, which threatens the sustainability of resources. The exploitation of forest resources has impacts on the following areas:

Figure 4.6. Forest products

(i) Economy

Forest and forest products provide wide range of economic benefits which contribute to the overall economy of country. Economic benefits include trade of forest products, employment opportunities and energy supplies. The collection of Non-Wood Forest Products (NWFPs) is one of the most viable alternatives for improving the rural economy. Bhutan has high-value NWFP like *Cordyceps sinensis* and *Matsutake* commercialised to expand the income generating source for the people.

The loss of forest productivity due to degradation leads to severe decline in revenue of the country. The over-exploitation of forest and forest product leads to exhaustion of resources, thereby affecting the livelihood of the people.

(ii) Environment

Forest play an important role in biogeochemical cycles. It acts as carbon sink that helps in maintaining the purity of the air by absorbing carbon dioxide. Forest also regulates the temperature and rainfall of the ecosystem. Forest products are biodegradable and eco-friendly.

The environmental recreational activities and unplanned extraction of forest products result in biodiversity loss, ecological dysfunctions and natural resource degradation. It also reduces the capacity of forest as carbon sink. For example, the harvest of timber reduces the forest cover, which decreases the richness of biodiversity, disrupts biogeochemical cycles and also reduces the capacity to absorb carbon dioxide. It makes the degraded area vulnerable to soil erosion, landslide and floods.

(iii) Society

The forest provides amenity services like recreation and ecotourism. It brings aesthetic enjoyment and spiritual fulfillment and often serves as inspiration for art, culture and folklore. Forest also provides opportunities to enhance science and education. Forest and forest products ensure employment and preservation of rural life. For example, the resources for bamboo products and traditional wooden products are provided by forest. Besides employing people in rural areas, it also preserves the age-old traditional skills of art and craft.

The increased dependency on forest and forest products has exploited the environment beyond its recovery. Conventional and inefficient practices of extracting forest products have lead to degradation of forest. This has impact on populations ,livelihood, income generation and aesthetic amenities.

Reprint 2022

Questions

1. Land, water and forest are the major natural resources of the Earth. How are they being degraded?
2. How is poverty related to environmental degradation?

Exercise

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

   i. Ecological Footprint can be used as a tool to assess the

      A. destruction of productive land area of productive.

      B. impacts of consumption and lifestyle on the environment.

      C. living standard of the people.

      D. level of human activities that pollutes the environment.

   ii. Which of the following combination is NOT the use of land?

      A. Agriculture, mining and industries

      B. Forest, agriculture and industries

      C. Industries, buildings and agriculture

      D. Mining, fishing and road

   iii. Which of the following are examples of renewable natural resources?

      A. Water, coal, medicinal herbs

      B. Soil, river, minerals

      C. Timber, fuel, fish

      D. Water, solar, air

   iv. Which of the following shows the best possible reasons for the natural resource degradation?

      A. Increase per capita income of the country, emphasis on gross domestic product, improvement of living standard.

      B. Increase gross domestic product, enhance living standard, sustainable development.

      C. Investment in ecotourism, improvement of living standard, strict laws and monitoring system.

      D. Use of green energy, gross domestic product, increase per capita income of the country.

Reprint 2022

v. Udzorong village has 5000 acres of land. Only 3000 acres of land are used to support human demands for food, fibre, timber, energy, space for infrastructure, and to absorb the waste produced. This available land is referred to as

A. biocapacity.
B. ecological footprint.
C. carbon footprint.
D. carrying capacity.

2. ***Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.***

Column A	Column B
1. Carbon sinks	a. Loss of species
2. Carrying capacity	b. Agroforestry
3. Ecological Footprint	c. Forest
4. Over-exploitation	d. Ecosystem stability
5. Wildlife trade	e. Resource consumption
	f. Invasive species.
	g. Desertification

3. ***Fill in the blanks with the correct form of word(s).***

i. The maximum population of a particular organism that a given environment can support without detrimental effects is …………………

ii. The excessive use of natural resources in a non-sustainable form is termed as…………

iii. The deterioration in the quality and quantity of resources is known as natural resource……………...

iv. The ability of the bioproductive land and water to generate resources required and absorb waste produced is called ……………

v. The availability of food, water and shelter in ecosystem determines ………… capacity of particular ecosystem.

4. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.***

i. All the renewable resources are exhaustible.

ii. Human-ecosystem interaction is unsustainable when coadaptation takes place.

iii. Climate change, biodiversity loss and global warming are caused due to human activities.

iv. An organism at the consumer level has less ecological footprint than organism at the producer level.

v. Ecological Footprint measures emission of greenhouse gases in the environment.

5. ***Answer the following questions.***

i. Describe the social and environmental impact of land degradation.

ii. Discuss the relationship between Ecological Footprint and biocapacity.

iii. Over-harvesting of wild species, unsustainable hunting, fishing and logging, and illegal trade of plants and animals are some examples of over-exploitation. Write down 5-6 consequences of over-exploitation.

iv. Study Table 4.2 and answer the questions:

Table 4.2.

Region	Population (Millions)	Biocapacity (Millions of global hectres)	Ecological Footprint (gha per person)	Biocapacity (gha per person)	Ecological surplus or Deficit (gha per person)	Total Ecological Footprint (millions of gha)
World	6,739.6	12,130.00	2.7	1.8	-0.9	1896.92
Denmark	5.5	20.40	8.3	4.8	-3.5	46.65
Australia	21.5	313.90	6.7		7.9	
Austria	8.3	27.40	5.3			

Adopted from: Global Footprint Network Oakland, CA, 2008

a. Calculate the missing values and complete Table 4.2.

b. Deduce the meaning of ecological surplus and ecological deficit from the table.

c. Identify the country in which the Ecological Footprint overshoots the biocapacity. How would you relate it with resource consumption?

v. Identify some examples of direct and indirect exploitation of natural resources evident in your locality.

vi. What are some of the initiatives taken by our government to curb the problems of over-exploitation?

Chapter 5

Pollution

Pollution is the change in composition of the environment brought about by various human activities in industries, construction, transport, and agriculture. These activities lead to generation and release of polluting substances known as pollutants. The pollutants have potential to cause adverse effects on the environment and organisms. Therefore, various control measures must be adopted in order to maintain the pollution at the minimum level.

Reprint 2022

1. Natural Resources and Pollution

Learning Objectives

On completion of this topic, you should be able to:

- explain air, water and land pollution.
- explain the causes of pollution.
- describe different types of pollutants and their sources.
- evaluate the effects of pollution on human and environment.

Our planet in its natural state is balanced and suitable for growth, development and reproduction of all living organisms. But, due to rapid urbanisation and industrialisation, the environment has been polluted to the extent that it threaten the existence of all forms of life on the Earth. Human activities, such as agriculture, industry and transportation, and natural phenomenon like volcano and forest fire produce a large amount of pollutants.

A. Air pollution

Air pollution is the addition of chemicals and particulate matters into the air resulting in alteration of the normal composition of the atmosphere. The change in the composition of air causes adverse effects on environment and organisms. Air pollution is common in large cities and industrial areas because of increase in population and human activities.

The substances which cause air pollution are called air pollutants. The pollutants which are added directly to the atmosphere from the sources are known as primary pollutants. For example, sulphur dioxide (SO_2), volatile organic compounds (VOC), particulate matters, lead (Pb), ammonia (NH_3) and carbon monoxide (CO). Particulate matter is a mixture of solid and liquid particles suspended in the air. The particulate matter with the diameter of less than 10 micrometer is called PM10 and the one with the diameter of less than 2.5 micrometer is called PM2.5. The PM2.5 is generally considered as fine particles.

Secondary pollutants are those that are produced by chemical interactions between the primary pollutants and the atmospheric constituents. For example, nitrogen dioxide(NO_2), ozone (O_3), hydrocarbons (HC), including acid rain which is formed when sulphur dioxide or nitrogen oxides reacts with rain.

Air pollution is expressed in terms of Air Quality Index (AQI). The change in the concentration of different pollutants is interpreted in the AQI index value ranging from 0 to 500. For example, as per the Environmental Protection Agency (EPA) standard chart Table 5.1, if the concentration of SO_2 is 0.14 parts per million (ppm) measured over a 24-hour period, the AQI value ranges from 51 to 100 which is moderate; hence, it is at the permissible level and safe. Different range are also indicated by colour code.

Table 5.1. Air Quality Index

AQI Categories:	Ozone (ppm)	Particulate matter (µg/m³)		Carbon monoxide (ppm) [8 hour]	Sulfur dioxide (ppm) [24 hour]
		PM 2.5 [24 hour]	PM 10 [24 hour]		
Good (Up to 50)/(Green)	*0 - 0.064*	*0 - 15*	*0 - 50*	*0 - 4*	*0 - 0.03*
Moderate (51-100)/(yellow)	*0.065 - 0.084*	*> 15 - 40*	*> 50 - 150*	*> 4 - 9*	*> 0.03 - 0.14*
Unhealthy for sensitive group (101--150)/(orange)	*0.085 - 0.104*	*> 40 - 65*	*> 150 - 250*	*> 9 - 12*	*> 0.14 - 0.22*
Unhealthy (151--200)/(Red)	*0.105 - 0.124*	*> 65 - 150*	*> 250 -350*	*> 12 - 15*	*> 0.22 - 0.30*
Very Unhealthy (201--300)/ (Purple)	*0.125 - 0.404*	*> 150 - 250*	*> 350 - 420*	*> 15 - 30*	*> 0.30 - 0.60*
Hazardous (301-500)/(Maroon)	*0.405 - 0.600*	*> 250 - 500*	*> 420 - 600*	*> 30 - 50*	*> 0.60 -1.00*

PM2.5 - particulate matter smaller than 2.5 micrometer.

PM10 - particulate matter between 2.5 to 10 micrometer.

a. *Causes of air pollution*

The causes of air pollution are generally classified into natural and anthropogenic in origin.

(i) Natural causes

Natural phenomena, such as volcano, forest fire, pollination, dust storms and microbes in the air generally cause air pollution. The pollutants emitted during volcanic eruption include sulphur dioxide, carbon dioxide and hydrogen fluoride. Besides the volcanic gases, a huge amount of volcanic ashes are also released polluting the air.

Forest fires ignited by lightning emit carbon monoxide, sulphur dioxide, nitrogen dioxide, and particulate matters. Lightning also converts nitrogen into nitrogen oxides. Methane is also one of the air pollutants which is produced in the environment under an anaerobic condition by bacteria on decomposing the organic matter. Almost half of the world's methane is emitted from natural sources, such as wetlands, rivers and streams, on the ocean floor and permafrost.

(ii) Anthropogenic causes

Figure 5.1. Pollution by industries

The major contribution to air pollution is by anthropogenic causes, such as emission from industries and automobile, release of pollutants from farming and mining, and the use of household products. Many manufacturing industries use a large amount of fossil fuels, which release a huge amount of oxides of carbon, sulphur and nitrogen; hydrocarbons, organic compounds, hydrogen fluoride, etc., into the atmosphere. Household products such as foam insulation, electronic equipment, refrigerator and air conditioner release chloroflurocarbons (CFC), which deplete the ozone layer. Mining and extraction of minerals release a large amount of dust and chemicals into the air. The pollutants released from automobiles include carbon monoxide, nitrogen oxides, lead oxides, hydrocarbons and VOCs.

In agriculture, spraying of pesticides releases many pollutants like chlorinated hydrocarbons and organic phosphates. Ammonia, a common by-product of agricultural activities is considered hazardous.

The air pollutants generated at home by burning of wood, central heating, cooling systems, smoking, and several household products, such as paints, solvents, insecticidal sprays, are indoor pollutants. Globally, the indoor pollutants are considered more hazardous than the outdoor pollutants.

b. Control of air pollution

Air pollution has significant impacts on our health, environment and economy. Air pollution causes respiratory and cardiovascular diseases. It also damages ecosystems and biodiversity, and decreases agricultural and commercial forest yields.

Formation and emission of pollutants can be minimised at the source. For instance, low sulphur content fuels which have less pollution potential can be used as alternatives to high sulphur content fuels. The use of modified industrial techniques, such as dispersion, gravitational settling, adsorption, and absorption reduces emission at the source. The industrial air pollutant leakages can be prevented by enhancing the efficiency of machineries through routined maintenance of equipment. It is also important to install pollution control equipment to remove the gaseous pollutants from the main gas stream.

The formulation and implementation of policies and acts like environmental impact assessment (EIA) on air pollution, and the integration of environmental

Reprint 2022

protection requirements in the developmental activities can contribute to the control of air pollution.

Activity 5.1. *Substituting coal in residential and commercial use*

Instruction:

1. Work in groups .
2. Read the following case study carefully and answer the questions that follow:

If China's cities are to meet WHO standards for air quality, the practice of burning coal, biomass, and plastic wastes in urban areas by residential and commercial users will have to end. Burning biomass and waste outside or in household stoves produces very large volumes of pollutants per kilogram of combusted material in close proximity to population centers. Many boilers and furnaces in China's urban areas that burn these fuels are not equipped with pollution control equipment. In light of the age and small scale of these units, installing and operating pollution-control equipment so that emissions can be reduced to levels consistent with WHO air quality standards either would not be feasible or would be more expensive than moving to alternative sources for larger units. It would also be difficult to ensure that these units are operating correctly. Over the last several decades, most countries have found that coal needs to be replaced by natural gas or electric heat generated by fuels other than coal to effectively reduce emissions from boilers used for residential and commercial heating. In the last century, London and Budapest mandated that coal be replaced by natural gas or other fuels for heating as a means of reducing air pollution. Beijing is already replacing all of its coal-fired facilities, including combined heat and power plants, with gas-fired plants. All coal-fired plants were to be closed by the end of 2014.

Burning natural gas or propane emits virtually no particulate matter or sulfur dioxide, although it does produce nitrogen oxides and carbon monoxide. If natural gas were to be substituted for coal, biomass, or plastic and other refuse in all boilers in Chinese cities, urban concentrations of particulate matter and sulfur dioxide would drop sharply, as occurred in cities in the United States and Europe.

City and district governments would need to implement such a measure. The governments of larger cities, especially Beijing, where air pollution has become a severe political problem, have demonstrated the political will and wherewithal to enforce such a measure, at least for apartment buildings and commercial establishments. As the Chinese government has declared "war" on pollution, municipal governments of smaller cities are caught in the middle: Lacking the financial resources of Shanghai and Beijing, they might be more reluctant to impose these costs on businesses, but they are also under pressure to implement pollution-reduction measures. For reasons of habit and cost, many households and establishments are likely to resist replacing coal and trash with natural gas or propane, especially if they need to buy a new furnace or stove and, in the case of natural gas, install a connection. In these instances, local governments would need to confirm the activities of inspectors, who have shown themselves willing to look the other way in exchange for a bribe. Setting up hotlines or other means of reporting violations would probably be a necessary additional step.

Source: http://www.rand.org/content/dam/rand/pubs/research_reports/RR800/RR861/RAND_RR861.pdf

Questions

1. Why is natural gas preferred over coal?
2. In the case study, China is seen as a very important player in global climate policy negotiations. Justify.
3. What challenges do the communities face to abide by the decision of China's Government policy on air pollution as per the case study?
4. List a few significant initiatives that Bhutan has taken towards controlling air pollution.
5. How do the initiatives (in question 4) affect the industries in Bhutan?

B. Water pollution

The contamination of water bodies leading to adverse effects on the living organisms using or living in it, is called water pollution.

There are several causes that lead to contamination of water, which include industrial activities, agriculture practices, poor waste management, decay and decomposition of organic matters, oil leakages, and sedimentation due to erosions. Figure 5.2 provides an overview of the types of pollutant and their impacts on the environment.

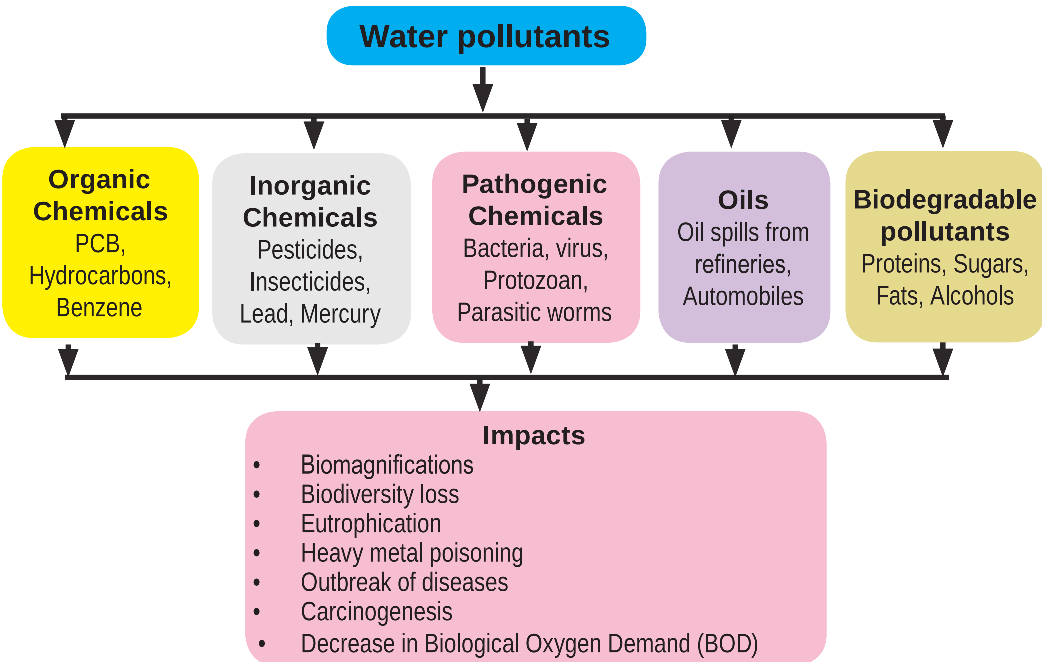


Figure 5.2. Types of pollutants and their impacts

Reprint 2022

a. Water pollution control

Water pollution can be controlled by appropriate land-use practices and proper disposal of industrial, domestic, and agricultural wastes. It can also be reduced by careful monitoring and controlling of pollutants coming from a point source and non-point sources.

Figure 5.3. Sewage outfall

Point sources discharge pollutants into specific locations through drainage pipes, ditches, or sewer outfalls, for example, pollutants from factories, power plants, sewage outlets, underground coal mines, oil wells, etc. These sources are distinctively identifiable, so they are relatively easy to monitor and regulate. Pollution from the point sources can be minimised by recycling or treating the harmful wastes before they are discharged into the water bodies.

Figure 5.4. Runoff water from farmland

Non-point sources are scattered and have no specific location of discharge. Pollutants entering the water bodies from non-point sources have numerous origins and routes, making it difficult to identify and manage the pollution. The chemical fertilizers and pesticides from agricultural lands, animal wastes, oil discharge, metals, toxins and large amounts of sediment carried by runoff enter into water bodies.

Pollutants from non point sources can be controlled by adoption of appropriate land management practices such as controlled grazing, prevention of erosions and preservation of wetland. Wetland acts as natural processing facilities that remove contaminants and helps to protect surface and groundwater. People can be encouraged to recycle waste and to minimise the use of chemical fertilizers and pesticides in agricultural fields.

Activity 5.2. Understanding the quality of drinking water in Bhutan

Instruction:

Study Table 5.2 and answer the questions that follow:

Table 5.2. General chemical parameters causing undesirable effect and their permissible limit

Sl. No	Chemical parameter	Permissible limit (mg/L or ppm)
1	Calcium	No permissible limit but recommended < 75
2	Free Residual Chlorine	Target range, 0.2 – 0.5
3	Iron	No permissible limit but recommended < 0.3
4	Manganese	0.4 Maximum permissible limit
5	Sulphate	No permissible limit but recommended < 250
6	Fluoride	1.5
7	Nitrates	50
8	Arsenic	0.01
9	Lead	0.01
10	Mercury	0.006

Source: Adapted from NEC, Bhutan drinking water quality standard, 2016

Questions

1. Which chemical parameter in Table 5.2 may be considered as the most toxic? Is there any history of poisoning from this substance?
2. Nitrates in drinking water can cause reduction in oxygen carrying capacity of the blood. What is the permissible level of nitrates in drinking water? Identify the possible sources which would increase the level of nitrates in the drinking water?
3. Why should people add chlorine in water? Why should its addition be within the permissible range?
4. List some of the measures to attain high drinking water quality standard in your locality?

C. Land pollution

Land pollution is the deterioration of the Earth's land surfaces through anthropogenic activities and natural processes. This undesirable change in physical, chemical and biological composition of soil reduces the soil fertility and affects plants and animals.

a. Causes of land pollution

Natural events like volcanic eruptions and tsunamis can cause land pollution. Large amount of sulphur compounds released into the atmosphere during volcanic eruptions combine with rain to form acid rain. This leads to acidification of soil. When tsunamis hit the coastal land, the flush of saline water onto soil can lead to soil salinisation.

Construction

Releases heavy metals and solvents

E-waste

Release heavy metals

Solid waste

Release heavy metals and phthalates

Causes of land pollution

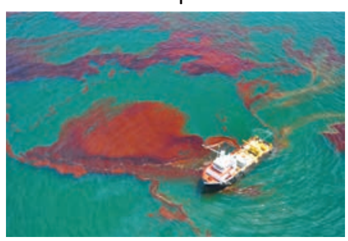
Mining

Releases heavy metals and hydrocarbons

Volcano

Release heavy metals and volcanic ashes

Oil spill



Release hydrocarbons

Figure 5.5. Causes of land pollution

The anthropogenic activities are generally considered as the main causes of land pollution. The rapid increasing human population and industrialisation lead to rise in demand for various manufactured products. The wastes produced from those products contribute to land pollution. The waste products may contain chemical pollutants like heavy metals, which have lots of effects on environment and organisms. Heavy metals in soil have higher persistence and last longer than that of other pollutants. Some of the activities that cause land pollution are shown in Figure 5.5.

b. *Effects of land pollutants on human health and ecosystem*

Chemical fertilizers contain toxic substances like nitrates, sulphates, phosphates, etc. These substances reaching human body can cause health hazards. For instance, nitrates from the soil contained in vegetables can react with haemoglobin to form methaemoglobin in blood, which reduces the O_2 carrying capacity of the blood. Methaemoglobin causes headache and giddiness. Urea is the most commonly used nitrogen fertilizer worldwide. The overuse of urea in agricultural fields affects the soil organisms, especially the earthworms which are known for their roles in soil fertility.

Figure 5.6. Pesticides

Pesticides used in agriculture contain chemicals like hexachlorobenzene and butachlor, which get accumulated in plants and soil. They reach animal body through food chain. Presence of pesticides in animal body may affect reproduction, hormonal imbalance and cause respiratory related diseases. Pesticides also affect the habitats of organisms reducing the species diversity in an ecosystem.

Figure 5.7. Oil spill

Oil spill can happen during storage, transportation and use. The chemicals present in the petroleum products are hydrocarbons like propane and butane, and aromatic hydrocarbons like benzene, toluene and xylene. These petrochemicals can cause cancer, respiratory disease and skin problems in human. They also deteriorate the water quality, which affect the habitats and wildlife.

Heavy metals like lead (Pb), zinc (Zn), mercury (Hg), cadmium (Cd), and nickel (Ni) are toxic in nature and affect the health of organisms. They also reduce the percolation capacity of the soil because these heavy metals clod the soil particles. Soil contaminated by heavy metals poses great threats to human health as the harmful metals reach our body through food chain.

Waste like sewage, animal waste, industrial waste and municipal waste are dumped in the soil. They decrease the quality of soil and reduce its water holding capacity. They also have toxic effects on plants.

Radioactive substance contamination in the environment is of great concern because of the serious and long lasting hazardous effects on humans and ecosystems. The radioactive substances cause cancer and mutation in organisms, and damage the environment.

c. Control and Prevention of land pollution

Land pollution can be reduced by application of effective technology for dumping waste like compressing and covering of landfills. Waste dumped should not disturb the underground water levels and there should be proper drainage system for the collection of leachates. Adoptions of the 7 R's; refuse, reduce, reuse, repair, re-gift, recover and recycle of waste management in the community is considered as one of the effective strategies to reduce land pollution.

The industrial effluents should be first treated before discharging them on to the land. Bioremediation is a promising land-cleaning technology, in which microbes of various kinds eat and digest waste and turn it into safer end-products. Phytoremediation is a similar concept, but involves plants, such as willow trees, to absorb contaminants from the soil.

Activity 5.3. *Understanding the waste management and prevention*

Instruction:

Read the extract from "Waste Management and Prevention Act of Bhutan, 2009" and answer the questions that follow.

CHAPTER III

MANAGEMENT REQUIREMENTS FOR CATEGORIES OF WASTE

Non-hazardous Waste

Implementing agencies shall ensure that the reduction, reuse, recycling and disposal of non- hazardous waste are addressed in an environmentally sound manner. In doing so, agencies shall:

(a) Provide waste segregation and reduction mechanisms at source; and

(b) Ensure collection and adequate management of waste at an approved site or facility inter-alia composting for organic wastes.

Hazardous Waste

(a) Implementing agencies shall ensure that the reduction, reuse, recycling and disposal of non-hazardous waste are addressed in an environmentally sound manner. In doing so, agencies shall:

i. Undertake segregation and relevant pretreatment.

ii. Ensure collection and adequate management of hazardous waste at an approved site or facility.

Reprint 2022

(b) Hazardous wastes shall not be imported into the Kingdom of Bhutan.

(c) Hazardous wastes may only be exported subject to the prior written consent of the country of import.

Medical Waste

Implementing agencies shall ensure that the minimisation, storage, treatment and disposal of medical, pharmaceutical and other biologically hazardous waste are addressed in an environmentally sound manner. In doing so, agencies shall ensure appropriate pre-treatment of this type of waste.

E-Wastes

Implementing agencies shall ensure that the minimisation, storage, treatment and disposal of waste from the production and use of electrical and electronic equipment are addressed in an environmentally sound and safe manner. In doing so, a system shall be established by the relevant implementing authority to provide for the proper collection, treatment and safe disposal of end-of life electrical and electronic equipment.

Other Waste categories

The waste categories enumerated in sections 12-15 of this Act may cover waste generated from any and all sources, including but not limited to industrial wastes, municipal waste and agricultural waste.

Source: Waste Management and Prevention Act of Bhutan, 2009

Questions

1. Based on the information given in the text, complete Table 5.3.

Table 5.3.

Sl.no.	Type of waste	Examples	Management requirement
1	Hazardous waste		
2	Non-hazardous waste		
3	E- waste		
4	Biodegradable waste		
5	Non-biodegradable waste		

2. How should hazardous waste be managed as per this policy?
3. Identify the types of waste produced at your home and mention proper means of disposing them.
4. How does this policy contribute to improving the health of the environment?

Questions

1. Every day, Aum Dema dumps around 5 kg of kitchen waste in a small stream near her house.
   a) How does this affect the quality of water in the stream?
   b) How should Aum Dema manage her kitchen waste using 7R model?.
2. Read the statements given in the following Table 5.4 carefully and put tick or cross mark for the statement that you agree or disagree with by giving suitable justifications:

Table 5.4.

Sl.no	Statement	Response		Justification
		Agree	Disagree	
1	Minimise the use of inorganic fertilizers and pesticides.			
2	Implement efficient regulations on clean drinking water management.			
3	Release factory effluents to the nearby water bodies.			
4	Defecate in open land and dispose wastes everywhere			
5	Washing clothes near the water sources must be prohibited.			
6	Applications of techniques such as absorption, ion exchange, electrolysis, osmosis to remove heavy metals.			
7	Instill proper sewage treatment plants.			
8	Bury solid wastes.			
9	Recycle wastes.			
10	Burn solid wastes.			

3. Which water pollution control practices are prevalent in your locality?
4. What are the initiatives taken at the national level towards water pollution control?

2. Chemical Pollutants and Toxicity

Learning Objectives

On completion of this topic, you should be able to:

- define toxin, toxicology and toxicity.
- investigate the effects of chemical on plants.
- describe the movement of toxin in the environment.
- explain the various ways to measure toxicity.
- explain the mechanisms of minimizing the toxic effects of chemical pollutants.

Every day lots of chemical pollutants are discharged into air, water and land from various sources. Some of these pollutants are hazardous and toxic and remain in the environment for many years.

a. Toxic and hazardous substances

Large quantities of chemicals are discharged, emitted, and released into the environment. Some chemicals are potentially harmful to the life forms because of their toxic nature. Any chemical substance that has hazardous impact on organisms and environment are called toxic substances. The strength of a substance by which the degree of damage on an organism varies is called toxicity of a substance.

The branch of science dealing with the study of adverse effects of chemicals on living organisms is called toxicology. Toxic pollution occurs when the chemicals that are discharged into the environment accumulate to toxic levels resulting in the reduction of wildlife numbers, degradation of ecosystem and threats to human. For each individual organism, there is a lower limit of exposure to a toxicant, below which no effect occurs. This lower limit of exposure to a toxicant is often termed Threshold Effect.

Based on the magnitude of exposure, toxicity can be of three types:

Acute toxicity: Some substances have adverse effects occurring within a short period of time (within 14 days of exposure) after a single or multiple exposure. Such substances are said to have acute toxicity. The effects of acute toxicity are generally fatal. For example in 1989, about 5,000 people died and 30,000 were permanently disabled due to exposure to methyl isocyanate from an industrial accident in India.

Sub-chronic toxicity: The substances which have adverse effects resulting from a repeated exposure over a certain period of time (several weeks or months) are considered to have sub-chronic toxicity. Substances with low toxicity may become highly toxic after prolonged exposure to it even at low doses due to accumulation. For example, the repeated exposure to air pollutants and particulate over a certain period results in respiratory related diseases, such as asthma, bronchitis and emphysema. Similarly, ingestion of lead over a period of several weeks can result in anemia.

Chronic toxicity: The substances which have adverse effects resulting from repeated and continuous exposure over an extended period (many months or years) are considered to have chronic toxicity. The carcinogens exhibit chronic toxicity. Kidney disease in workmen developed due to several years of exposure to lead and pulmonary fibrosis in coal miners is a good example of chronic toxicity. The discharge of methylmercury from a chemical plant in Minamata Bay in Japan has also lead to death of many people due to chronic toxicity through regular consumption of contaminated seafood over extended period of time.

The substances which have intrinsic properties, such as explosiveness, flammability and ability to oxidize, and cause adverse effects are known as Hazardous Substances. Toxic substances are always hazardous, but hazardous substances may not be toxic. For example, inorganic acids like hydrochloric acid and sulphuric acids are toxic hazardous substances, organic acids like acetic acid and citric acids are non toxic but hazardous.

A toxin is any poisonous substance of microbial (bacteria or other tiny plants or animals), plants, or synthetic chemical origin that reacts with specific cellular components to destroy cells, alter growth or development, and even lead to death of the organism. Toxins can be either endogenous or exogenous. Endogenous toxins are produced by the body as byproduct of biochemical processes, and may tend to accumulate in the joints. Exogenous toxins are toxins ingested or absorbed into the body from external sources, including food, water and air. Table 5.5 contains the ten global priority list of toxic and hazardous substances.

Table 5.5. Top 10 toxic and hazardous substances

Rank	Name of Chemical	Hazardous effect
1	Arsenic	Hyperkeratosis, carcinogenic, cardiovascular and neurological effects.
2	Lead	Renal, haematological, developmental, cardiovascular and endocrine effects.
3	Mercury	Developmental and neural effects.
4	Vinyl chloride	Cardiac arrhythmias, carcinogenic, developmental and neurological effects.

5	Polychlorinated biphenyls	Carcinogenic, immunogenic, teratogenic and developmental effects.
6	Benzene	Carcinogenic, abnormal bleeding and immunologic effects.
7	Cadmium	Cardiovascular, respiratory, renal and developmental effects.
8	Benzo(a)pyrene	Carcinogenic, reproductive, immunologic effects.
9	Polycyclic aromatic hydrocarbons	Carcinogenic, immunologic and reproductive effects.
10	Benzo(b)fluoranthene	Carcinogenic, immunologic and reproductive effects.

Source: Adapted from ATSDR 2015 Substance

b. *Measuring toxicity*

Toxicity can be measured by the effect the substance has on an organism. The extent of toxicity with the same dose on the body depends on gender, age, body weight and tolerance. The commonly used methods to measure toxicity are lethal dose (LD_{50}) and Lethal concentration (LC_{50}).

(i) Lethal Dose (LD50)

The LD_{50} is a standard measure for expressing the toxicity of chemicals. Lethal dose (LD_{50}) is defined as the dose required to kill half the members (50%) of the test population. It is expressed in terms of mg/kg body weight. LD_{50} is a general indicator of a substance's toxicity within a short period of time. It is a measure of acute toxicity.

(ii) Lethal Concentration (LC_{50})

The LC_{50} is a standard measure of the toxicity of the surrounding medium that kills half (50%) of the sample population of a specific test animal in a specific period through exposure via inhalation. LC_{50} is measured in micrograms or milligrams of the material substances per liter.

(iii) Dose-response relationship

The total amount of chemical administered on, or taken by an organism is called a dose, and the effect a chemical has on a living organism is called the response. The effect a chemical has on a living organism is related to its dose and the resultant concentration of chemical in the organism. Toxicity tests enable toxicologists to learn about responses of living organisms to doses of chemicals.

Threshold dose ($ThD_{0.0}$): The threshold is the dose below which no effect is detected, or above which an effect is first observed. The threshold information is useful in extrapolating animal data to humans and calculating what may be considered a safe human dose for a given toxic substance. The threshold dose ($ThD_{0.0}$) is measured as mg/kg/day. To determine the equivalent dose in man, the $ThD_{0.0}$ is multiplied by the average weight of a man, which is considered to be 70 kg.

For determining a threshold level, two important terms need to be understood:

No Observed Adverse Effect Level (NOAEL) – it is the highest dose at which no observable adverse effect is seen.

Low Observed Adverse Effect Level (LOAEL) – it is the lowest dose at which an adverse effect is observed.

Figure 5.8 is an example of dose response relationship curve of substance X. At the dosage above 7 mg/kg, the first effect is observed and this dosage point is threshold dose. The dosage at 10 mg/kg, there is no observed adverse effect and this dosage point is called no observed adverse effect level (NOAEL). The dosage about 19 mg/kg shows adverse effect level and this point is called the lowest adverse effect level (LOAEL). The lethal dose (LD_{50}) of substance X is 21mg/kg. At this dosage, half of the test subject die.

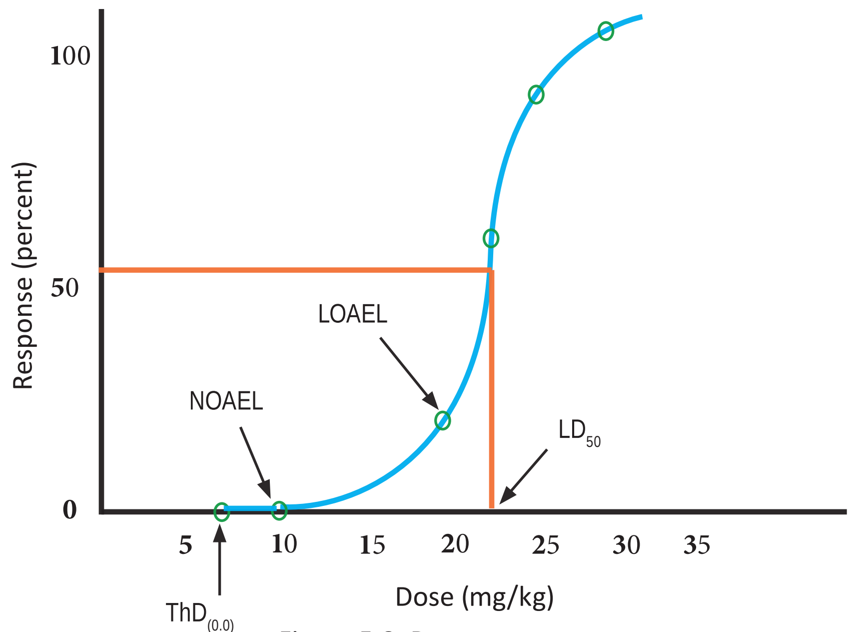


Figure 5.8. Dose response curve

Activity 5.4. *Testing the effect of chemicals on seed germination*

Materials required:

i. 12 nos. of 50 mL beaker
ii. cotton
iii. detergent and disinfectant cleaner (Lysol) solution
iv. radish seeds
v. 1 permanent marker
vi. 1 tray
vii. water
viii. Sealing plastic

Experimental procedure:

1. Prepare detergent and Lysol solutions with the concentration of 0, 20, 40, 60, 80 and 100% in 50 mL beakers and label them accordingly.
2. Place a thin layer of cotton in the bottom of every beaker.
3. Carefully pour the detergent solution into the beakers containing the cotton cushion.
4. Carefully place about 10 seeds on the moist cotton and seal the beakers with sealing plastic.
5. Place the beakers on the tray and keep it in well-illuminated place.
6. Repeat the same procedures from 1-5 with Lysol solution.
7. Observe the set up and collect data at the same time till the seeds start to germinate.
8. Record the observations in the given in Table 5.6 and extend the observation days depending on the germination of seeds.

Table 5.6. Response of radish seeds to different concentrations of detergent solution

Beaker No.	Dose	Day 1: Observation		Day 2: Observation	
		Detergent	Lysol	Detergent	Lysol
		No. of seeds germinated	No. of seeds germinated	No. of seeds germinated	No. of seeds germinated
1	0 %				
2	20 %				
3	40 %				
4	60 %				
5	80 %				
6	100%				

Reprint 2022

Questions

1. What percent of Lysol and detergent solution inhibits the seed germination?
2. Which concentration supports the germination of seeds?
3. What is the controlled variable in this experiment?
4. What conclusions can you draw from this experiment?

c. Movement of toxins in the environment

The chemicals move through the biological systems based on their molecular size, solubility, stability and reactivity in various components. Water soluble compounds move readily and widely through the environment. The transformation, degradation and sequestration of chemicals in the environment occur through three processes: chemical, biological and physical.

Physical process: The volatile toxicants evaporate and the airborne particulate matter remains in the air. The fate of air-borne chemical depends upon whether it is in the particulate or gaseous phase. The toxic chemicals present in the form of particles are removed by natural process such as dry deposition, wet deposition, gravitational settlement, impaction on and interception by the Earth surface objects. The dry deposition mechanism is effective for particles greater than approximately 2 μm in diameter, while the wet deposition is most effective for smaller particles. The gaseous phase chemical of contaminants in the air are removed by absorption or reaction with the Earth's surface objects. These toxicants undergo photodegradation and precipitation.

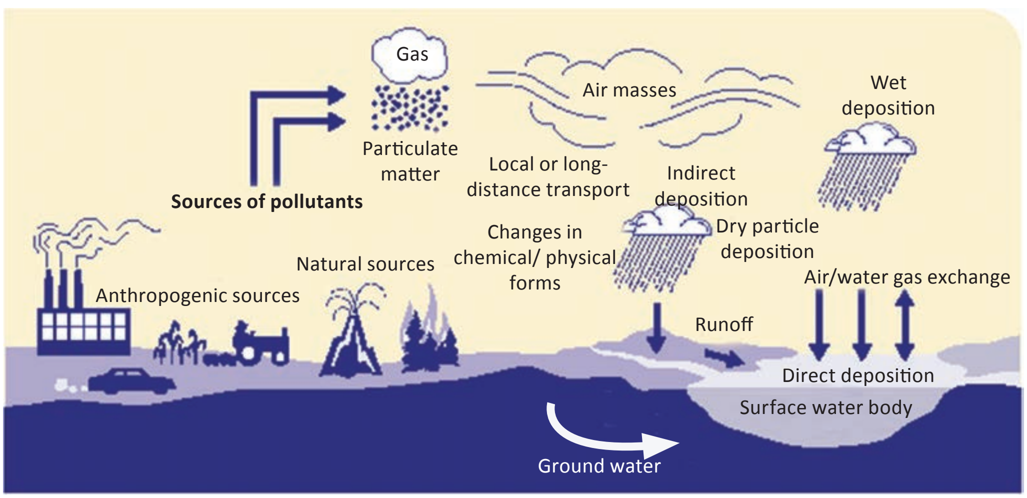


Figure 5.9. Atmospheric release, transport and deposition process

Pesticides used in agriculture leach into nearby water bodies and reach groundwater, or percolate through the soil to lower soil layers. The water persistent borne toxicants undergo sedimentation in the bottom sediments of lakes and seas. Bottom sediments of lakes and impoundments are often major sinks and sites of eventual burials of persistent toxic organic chemicals.

Chemical process: The toxicants in the air, water and soil undergo metabolism due to hydrolysis, oxidation and reduction. These transformation processes alter the physiochemical and toxicological properties and reduce exposure concentrations of chemicals released in the atmosphere. These processes result in both activation and detoxification of toxins.

Biological process: Body cells have the mechanisms of selective absorption and storage of a great variety of molecules. This allows cells to accumulate nutrients and essential minerals, but at the same time cells also absorb toxicants. The dilute toxicants found in the environment reach dangerous level inside the cells and tissues. This process of accumulation of toxicants in the cells and tissues is called bioaccumulation. Toxic substances are also magnified through food chain called biomagnification. Biomagnification occurs when the toxic burden of a large number of organisms at a lower trophic level is accumulated and concentrated by a predator in higher trophic level.

The toxicants are degraded by microorganisms, such as bacteria, or undergo a transformation in the body of organisms due to enzymatic actions. This

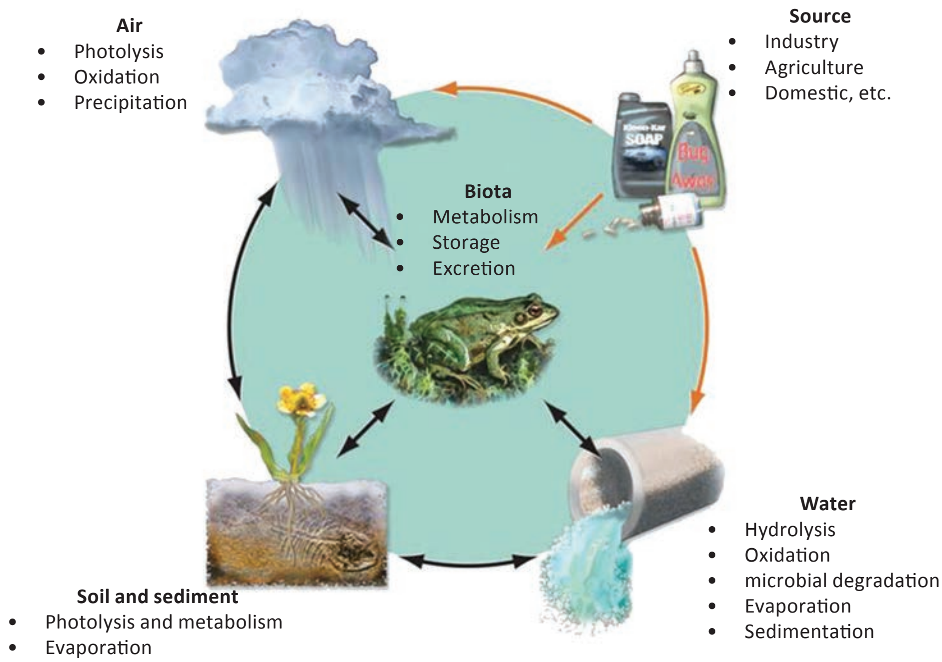


Figure 5.10. Movement of chemicals in the environment

degradation process usually leads to the formation of less harmful products, but sometimes more toxic products are produced. The process of transformation of chemical substances from one form to another due to enzymes or microorganisms is called Biotransformation. The transformation of toxicants into more toxic compounds brought about by microorganisms or inside the body due to biochemical processes is called Bioactivation. Reduction of toxicity due to transformation to a less harmful product is called Detoxification.

The pesticide which does not undergo either degradation or biotransformation is called persistent pesticide, for example, polychlorinated biphenyls (PCB) and Dichloro diphenyl trichloroethane (DDT). It moves over long distances and remains in the environment for a long duration leading to adverse environmental effects and human health problems.

Questions

1. Make an illustration of how lead from the factory reaches human body and causes health hazards.
2. Explain the factors which determine the toxicity of a substance.
3. Evaluate the pros and cons of using chemical fertilizers in vegetable garden.
4. "Chemical weapons used in wars have long term effects on environment and people." Justify the statement.

3. Health Hazards of Toxic Substances

Learning Objectives

On completion of this topic, you should be able to:

- explain the routes of exposure and susceptibility to toxic substances to humans.
- evaluate the impacts of toxic substances on environment and human health.

Toxic substances can cause serious health effects. The degree of health effect is related to the substance exposed to its concentration, the route of exposure, the amount absorbed by the body and duration of exposure. The health effects may occur immediately or may be delayed. Health effects that occur immediately after a single exposure are called acute effects, and that which occurs after years of exposure are called chronic effects. To prevent health effects due to exposure to toxic substances, it is important to understand their potential hazards.

a. Route of exposure and susceptibility to toxic substances

People are exposed to toxic substances in various ways, mainly through surrounding environment and workplace. The largest exposures to toxins are found in industries, where workers are exposed to toxins thousands times higher than they would be in any other environment. For instance, the European Agency for Safety and Health at Work warns that 32 million people in European Union are exposed to high levels of carcinogens and other toxicants in their work places.

Children are generally more susceptible to toxic effects because they have less-developed immune systems and their bodies have lesser ability to degrade or excrete toxic substances. The pregnant women are more susceptible to environmental pollutants which results in birth deformities and deaths. The birth defects in millions of children were attributed to environmental toxins. According to the World Health Organisation (WHO), more than three million children under five die each year from environment related causes and conditions.

The following are some of the common routes of toxic substances getting into the human bodies (Figure 5.9).

(i) Inhalation

Most people are exposed to sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2) and polycyclic aromatic hydrocarbons (PAHs) through breathing. These toxic substances are emitted from wood smoke, vehicle emissions and industrial exhaust. Vehicle and industrial exhausts contain high level PAH compounds which affect human respiratory system. Workers who work in, or

Reprint 2022

people who live nearby manufacturing factories suffer from the highest exposure through this route compared to people working and living elsewhere.

(ii) Ingestion

Toxic substances such as polychlorinated biphenyl (PCB), volatile organic compounds and dieldrin enter water bodies through anthropogenic activities. People are exposed to these toxicants by drinking water containing these substances. People are also exposed to toxicants such as heavy metals like mercury and arsenic through biomagnification.

(iii) Dermal contact

The polycyclic aromatic hydrocarbons (PAHs) and pesticide malathion are easily absorbed through skin. Contact with contaminated soil, or bathing in the contaminated water are the common ways of exposure to toxins.

Figure 5.11 Route of exposure to toxic and hazardous environmental factors

b. Impacts of toxic substances on the human health and environment

(i) Human health

Effects of toxic pollutant on human health are of two categories: acute effects and chronic effects. Acute effects include poisoning and illnesses caused by relatively high doses and accidental exposures. Chronic effects include cancer, birth defects, immunological problems, endometriosis, neurological problems, Parkinson's disease and other chronic degenerative diseases.

Polychlorinated biphenyls and dioxins are endocrine disrupters that disrupt the hormonal functions and also cause cancer. It also disrupts immune system and makes people susceptible to varieties of infections. The classes of metabolic poisons that superficially attack nerve cells are called neurotoxins. Heavy metal such as lead and mercury destroy nerve cells and cause permanent neurological damages. The hydrocarbons (Dieldrin, Aldrin) disrupt nerve cell membranes necessary for nerve action. Organophosphates (Malathion, Parathion) inhibit acetylcholinesterase, an enzyme that regulates signal transmission between nerve cells and the tissues or organs they innervate. Most neurotoxins are both extremely toxic and fast-acting toxins.

A variety of environmental chemicals such as organophosphate, chlorpyrifos and benzene have been found to be mutagenic. Mutagens are agents that produce mutations or changes in genetic material. Radioactive chemicals and some organic and inorganic substances that exist in the environment are generally carcinogenic.

(ii) Environment

The emissions of nitrogen oxides (NO_X) and sulphur dioxides (SO_2) from industries are responsible for the formation of acid rain. In some places, acid rain and acid fog have caused permanent damage to plants and lake ecosystems. Acidity causes forest decline partly by damaging leaf tissues and weakening the seedlings. Acidity also reduces nutrient availability in forest soils.

Figure 5.12 A fir forest destroyed by acid rain.

The chlorofluorocarbons cause the destruction of ozone in the stratosphere and create the possibility of serious environmental damage from radiation.

The chemical fertilizers and pesticide run-off from agriculture farms cause eutrophication which affects water ecosystem. The toxic chemicals from the landfill waste sites leach into the rivers and seas and induce genetic changes that affect the ability of organism to survive and reproduce.

c. Ways to minimise the use of toxic chemical pollutants

Some of the ways to minimise the use of toxic chemicals are as follows:

(i) Organic farming

People are exposed to various kinds of pesticides through consumption of vegetables and other agricultural products. The toxic chemicals present in the pesticides are collected in the vegetables and enter into the human body. The organic fruits and vegetables are free from chemicals and safe for consumption. Organic agriculture contributes to the overall health of living organisms and the environment. Therefore, creating awareness on health benefits of consuming organic farm products and encouraging the practice of organic farming in the communities can prevent or minimise the use of toxic chemicals in food production.

(ii) Regulations

The implementation of laws and acts on pollution helps in reducing the level of emissions from the sources. For example, manufacturing industries in Bhutan have the permissible level of emission set by National Environment Commission (NEC). Factories are not given environmental clearance for operation if the level of emission exceeds the permissible level. The concerned agencies should carry out strict monitoring of pollutants and uphold the laws to make the Earth a safer place to live.

The Bhutan Food and Regulatory Authority (BFRA) conducts regular tests to monitor the level of chemicals in the farm products available in the market. The organisation also conducts chemical tests on the imported consumable items. If the level of chemicals exceeds the permissible range, these products are banned in the market.

(iii) Emphasise on alternative technologies

The use of traditional and old machineries in the factories emits high level of carbon dioxide and greenhouse gases (GHG) into the atmosphere. The use of efficient modern technologies reduces air emissions and other pollutants. For example, new technologies replace the old technologies to control chemical pollution.

The use of renewable energy sources like solar, wind, geothermal, hydropower and biofuels helps in meeting the world's increasing energy needs with cleaner and sustainable way.

Questions

1. How does the increased level of nitrogen dioxide and sulphur dioxide in air affect the natural vegetation?
2. People generally believe that natural fertilizers are safe, while the industrial fertilizers are not. Justify your stand on this statement.
3. People in urban areas generally use chemical insecticides to keep away mosquitoes and other insects from home. Explain the ill effects of the use of insecticides and suggest safer substitutes for them.

Reprint 2022

Exercise

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

   i. Which of the following pollutants are considered when measuring air quality?

      A. CO, O_3, PM

      B. B. NH_3, PM, CO

      C. C. Pb, SO_2, PM

      D. D. PM, O_3, VOC

   ii. Which of the following is a point source pollutant?

      A. Industrial sewage

      B. Agricultural runoff

      C. Sediments from soil erosion

      D. Pesticides

   iii. The gases such as ....are the examples of primary pollutants.

      A. SO_2, NO and CO

      B. SO_2, NO and O_3

      C. NO_2, O_3 and CO

      D. O_3, $SO_2$and NO_2

   iv. Which of the following is NOT a factor that causes the inhalation of toxic substances?

      A. Concentration of toxic substance in the air.

      B. Speed of the wind.

      C. Length of exposure.

      D. Size of toxic particle.

   v. The term “persistence” of a pollutant in the environment refers to the

      A. concentration of a pollutant in the environment.

      B. distance a pollutant spreads in the environment in a given time.

C. length of time required for the pollutant to disappear from the environment.

D. measure of the harm a substance can cause to humans and other living organisms.

vi. The biomagnification is caused due to

A. higher affinity of a chemical substance with the body tissue.

B. stable nature of a chemical substance.

C. toxic nature of a chemical substances.

D. unstable nature of a chemical substances.

2. ***Fill in the blanks with the correct form of word(s).***

i. The use of microbes to remediate the toxic pollutants is called …………..

ii. Well ventilated buildings, better alternatives source of energy, getting rid of any possible pollutants can improve the quality of …………………… air.

iii. The ingested nitrates combine with haemoglobin to form………………

iv. The dose below which no effect is detected, or above which an effect is first observed is called........................

v. .... is a degree to which a substance can damage an organism.

3. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.***

i. Non-point pollution sources are easy to identify and monitor.

ii. Dumping leftover food items from your school mess into a fish pond is good for aquatic life.

iii. The chloroflurocarbons (CFCs) are replaced by hydrofluorocarbons (HFCs) because most of the HFCs are degraded before reaching the stratosphere.

iv. Non toxic chemicals become toxic in the body due to the action of enzymes.

v. Toxicity can be measured as the effect the substance has on an organism, tissue or cell.

4. ***Answer the following questions.***

i. Sodium cyanide has an oral LD50 of 15 mg/kg in rats. What does the statement mean?

ii. Describe the social and environmental impacts of land degradation on people?

iii. How do the agricultural practices cause air, water and soil pollution?

iv. Figure 5.13 shows the graph for the result of heavy metal test from three different water sources. Study the data and answer the questions that follow:

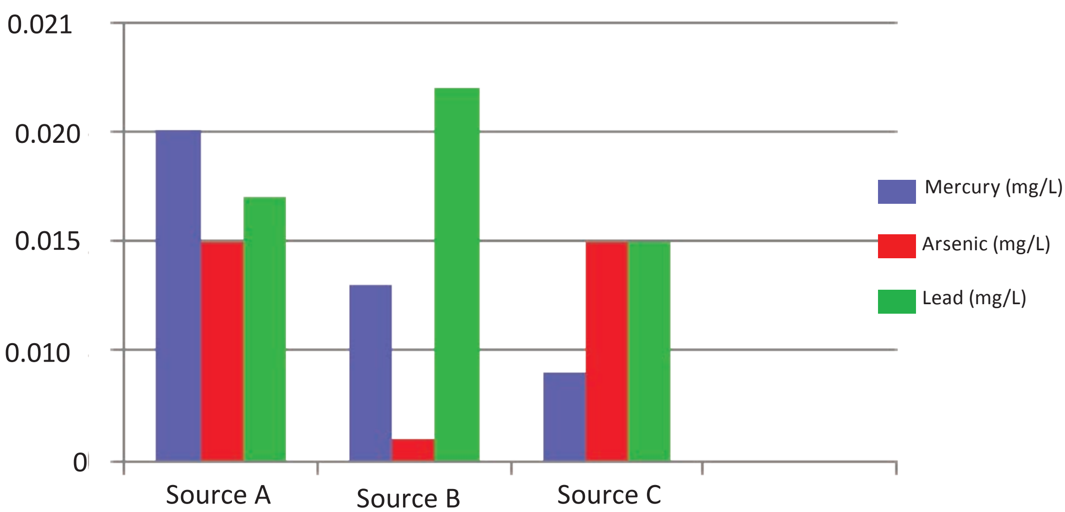


Figure: 5.13. The level of arsenic, mercury and lead in mg/L

a) Which source of the water appears to be favourable for drinking? Why?

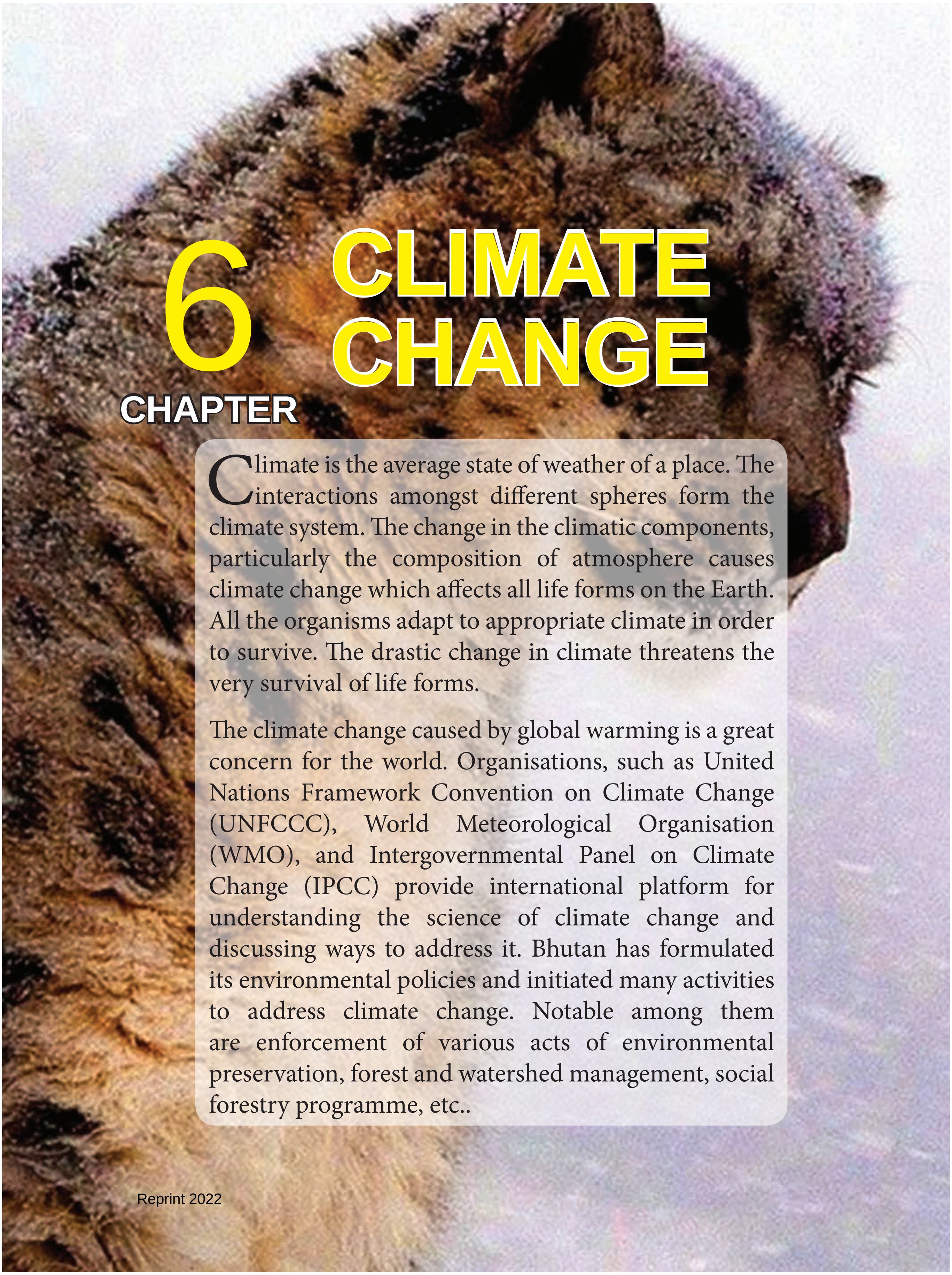
b) Describe water sources A, B and C.

c) If family A and family B are consuming water from the sources A and B respectively, what health implications are expected in these two families??

v. "The aesthetic loss of Taj Mahal is the direct result of air pollution". Justify the statement.

vi. Sodium cyanide has an oral LD_{50} of 15 mg/kg in rats. What does the statement mean?

Reprint 2022



CHAPTER 6 CLIMATE CHANGE

Climate is the average state of weather of a place. The interactions amongst different spheres form the climate system. The change in the climatic components, particularly the composition of atmosphere causes climate change which affects all life forms on the Earth. All the organisms adapt to appropriate climate in order to survive. The drastic change in climate threatens the very survival of life forms.

The climate change caused by global warming is a great concern for the world. Organisations, such as United Nations Framework Convention on Climate Change (UNFCCC), World Meteorological Organisation (WMO), and Intergovernmental Panel on Climate Change (IPCC) provide international platform for understanding the science of climate change and discussing ways to address it. Bhutan has formulated its environmental policies and initiated many activities to address climate change. Notable among them are enforcement of various acts of environmental preservation, forest and watershed management, social forestry programme, etc..

Reprint 2022

1. The Climate Systems

Learning Objectives

On completion of this topic, you should be able to:

- differentiate between weather and climate.
- define climate system.
- explain the mechanism of climate feedback.
- explain the factors that regulate the climate system.

Climate functions as a system and is influenced by several factors that occur in four spheres of Earth system. The day-to-day changing conditions of the atmosphere as regards to temperature, rainfall, wind, humidity, sunshine and cloudiness defines the climate system of any place. It is also influenced by solar radiation and anthropogenic activities.

A. What is climate?

Climate refers to the average weather conditions and its variability over a certain time-span, ranging from months to years. The climate of a particular region is measured by assessing the patterns of variation in temperature and precipitation over a long period of time. On the other hand, weather only describes the short-term conditions of these variables in a given region. Weather is the part of daily experiences of all living organisms including human beings. Weather conditions are essential for health, food production and well-being of all organisms. Climate varies from place to place as it is affected by latitude, altitude, vegetation, presence or absence of mountains, or other geographical factors.

The climate system is driven by energy received from the Sun as shown in Figure

The climate of Bhutan can be described based on temperature and precipitation occurrence on three broad regions:

- The southern belt is hot and humid with temperatures remaining between 13°C and 31°C, and an annual rainfall ranging from 2500mm to 5000mm.
- The central inner Himalayas have a cool temperate climate with the temperature of 6 °C to 29 °C, and an annual average rainfall of about 1000 mm.
- The northern region has an alpine climate with the temperature ranging between 0°C to 25°C, and an annual rainfall of around 400 mm.

Reprint 2022

6.1. Some of this incoming solar energy is reflected back into the space, while the rest is absorbed by the land and ocean and re-emitted as radiant heat. The radiant energy is measured in terms of power, watts per square meter (W/m^2). Some of this radiant heat is absorbed and re-emitted by the lower atmosphere in a process known as the greenhouse effect. The Earth's average temperature is determined by the overall balance between the amount of incoming energy from the sun and energy emitted back to the space. Therefore, the atmosphere, lithosphere, and hydrosphere along with the cryosphere of the Earth are the components of the climate system. These components interact with one another determining the day-to-day weather and the long-term average weather conditions that is referred to as climate.

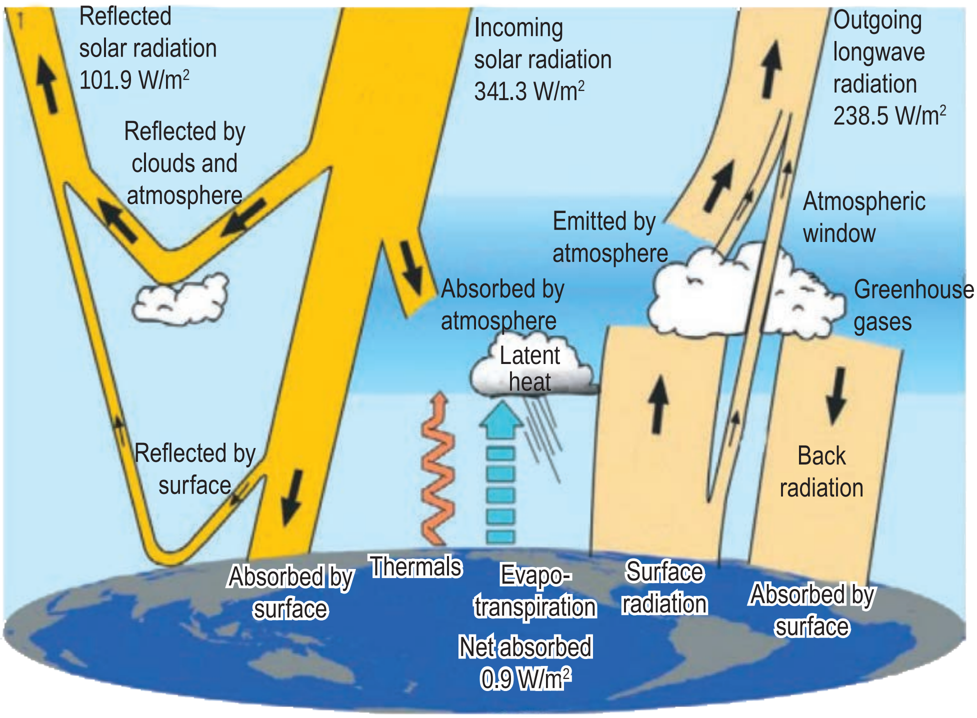


Figure 6.1. The Earth's radiation (W/m^2) and energy balance (Trenberth, Fasullo, Kiehl, 2008).

An important feature of the climate system is that the sun's energy is not distributed uniformly. Equatorial region of the Earth receives maximum energy, whereas the polar regions receive less energy. This non-uniform energy distribution leads to temperature differences, and the atmosphere and oceans play important roles in transporting heat from the warm tropics to the cold polar regions. The resulting heat transportation causes ocean currents, atmospheric circulation, evaporation and precipitation that a place ultimately experiences as weather. For instance, El niño and La niño are major ocean-currents caused due to ocean-atmosphere interaction linked to a periodic warming and cooling of the sea surface temperature across the central and east-central Equatorial Pacific as shown in Figure 6.2a. They occur every three to five years and remain for eight to nine months, and they have far-reaching effect on weather and climate. During an El niño year, due to unusual sea surface temperature, the atmosphere draws moist air from the ocean resulting to intense storms and heavy rain. On the other hand, the intervening La niño years brings hot and dry weather (Figure 6.2b).

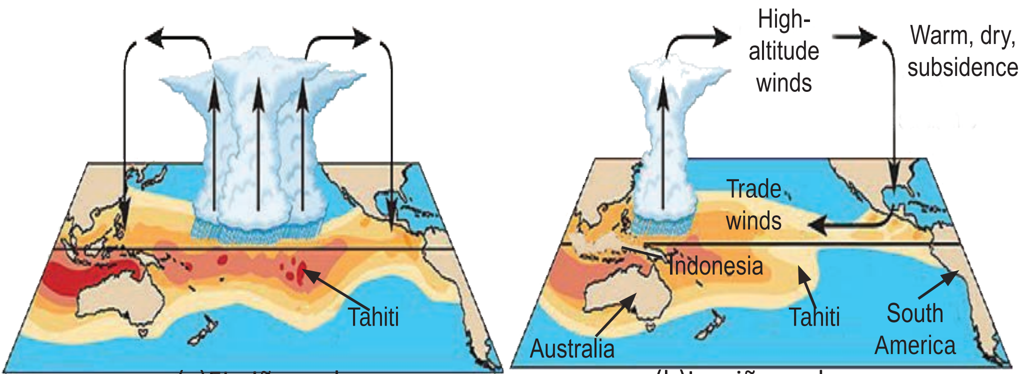


Figure 6.2. Ocean-currents(Cunnigham, Cunnigham, 2008)

The climatic conditions can be influenced by feedback mechanisms in climate system. The feedback mechanism determines the climate sensitivity and future climate state. Any change in components of climate system results to feedback mechanism. It may amplify (positive feedback), or diminish (negative feedback) the climatic condition to occur either warming or cooling.

For example, increasing concentration of greenhouse gases warm the Earth causing melting of snow and ice, exposing the darker land and water surfaces beneath. This melting reveals darker land and water surfaces that are beneath. These darker surfaces absorb more of the Sun's heat causing more warming, which causes more melting, and so on in a self-reinforcing cycle. This feedback loop known as the 'ice-albedo feedback', amplifies the initial warming caused by the rising levels of greenhouse gases.

In another case, when Earth's surface warms, there will be increase of water vapour in the atmosphere. This will lead to formation of low clouds showing albedo feature, reflecting solar radiation that results in cooling of the Earth surface. But as more water vapour formation takes place, high clouds are formed and will bring positive feedback.

Reprint 2022

Activity 6.1. *Understanding interactions in the climate system*

Instruction:

Study Figure 6.3 and answer the following questions.

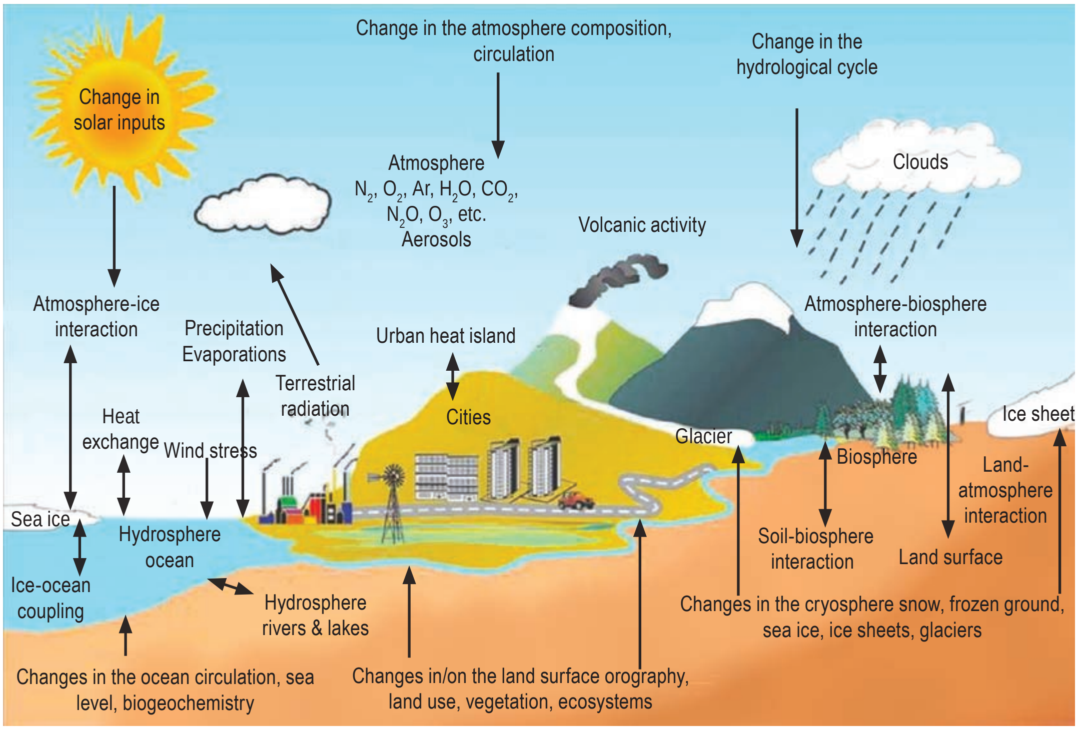


Figure 6.3. Schematic diagram of the components of the global climate system, their processes and interactions and some aspects that may change (IPCC, 2001).

Questions:

1. Atmosphere and biosphere interaction is a two-way process. How do these interactions contribute to climate system?
2. Identify the source of terrestrial radiation and describe its effect on the atmosphere.
3. How will the ice-ocean coupling interaction be affected when solar inputs become low?

B. Components of the climate system

a. Atmosphere

Atmosphere regulates the amount and intensity of heat and light entering the Earth's surface. It maintains the Earth's temperature by regulating the movement of radiations from the space to the Earth. The ozone layer filters large amount of solar radiations from entering the Earth's surface. The earth's surface absorbs the radiations filtered through the ozone layer and emits infra-red radiations. The greenhouse gases present in the atmosphere absorb the infrared radiations re-emitted by the Earth. It leads to trapping of heat raising the temperature of Earth's surface. GHGs can re-emit infra-red radiations towards the earth's surface. Atmospheric circulation due to uneven heating of gases helps in distribution of heat around the globe.

Besides greenhouse gases, solid and liquid particles (aerosols) and clouds present in the atmosphere also react with radiations in complex manner influencing the Earth's temperature.

b. Hydrosphere

The oceans store huge amount of heat during the summer and release it during winter. The high thermal inertia of oceans helps in storage of huge amount of heat and stabilizes the atmospheric temperature. The movement of oceans and seas are caused by surface and thermohaline circulations, which distribute heat around the globe and influence the water cycle. The hydrosphere along with atmosphere and lithosphere give rise to monsoonal cycles that cause different rainfall patterns around the globe.

c. Cryosphere

The continental ice sheets, snow, glacier and permafrost play vital role in climate system due to their high reflectivity of solar radiations. They buffer the changes in the temperature of the Earth's surface.

d. Lithosphere

Land surface emits infrared radiation after absorbing Sun's radiation. Large surface of land contributes to heating of the Earth by emitting huge amount of infra-red radiation to the atmosphere. The quick heating and cooling property of land helps in the development of air currents during summer and winter. The evaporation of water from land enhances the atmospheric moisture which is another important factor to determine the climate. The difference in temperature between lithosphere and hydrosphere leads to the development of air current that regulates precipitation.

Reprint 2022

e. Biosphere

Living organisms play major role in maintaining the composition of different spheres. During photosynthesis, autotrophs use CO2 to fix carbon into organic substances, which pass to other organisms through food chains. Likewise, during respiration, heterotrophs release CO2 to the atmosphere. Such processes bring an alteration in the atmospheric CO2 content which can have a direct influence on the climate.

Transpiration is a major contributor of atmospheric moisture. The change in the state of water helps in energy transfers among different spheres. Large amount of water is evaporated during transpiration and therefore, can have direct influence on precipitation.

Questions

1. Altering the composition of the atmosphere would result in change in the weather and climate. Explain.
2. Explain water vapour as a greenhouse gas.
3. How does the climate affect the food security of the society?
4. Table 6.1 shows average temperature and precipitation pattern in Bhutan for the last 10 years. Study Table 6.2 and answer the following questions:

Table 6.1.

Climate variable	Years									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Temperature (°C)	32	31	25.7	28	31.8	30.9	33.1	24.6	26.1	23.6
Precipitation (cm)	56.4	48.46	31.85	41.5	48.2	48.5	49.23	56.2	66.2	68.9

a) What type of weather did Bhutan experience in 2006?

b) In which year did Bhutan experience the hottest and the wettest weather?

c) Calculate the average temperature and precipitation from 2008 to 2012. Describe the climate that Bhutan experienced during these years?

d) Draw a line graph showing the relationship between temperature and precipitation. What conclusion can you draw about the climate of Bhutan?

Reprint 2022

2. Climate Change

Learning Objectives

On completion of this topic, you should be able to:

- define climate change.
- predict the trend of climate change in future
- justify global warming as the effect of anthropogenic activities.
- explain the factors responsible for climate change.
- explain the impact of global warming on climate change.
- evaluate the impacts of climate change on biodiversity, water resources, agriculture, and human health.
- explain some of the significant national responses and international responses towards climate change.

Climate changes with the variation in the weather conditions. Weather conditions occur naturally in rhythm with the Earth's diurnal temperature, humidity, wind and precipitation. However, human interference with natural world through resource utilisation has adversely affected the daily weather conditions, accelerating the changes in climate. Delayed monsoon, excessive heat or cold, disappearance of snow from the mountain tops, etc., are indicators of climate change.

A. What is climate change?

Climate change can be defined as any significant change in climate that persists for an extended period, typically decades or longer. The change in the climate is caused by the alteration of the climatic components.

The Intergovernmental Panel for Climate Change (IPCC) defines climate change as, "the change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity."

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

a. Patterns in climate change

The change in temperature in the past years has been mainly due to the accumulation of carbon dioxide in the atmosphere. Figure 6.4 indicates a strong correlation between carbon dioxide concentration in the atmosphere and temperature.

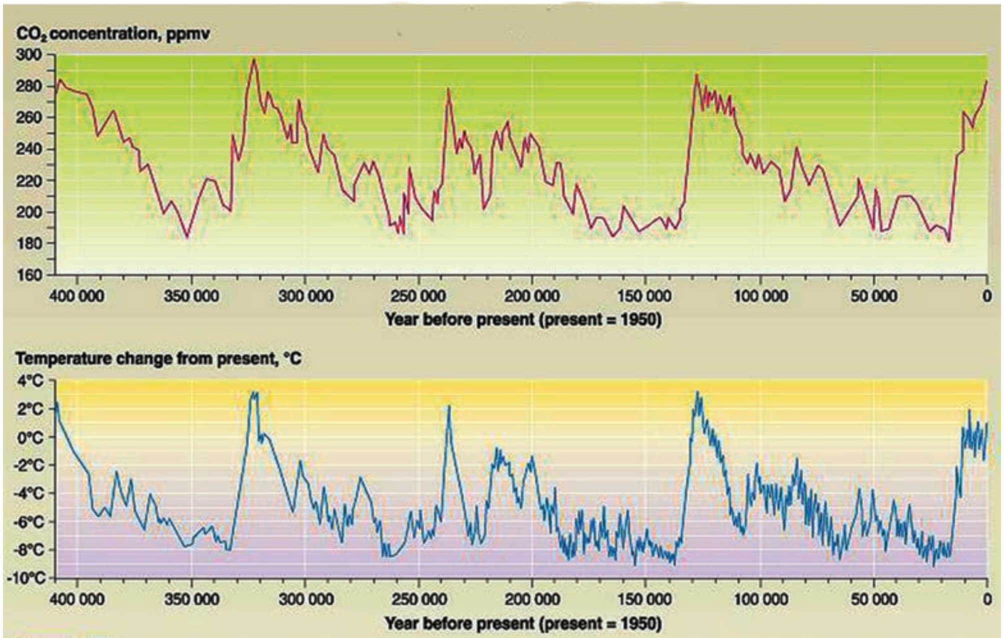


Figure 6.4. Temperature and Carbon dioxide concentration in the atmosphere over 400,000 years (J. R. Pelit, Jouzel, et al. 1999)

Since industrial revolution, the burning of fossil fuels, deforestation, and other human activities have contributed to rapid increase in atmospheric concentrations of greenhouse gases, such as CO_2 and methane. In 2007, the concentration of carbon dioxide was approximately 383 ppm (parts per million) and methane concentration showed a similar rise.

According to IPCC states that the global average surface temperatures rose by approximately 0.6 to 0.9^{o}C between 1906 and 2005; the rate of warming over the last 50 years has almost doubled over the last 100 years. The Arctic region is experiencing an even greater temperature change with an increase of about 0.09^{o}C in the past 100 years. The precipitation has generally increased over land in the north of 30°N latitude between 1900 and 2005, but has displayed a downward trend in the tropics since the 1970s. Droughts have also become more common since the 1970s, especially in the tropics and subtropics.

b. Evidences of climate change

Global temperature rise: The major global surface temperature reconstructions show that the Earth has warmed since 1880. The decline in solar output was observed in the years 2007 to 2009, but still the surface temperature of the Earth continued to increase.

Sea level rise: Global sea level rose by about 17 cm (6.7 inches) in the last century. The rate of sea level rise in the last decade is almost double that of the last century. The increase in concentration of greenhouse gases in the Earth's atmosphere increases the temperature of air and water, which causes sea level to rise in two ways. First, warmer water expands, and this thermal expansion of the ocean causes sea level to rise. Second, melting land ice flows into the ocean, leading to sea level rise.

Warming ocean: The oceans have absorbed much of this increased heat with the top 700 m (about 2,300 feet) of ocean showing warming of 0.30 ^{o}F since 1969.

Shrinking of ice sheets: Greenland and Antarctic ice sheets have decreased in mass. Data from National Aeronautics and Space Administration's (NASA) gravity recovery and climate experiment show that Greenland lost 150 to 250 km^3 of ice per year between 2002 and 2006, while Antarctica lost about 152 km^3 of ice between 2002 and 2005.

Glacial retreat: Glaciers are retreating almost everywhere around the world, including in the Alps, Himalayas, Andes, Rockies, Alaska and Africa.

Decrease in snow cover: Satellite observations reveal that the amount of spring snow cover in the Northern Hemisphere has decreased over the past five decades and the snow is melting earlier. As the temperature increases, the amount of time for snow to remain on the ground shortens. The temperature changes in Earth atmosphere also lead to change in moisture content that may result to erratic formation of snow.

c. Future climate projection

Future climate depends on the rate at which the levels of greenhouse gas concentrations in our atmosphere continues to increase, and the frequency of occurrence of natural processes (e.g. volcanic eruption) within the climate system. As shown in Figure 6.5, a continued emission of greenhouse gases would cause global warming. Using advance global climate models (GCMs), the IPCC concluded that the average global surface temperature is likely to rise by an additional 1.4^{0}C to 5.8^{0}C by 2100. This magnitude of warming is greater than that experienced over the last 10,000 years. Such fast rate of change in temperature of the Earth and its atmosphere would result in the following:

- fast rate of melting glacial ice,
- sea level rise causing floods in island and coastal region,
- world experiences erratic precipitation pattern, and
- damage to ecosystem, for example, degradation of forest.

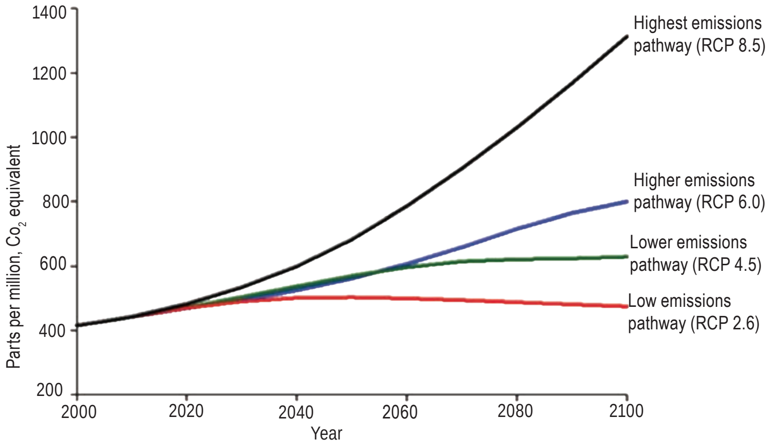


Figure 6.5(a). Projected atmospheric greenhouse gas concentrations from 2000-2100

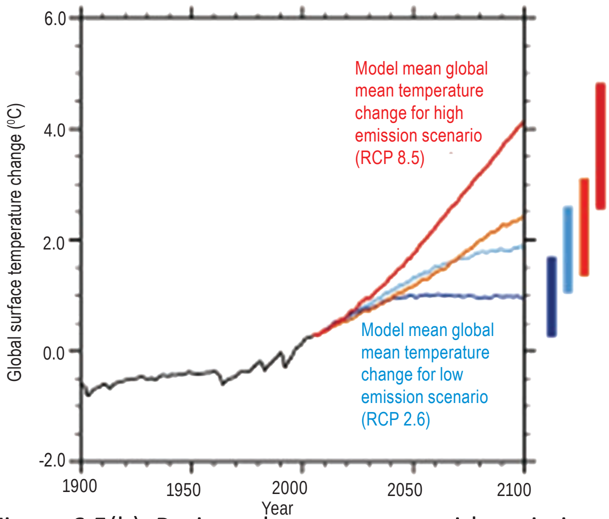


Figure 6.5(b). Projected temperature with emission of greenhouse gas

d. *Factors contributing to climate change*

The factors contributing to climate change can be categorised as:

(a) Natural factors:

As shown in Figure 6.6, the following natural factors cause change in climate:

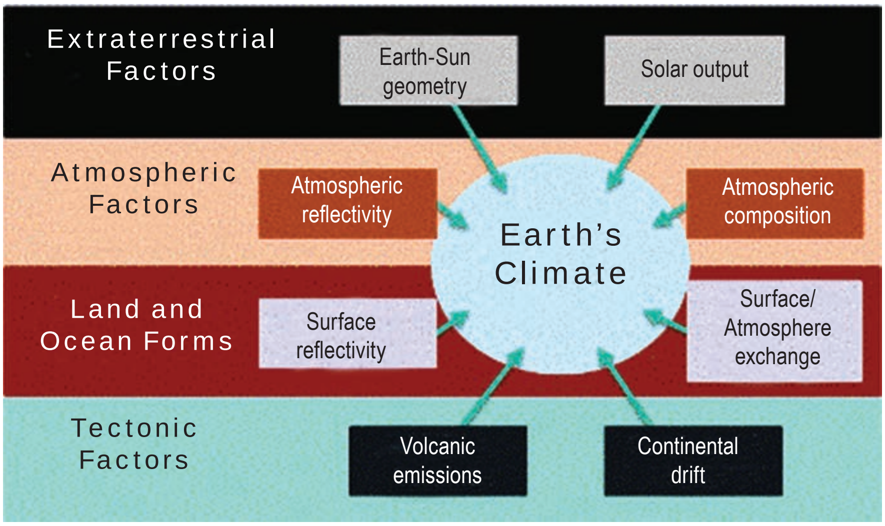


Figure 6.6. Factors affecting climate change

a. Extraterrestrial factors: They are the difference in the sun's activity, i.e., energy output from the sun, slow change in the Earth's orbit and tilting of its axis. Sun's energy output refers to change in the amount of ultraviolet component and other cosmic rays in the radiation. This variation results to change in temperature of Earth causing warming and cooling effects. Solar radiation also affects the planetary wind pattern which affects the ocean current.

b. Tectonic factors: Movement of tectonic plates could cause volcanic eruptions and changes in ocean currents. The main influences within the Earth are volcanic emissions and continental drift. The gases from the volcano alter the atmospheric composition and ocean currents result in the formation of cyclones.

c. Land and ocean factors: They include the reflectivity of the surface, the amount of heat in the oceans and atmosphere, and the amount of heat exchange between them.

d. Atmospheric factors: Atmosphere reflects the radiant energy re-emitted by the Earth surface. Alteration of the composition of the atmosphere by emission of greenhouse gases enhances the ability of the atmosphere to trap radiant energy, thereby increasing the average temperature of the Earth. This results in erratic weather patterns which leads to climate change.

(b) Anthropogenic factors:

Several anthropogenic activities lead to the alteration of the composition of atmosphere, resulting in climate change.

Figure 6.7. Spewing out carbon dioxide from industries

1. Burning of Fossil Fuel: Since the industrial revolution began, there has been extensive combustion of fossil fuels, such as coal, oil and natural gas to run factories, cars and produce electricity. For instance, every year, industries across the globe release a billion tons of carbon dioxide into the atmosphere. Therefore, industrial revolution is considered as one of the anthropogenic activities causing the change in composition and concentration of the atmosphere.
2. Vehicular Emissions: Globally, about 33 percent of the carbon dioxide is released from the automobiles. On an average, for each liter of petroleum fuel a vehicle burns, 2.3 kilogram of carbon dioxide is emitted into the atmosphere.

Figure 6.8. Vehicular emission

3. Farming and Agriculture: Carbon dioxide, nitrous oxide and methane are produced from farming and agricultural activities. Carbon dioxide is produced through various agricultural practices like tillage and farm machinery use. Use of nitrogenous fertilizers can lead to increase in the levels of nitrous oxide in the atmosphere. Livestock farming accounts for an extensive amount of the world's methane emissions in the atmosphere.

Trees absorb carbon dioxide from the atmosphere for photosynthesis.

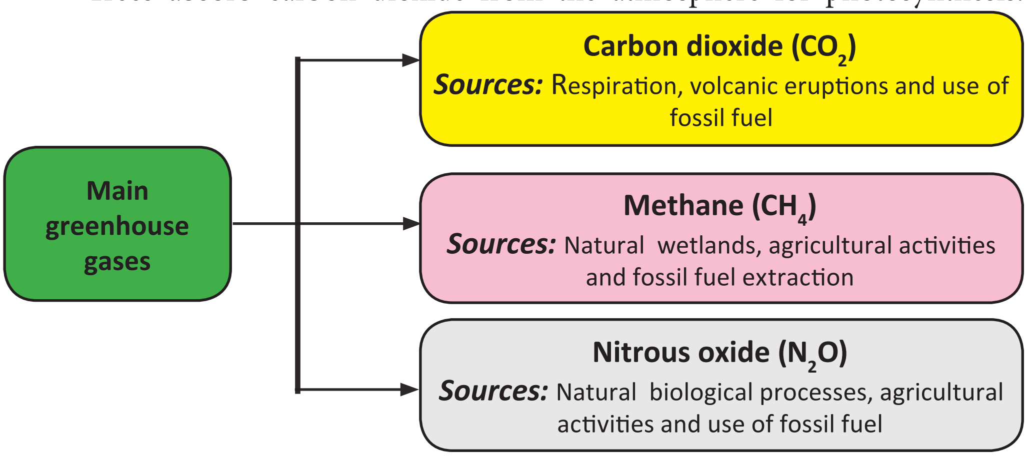


Figure 6.9. Greenhouse gases

Therefore, trees act as carbon sinks or reservoirs that accumulate carbon dioxide and help to regulate the natural greenhouse effect. However, clearing of forests for agricultural purposes reduces the potential of forest to absorb both heat and carbon dioxide.

(c) Greenhouse effect and Global warming

Atmospheric gases like carbon dioxide, methane and nitrous oxide trap solar radiation and warm the surface of the Earth. This phenomenon is referred to as greenhouse effect. The magnitude of greenhouse effect depends on the atmosphere's temperature and the concentration of these gases. The natural greenhouse effect is vital in maintaining the surface temperature of the Earth. However, the increase in concentration of CO_2 and other gases in atmosphere increases the natural greenhouse effect, upsetting the normal Earth's normal temperature. This is called enhanced greenhouse effect, which contributes to global warming.

Activity 6.2. *Understanding Greenhouse effect and Global Warming*

Instruction:

Study Figure 6.10 and answer the following questions:

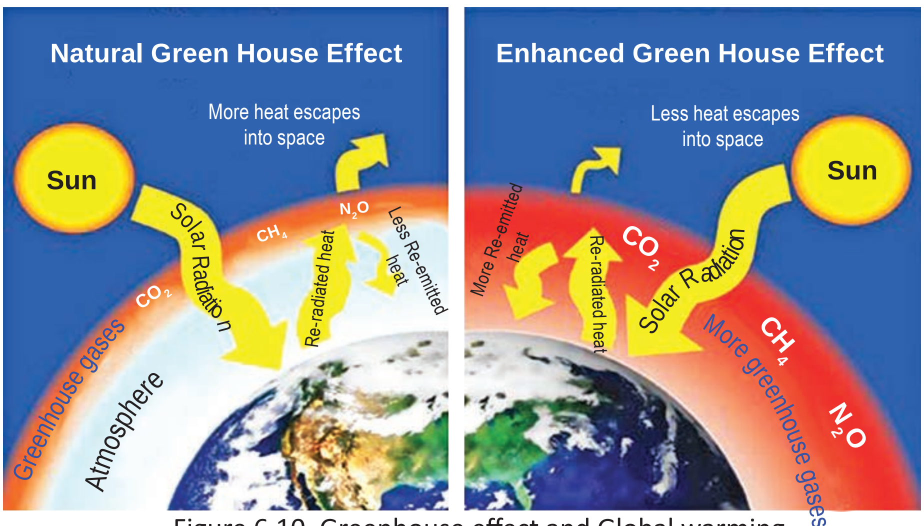


Figure 6.10. Greenhouse effect and Global warming

Questions:

1. What conclusion can you draw by comparing Figure 6.10a and 6.10b?
2. Why is increasing levels of methane (CH_4) in the lower atmosphere a concern?

3. What is global warming? Discuss some measures to reduce global warming.
4. Give two kinds of environmental impacts that may result from the increased greenhouse effect.

B. Impact of climate change

The existence of ecosystem depends on the climate of the Earth. Any change in climate affects the ecosystem and the natural habitat of plants and animals. Melting of ice caps, floods, landslides, drought, etc., are all consequences of climate change. Varieties of plants and animals have faced extinction due to climate change. Therefore, it has affected all the spheres of the Earth.

(a) Impact on ecosystem and biodiversity

Climate forms an indispensable part of an ecosystem, and any variation in the climate has the potential to change the structure and functions of an ecosystem. Increase in global temperature, for instance, can change the terrestrial ecosystems altogether. This may force species to shift their habitat range. For example, snow leopards *(Panthera uncia)* typically inhabit the area between the tree line and the permanent snow line. However, the increase in the temperature has forced the animals to move further up the mountain slopes, endangering the snow leopards due to scarcity of food.

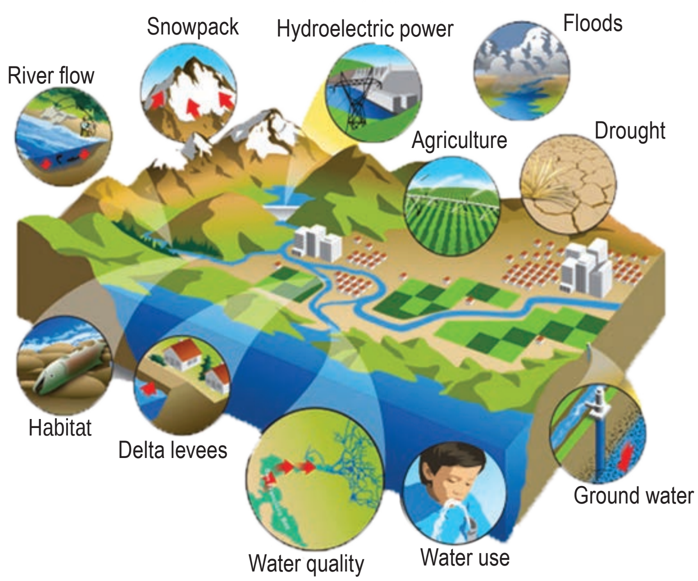


Figure 6.11. Impact of climate on water resources (California Department of Water Resource)

Reprint 2022

(b) Impact on water resources

Global warming increases the air temperature and enhances the rate of evaporation from land and water bodies. The erratic pattern of precipitation of the moisture results in heavy downpour. Heavy downpour surges the runoff into rivers and lakes, washing nutrients and pollutants into water sources and thus, deteriorating the water quality.

The melting of glaciers and heavy downpour cause rise in sea level and deteriorate the quality of fresh water through saltwater intrusion. This reduces fresh water supply in the islands and coastal regions. The rising sea level also affects the marine ecosystems because the amount of light reaching offshore plants and algae is reduced and endangered species become extinct. Thus, it impacts the population of organisms inhabiting islands and the coastal land.

Climate change affects ocean temperature, ocean current, the supply of nutrients, food chains and brings about extreme events such as cyclones. All of these, threaten the marine species by affecting their distribution, abundance, breeding and breeding cycles.

(c) Impact on agriculture productivity and food security

The climate change can make environmental conditions favourable for the growth and reproduction of pests and pathogens. The outbreak of pests and pathogens affects agricultural productivity and reduces food security of the nation. Besides, an increase in the average temperature of the atmosphere affects crop production.

Change in patterns of rainfall can affect soil quality, either due to enhanced erosion rates or decrease in soil moisture, both of which are important for higher crop yields. The IPCC predicts that precipitation will increase in high latitudes and decrease in most subtropical regions. As per IPCC, as temperature increases and rainfall pattern changes, crop yields are expected to drop significantly in Africa, India and Middle East countries. In Central and South Asia, increasing temperature and water stress are expected to lead to a 30 percent decrease in crop yields.

(d) Impact on human lives

People depend on ecosystem for the natural, cultural, spiritual, recreational and aesthetic resources. Consequently, impacts of climate change on health conditions are both direct and indirect. Direct impacts are related to weather conditions such as heat and cold waves and flash floods. Indirect health impacts can arise from crop failures, conflicts, hunger, malnutrition and spread of infectious diseases due to changing environmental conditions. Some of the existing health issues and potential future health hazards from global warming and climate change are vector-borne diseases, water-borne diseases, respiratory diseases and malnutrition.

Activity 6.3. *Investigating climate change*

Instruction:

1. Work in small groups. Each group will select one member as a group leader.
2. Every group will visit a nearby village and interview at least three elderly people and take note of their responses.
3. Develop interview questions based on the following guiding questions:

Guiding questions

a. *How many acres of farmland do you own?*

b. *What crops could you cultivate 10 years before?*

c. *Which crops cultivated are no longer cultivated? Why?*

d. *How has the crop yield changed now compared to 10 years before? What could be the reasons for the change?*

e. *Does your village have enough drinking water sources?*

f. *Compared to 10 years ago, what changes do you observe in the conditions of water sources?*

g. *Did you experience any change in rainfall pattern in your locality over last 10 years?*

h. *How frequently does your village experience natural disasters (flood, landslides, forest fire and disease outbreak)?*

5. Compile your findings from the interviews, and write a report. Your report should include the following:

   i. *Introduction (objective of the survey, when and how the information was gathered)*

   ii. *Main Body (a detailed information and information analysis)*

   iii. *Conclusion (sum up the points mentioned in the main body)*

Questions:

1. Is there a change in the crop yield in the locality? What could be the factors affecting the change?
2. What are the concerns shared by the interviewees with regard to water sources in their locality?
3. Does the locality grow new varieties of crop? Why?
4. What conclusion can you draw from the survey about the change in climate? Provide evidences to support your stand.

Reprint 2022

C. Responses to climate change

Bhutan is vulnerable to adverse impacts of climate change. To mitigate and adapt to climate change, Bhutan has become a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and other international environmental treaties. Bhutan has adopted the following national responses:

(a) Constitutional mandates to maintain 60% forest coverage

The Constitution of the Kingdom of Bhutan mandates the maintenance of a minimum forest cover of 60 percent for perpetuity. Article 5 Section 2 of the Constitution states that the Royal Government shall, "protect, conserve and improve the pristine environment and safeguard the biodiversity of the country; prevent pollution and ecological degradation; secure ecologically balanced sustainable development while promoting justifiable economic and social development; and ensure a safe and healthy environment."

Bhutan's total area under forest cover stands at 70.46 percent. Of the country's total area, 51.44 percent is under protected areas. These serve as long-term carbon sink, sequestering greenhouse gas emission. The protected area system of Bhutan, in terms of percentage, is regarded as one of the most extensive in the world.

(b) Environmental policy

Various environmental policies and action plans are adopted and implemented to conserve Bhutan's rich environment. The Vision 2020, National Forest Policy (1974, 2010), Forest and Nature Conservation Act of Bhutan (1995), Biodiversity Act of Bhutan (2003), Biodiversity Action Plan (2009, 2002, and 1998), National Environment Strategy for Bhutan (1998), and the National Adaptation Programme of Action (2006) are some of the policies and programs implemented to conserve Bhutan's environment.

(c) Carbon neutrality

Bhutan commits to remain carbon neutral by ensuring that its emissions do not exceed the capacity of its forests to absorb them. In 2015, at the Paris climate summit known as 21st Conference of Parties (COP21) of the UNFCCC, Bhutan reiterated to remain carbon neutral.

Several responses and initiatives are also taken by international organisations to address the climate change. In December 1990, the UN General Assembly decided to start negotiations to prepare international response to address climate change. Some of the significant events are as shown in Table 6.2.

Table 6.2. Events to address climate change

Years	International events
1988	*Intergovernmental Panel on Climate Change (IPCC) established: To assess the gravity of the climate problem.*
1991	*United Nations Framework Convention on Climate Change (UNFCCC) adopted: The ultimate objective of the Convention was to achieve the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.*
1997	*UNFCCC in Kyoto, Japan, signed a treaty called Kyoto Protocol: Kyoto Protocol created three cooperative mechanisms, Emission Trading, Joint Implementation and Clean Development Mechanism.*
2015	*Paris Convention on Climate Change: Aims to achieve a legally binding and agreement on climate, with the aim of keeping global warming below 2°C*

Questions

1. Which factor is the most significant in causing climate change?
2. Describe the ecological disturbances caused by global warming?
3. What are the benefits of Bhutan being a signatory member to numerous international environmental treaties?

3. Phenology and Climate Change

Learning Objectives

On completion of this topic, you should be able to:

- evaluate the relationship between phenology and climate variables.
- apply phenological observation techniques or skills to understand climate change in the locality.
- generalise phenological observation patterns to draw conclusions.
- explain the relationship between phenology and climate change.

Phenology is the study of recurring seasonal life cycle of plants and animals and its relationship with environment. It is increasingly being used as a tool to study the impact of climate change on plants and animals. Phenology has been used as an indicator of climate change. Phenology, as an indicator, shows the state of environmental conditions at a given period of time for a specific area. Changes in phenological events of plants and animals are among the most sensitive ecological response to climate change. Therefore, phenology is also called, 'globally coherent fingerprint of climate change'. Monitoring of such events provides a first-hand insight into the impact of climate change on biodiversity.

a. Signs of seasons

Generally, phenological events of plants and animals change with seasons, though each plant and animal differ in ways they respond to seasons. Each season is marked with distinctive signs that enable people to understand seasonal changes. For instance, as season changes from winter to spring, days get warmer, most plants exhibit spectacular display of leaves and flowers; birds migrate from lower elevation to higher elevation; bears come out of their winter hibernation; farmers commence sowing seeds in their fields. Observation and interpretation of signs of seasons can provide insightful information on what, when and how nature changes with seasons, and what factors drive those changes.

Activity 6.4. *Interpreting signs of seasons*

Instruction:

1. Work in four groups, Each group will represent a season.
2. Use school library or Internet facilities to:
   a. *list what months fall under your assigned season and discuss what indicates an arrival of each season by plants or animals. Collect as much information as possible to solve the exercise questions. Support your findings with suitable illustrations, drawings and photographs.*
   b. *explain the purpose of such changes in plants according to seasons.*
3. Groups will display the findings in the classroom in the order of seasonal cycles.

Questions:

1. What are the phenological characteristics of plants in each season?
2. What are the climatic variables that affect the phenological cycles?
3. How do animal respond to seasonal changes? Support your answer with examples.
4. How do farmers in your locality use the knowledge of phenology in agricultural practices?

b. *Bio-indicator and climatic variables*

Phenological events, such as budburst, flowering, fruiting, bird migration, etc., are driven by biotic, abiotic and genetic factors. While biotic and genetic factors vary little over time, abiotic factors change with the climate change. The phenological events as seasonal cycles are predominantly regulated by abiotic

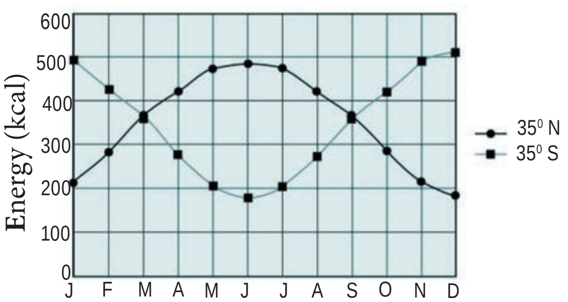


Figure 6.12. Day length and solar radiation received by Earth surface

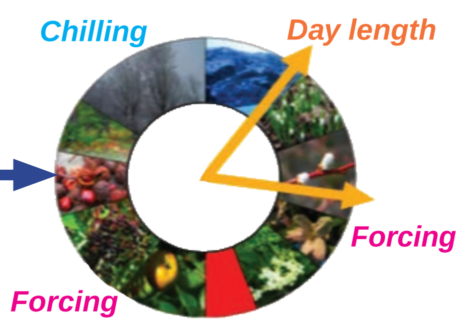


Figure 6.13. Factors effecting seasonal change.

climatic variables such as temperature, precipitation and day length. For instance, with warmer spring temperature, plants flower earlier.

The amount of precipitation acts either as forcing or constraining factors in flower development. In addition, the day length (hours of light against darkness) also affects the onset of spring flowering. However, the day length remains same from year to year as shown in Figure 6.12.

c. Phenology observation and recording

Phenology observation and recording are powerful ways of learning about the environment and its changes. It plays a vital role in understanding how climate change impacts plants and animals. Through this record, inferences can be made how seasonal cycles differ through the years.

Phenological events of plants can be observed using various methods. Depending on objectives and scale of investigation, it can be carried out in ways as listed:

(a) Single species and population observation

Phenology observation and monitoring can be made on single species of plants or animals. Single species observation can be done if the objective is to understand phenological events of a species in detail. On the contrary, in population observation, the events of entire population is observed and monitored to study the phenological events of the entire species and how they interact with each other.

(b) Status and event observation

1. Status observation:

In status phenology observation, observers visit the site regularly to observe phenological stages of plants and animals. Life stages or phenophases are reported as a series of 'yes' or 'no' questions in the observing or reporting form as shown in Table 6.3. These approaches ensure the capture of negative data (when the phenophase does not occur), repeat events (for example, a second wave of blooming is damaged by hailstones), and allow for an estimation of the uncertainty around the beginning or end date of a life stage. This helps to determine the onset and duration of each phenological event.

Table 6.3. Phenology observation and recording form

Species name: **Date**														
Phenophases	**Date:**		**Date:**		**Date:**		**Date:**		**Date:**		**Date:**		**Date:**	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Do you see seed budburst?														
Do you see young leaf?														
Do you see flower bud?														
Do you see open flower?														
Do you see young fruit?														
Do you see ripe fruit?														
Do you see leaf fall?														

2. *Event observation*

Event observation entails observing the occurrence of particular event of plant phenophases, or life cycle such as first onset of leaf, flower or migration of birds. The observation of life cycle event using event-based approach results in one data record compared to the multiple data records for the same event observed with the status monitoring approach.

Event-based monitoring generally skips repeat events and does not capture negative data. It cannot give information on duration and intensity of phenological events. Thus, it is only helpful in determining the onset of phenological events of plants and animals.

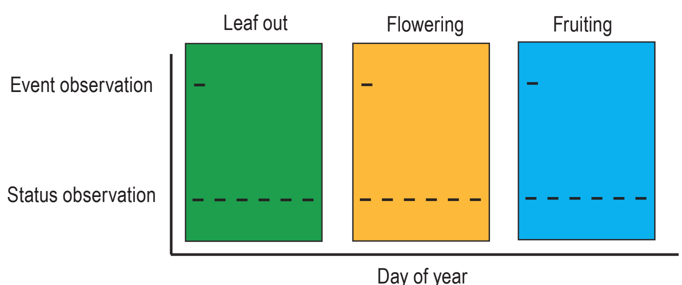


Figure 6.14. Status observation and event-based observation

(c) Hands-on and satellite based observation

Hands-on phenology observation entails visiting the plants or sites and physically carrying out the observation at a specific site. Whereas, satellite based monitoring entails observing the phenology of the entire landscape from satellite and deriving the information through a satellite image interpretation.

Activity 6.5. *Scalability of phenology observation*

Instruction:

Observe two methods of phenology study in Figure 6.15 and Figure 6.16 and answer the questions. If required, use internet to get necessary information on the two methods of observation.

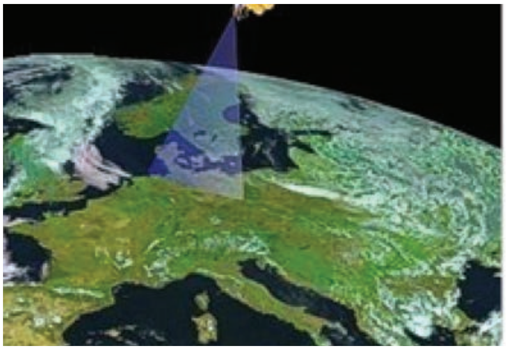


Figure 6.15. Satellite based phenology observation

Figure 6.16. Ground based phenology observation

Questions:

1. Which method is more suitable for phenology study of an ecosystem? Why?
2. How does the measurement of ground-based phenology observation compliment with the satellite based observation?

d. Phenology in practice

i. Phenophase definition and identification

A phenophase is a distinctive observable event in the life cycle of plants or animals, with a start and an end point. In plants, examples of these observable events, include budburst, first flower, first ripe fruit and color change. Although, there is considerable variation in the ways each species exhibit different phenophase stages, the generalised plant phenological sequences can be summarised as shown in Figure 6.17.

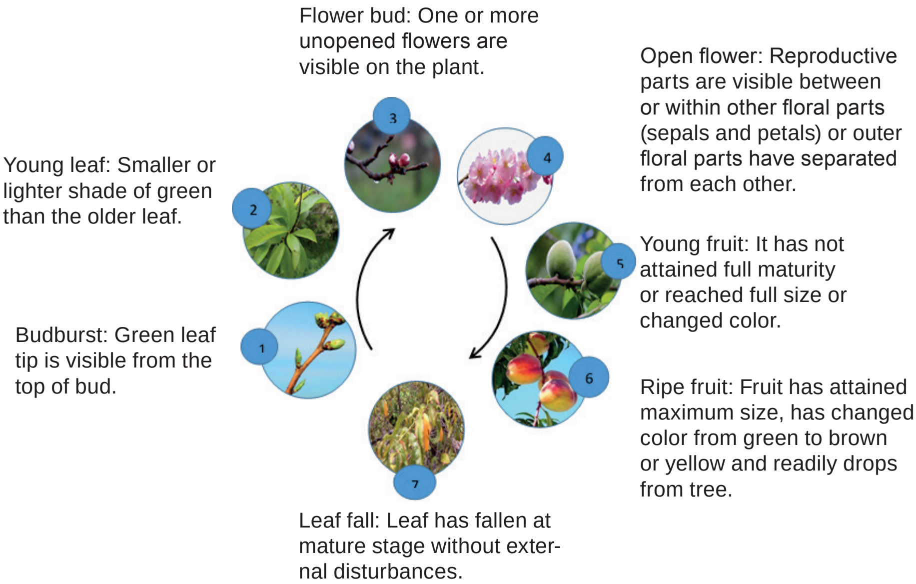


Figure 6.17. Phenological cycle

ii. Phenophase observation and recording

Generally, observing and recording phenology involves sets of general steps. Regardless of the nature of observation, observers are recommended to follow the steps as summarised by Figure 6.18. Ideally, observation can be made once in a week. The more details one records, the more valuable information one can gain in terms of understanding climate change and its impact. However, the most important objective of observation is to get the precise dates of key phenophases and its accurate identification.

Site selection: trees and shrubs- local environment, species preference.

Species selection: trees and shrubs- individual stand, herbs -patches/groups,
- If available, native species, if not, any other species.
- Species with distinct and easily observable phenophases.

Naming Species: Scientific name, common name, habitat and family (refer scientific nomenclature system for naming plant). Use appropriate materials for label.

Observing and Recording: phenophase definition sheet and observation form with you when you go to the field. Observe plants from different angle, and see for appearance of any new phenophase and record it.

Submission: Use available phenology web portal to submit the records. For example, in Bhutan, we have Bhutan Phenology Network (www.bpn.gov.bt)

Figure 6.18. Phenology observation and recording protocols

Activity 6.6. *Setting up the phenology trail and observation*

Materials required:

1. Observation form, phenophase definition sheet, trail setup guide, site and species selection guide and mobile app guide (downloadable from www.heroes.gov.bt/web/resources)
2. Android device with Uwice Heroes apps installed
3. Pencil and eraser.

Activity:

A: Setting up the phenology trail or trek

1. Set up the phenology trail in an area with good vegetative cover within the school campus. Limit the trail to a walking distance. The trail should serve as long term phenology monitoring site for the schools. Refer trail setup guide for more information.
2. Select, identify and mark plant species along the trail for phenology observation and monitoring.
3. Students are encouraged to observe the trees that had been already marked by previous observers along the trail, if available.

B: Download mobile apps and observation form

1. **Uwice Heroes** is mobile application to collect, store, analyze and visualize phenology data. Download and install mobile apps by searching 'Uwice Heroes' from the Google Play Store.
2. Use observation form or **Uwice Heroes** mobile apps for data collection, recording and submission. Each of this serve the same purposes.

C: Observe and record

1. Schedule the observation time during the nature club period. Make a calendar of observation to ensure that the plants are observed on same days of every week and every consecutive years.
2. Walk the trail, from starting point to end point. Stop at the selected plant species to observe for appearance of any new phenophases or animals sightings.
3. Identify the observed phenophases
4. Count or estimate the number of observable phanophases of the plant and record it either using mobile apps or printed observation form.

D: Create your own online data repository, analyze and visualize the data

1. Submit your observation data using mobile app or by registering and logging into online data repository (www.heroes.gov.bt/web/submit)
2. Explore your data and that of others through online interface (www.bpn.gov.bt/web/data_visualization)
3. Compare the onset of phenophases of given plant from one location to other location or from one year to year.

Questions:

1. What is the purpose of setting up the phenology trail?
2. What is the use of phenophase definition sheet?
3. Why is it good to have frequent observation of plant under the study?
4. How does your plant phenophase's timing differ from others or from year to year?
5. How will your data submission to Bhutan Phenology Study benefits people studying climate change?

Reprint 2022

c. Network of phenology

Globally, phenology has been widely used to study the impact of climate change on ecosystem. Among others, the countries, shown in the map (Figure 6.20), are currently implementing phenology as climate monitoring system. Each of this phenology network has unique ways of carrying out phenological events observation and recording. For instance, the ways in which phenology observations have been carried out determines its effectiveness in understanding climate change and its impact.

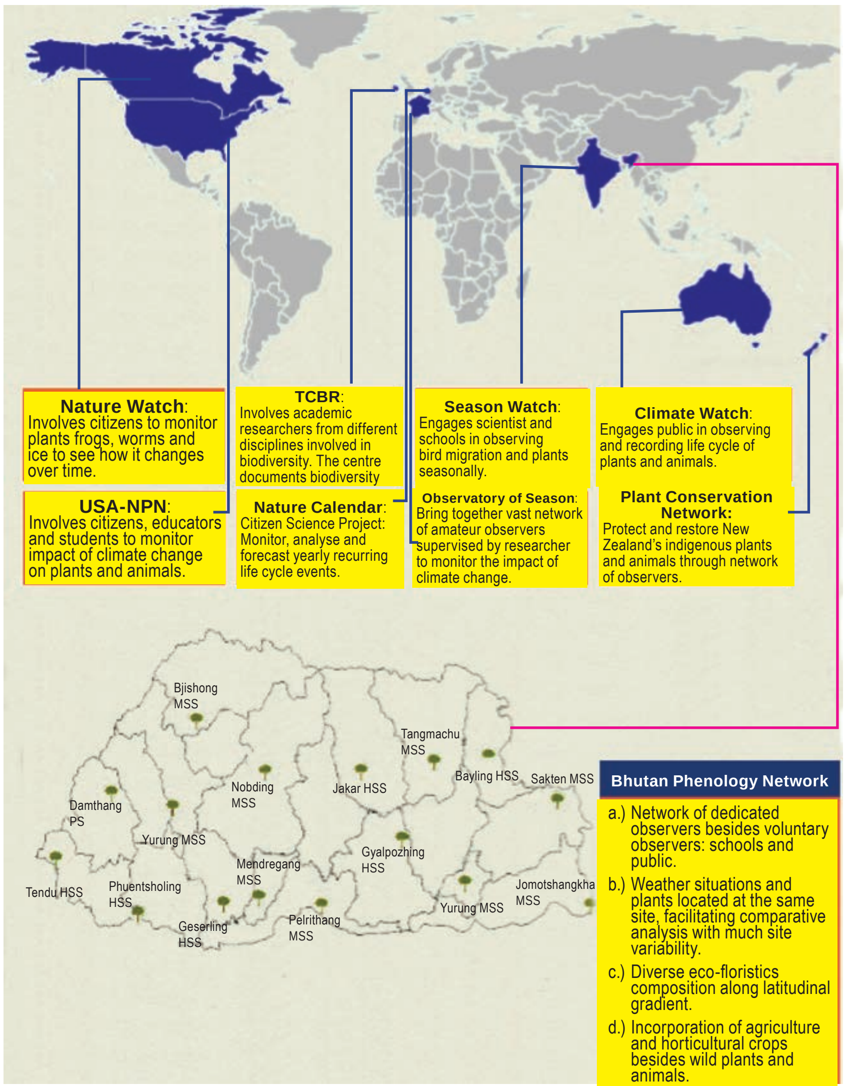


Figure 6.20. Maps showing the global phenology observation network

Exercise

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

   i. Which of the following significantly influences the climate of the Earth?

      A. Emission of greenhouse gases

      B. Melting of glacial ice

      C. Evaporation of water body

      D. Increase in absorption of solar heat by the plants

   ii. Which of the following reason describes that carbon dioxide is a greenhouse gas?

      A. Carbon dioxide readily absorbs and emits heat in infrared spectrum.

      B. Carbon dioxide produced during respiration add up to greenhouse gases.

      C. Burning of fossil fuel produces carbon dioxide.

      D. Carbon sequestration is less than its emission

      A. The natural processes like photosynthesis and respiration influences the concentration of

      A. CO2

      B. N2O

      C. SO2

      D. CFC

   iii. Karma is taking part in phenology study in a country where she helps to monitor how plants, frogs, worms and ice cover change over time. Her study contributes to monitor change in

      A. food chain.

      B. climate.

      C. pollution of level.

      D. quality of natural resources.

Reprint 2022

iv. The change in phenophases of plants and animals are among the most sensitive ecological response to

A. climate.

B. weather.

C. habitat.

D. precipitation.

2. ***Fill in the blanks with the correct form of word(s).***

i. The process by which heat is trapped by the gases inside Earth's atmosphere is called ________________.

ii. The phenomenon by which the forest absorbs large amount of carbon dioxide for photosynthetic process is called ________________.

iii. Ozone Solar variation causing climate change is an example of_________ factor.

iv. Temperature and _________are the most important elements in a climate description.

v. The influence of climate on the life cycle of organisms is known as _______________.

3. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.***

i. Solar energy is the source of energy that regulates the climate of the Earth.

ii. El niño is a result of global warming.

iii. The ability of the atmosphere to absorb and retain greenhouse gases increases with the decrease in atmospheric temperature.

iv. Increase in the concentration of the composition of atmosphere provides positive feedback, which in turn intensify the warming of the Earth.

v. The interactions between spheres determines the climate of a place.

4. ***Answer the following questions.***

i. State the relationship between climate change and weather.

ii. Describe negative feedback mechanism of the climate with an example.

iii. Differentiate between:

a) EI niño and La niño.

b) Pheonology and Phenophases

iv. Justify that climate change occurs when the components of the climate system is disturbed.

v. Explain the Carbon Neutral Policy strategies of Bhutan.

vi. The temperature of Earth's atmosphere is determined by the greenhouse effect. Explain Earth's greenhouse effect with illustration.

vii. Why is the Kyoto Protocol viewed as an important international agreement?

viii. What is the difference between status and event based phenology observation?

ix. A yearly variation in phenological cycle is not due to variation in day length. Justify.

7
CHAPTER
DISASTER RISK REDUCTION AND ENVIRONMENT

Disaster implies a sudden and overwhelming and unforeseen event that has impact on human lives and the environment. It is the result of different hazards that are of various nature such as geophysical, hydrological, climatological, biological and others. It has significant impacts on the human life causing loss of properties, injuries and even the loss of lives, disruption of transport and network communication, destruction of social service facilities and the environment.

Damages caused by a disaster can be effectively contained if there is a systematic effort to reduce exposure to hazards; potential hazard monitoring equipment is installed; preparedness capacity of the community is developed; and effective management systems and early warning system are in place. The early warning system is one of the important components of the system to reduce the risk from various hazards. It is used to forecast, transmit and disseminate the warnings of potential hazards.

1. Hazards and Disasters

Learning Objectives

On completion of this topic, you should be able to:

- define disaster.
- list types of hazards and their causes.
- explain the impacts of various types of hazards on the socio-economic structure and environment.
- explain the common hazards and disasters that Bhutan is vulnerable to.

The impact of natural or man-made hazard which causes environmental loss, increased mortality, illness or injury and disruption to livelihood of the people living in the vulnerable area is called disaster. A disaster occurs when a hazard hits vulnerable community. The combination of hazards, vulnerability and the capacity to reduce the potential negative consequence of disaster determines the risk.

A. Hazard, risk, vulnerability, coping capacity and disaster

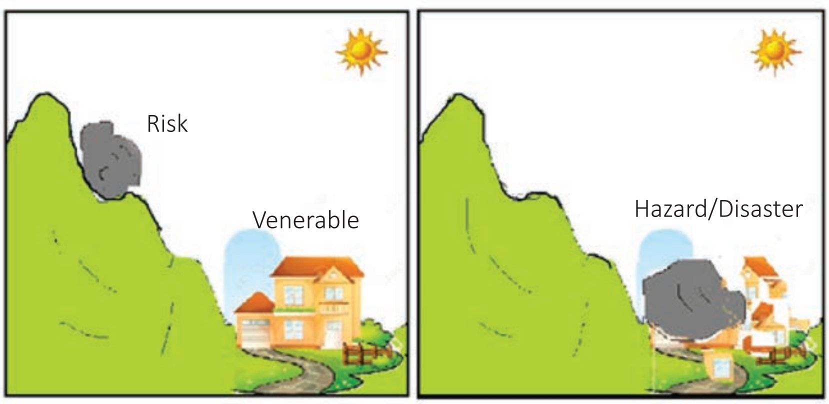


Figure 7.1. Risk, vulnerability and disaster

Reprint 2022

Hazard is a potential source of damage that may pose threat to life, health, environment or property to the extent of causing a disaster. Hazards can be either natural hazard (earthquakes, volcanic eruptions, cyclones, floods, landslides, etc.) or man-made (pollution, global warming, degraded environment, etc.). Hazards are termed disaster when they occur in inhabited areas causing heavy loss of lives and properties and vast damages to the environment that exceed the ability of the community to cope with its own resources. However, the hazard may not be termed as a disaster if it takes place in an area that is desolate without any harm to lives and property.

The degree of disaster in an area depends on the extent of susceptibility to which a community, structure, service, economy and the topography of a particular area are likely to be damaged or disrupted by the impact of a particular hazard. This situation is termed as a vulnerability. The geographical location, mitigation plans, demographic characteristics like population size, the income of the population, age group and the type of hazards determine the degree of vulnerability. Structural vulnerabilities can easily be identified and mitigated through proper planning.

Risk is the level of expected losses in the form of lives, injuries, damage to property, economy, and environment. The risk is widely recognised as a consequence of the interaction between a hazard and the characteristics that make people and place vulnerable and exposed. However, this risk can be modified by enhancing the level of the local preparedness or coping capacity of the community at risk. It is expressed by the following notation:

$$\text{Risk} = \frac{\text{Hazard} \times \text{Vulnerability} \times \text{Eposure}}{\text{Coping capacity}}$$

The ability of the vulnerable community to reduce the risk is termed as coping capacity. It is the combination of all the strengths, attributes and resources available that can be used to mitigate or reduce the effects of the disaster on physical structures, society and economy of the vulnerable community or organisation.

B. Types of Hazards

a. Geophysical hazards

These are hazards brought about by the physical processes in the Earth's crust. They include the following:

(i) Earthquake

Earthquakes are caused due to the sudden release of accumulated stress around the faults in the Earth's crust. Stresses build up on both sides of the fault because of the continuous tectonic plate motion. When the stress between the tectonic plates becomes high, the rock layer in the Earth crust is displaced accompanied by release of energy in the form of wave causing tremor. An earthquake usually lasts for a minute but aftershocks can be felt for many days. The level of damage caused depends on many factors such as the magnitude, depth of the earthquake (focal depth) and vulnerability of the structures and their distance from the earthquake's origin (epicenter).

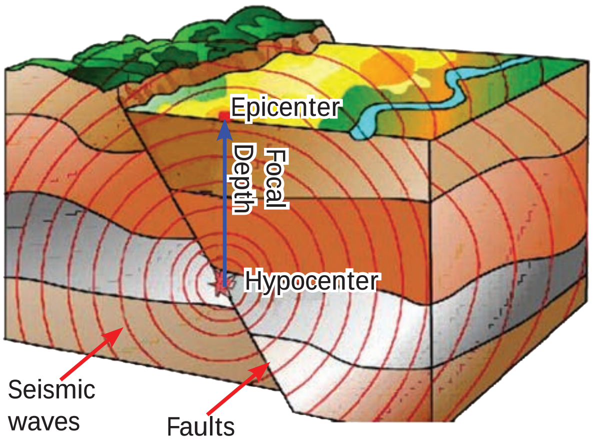


Figure 7.2. Epicenter and seismic waves

The point within the Earth along the sliding geological plate where an earthquake originates is called the focus, or hypocenter. The point on the Earth's surface directly above the focus is called the epicenter. The shock wave which originates at the focus and travels through the Earth is known as seismic waves. Most earthquakes occur along the plate boundaries because of the movement of the tectonic plates relative to one another. The movement of plates can be divergent, convergent or transform (Figure 7.3).

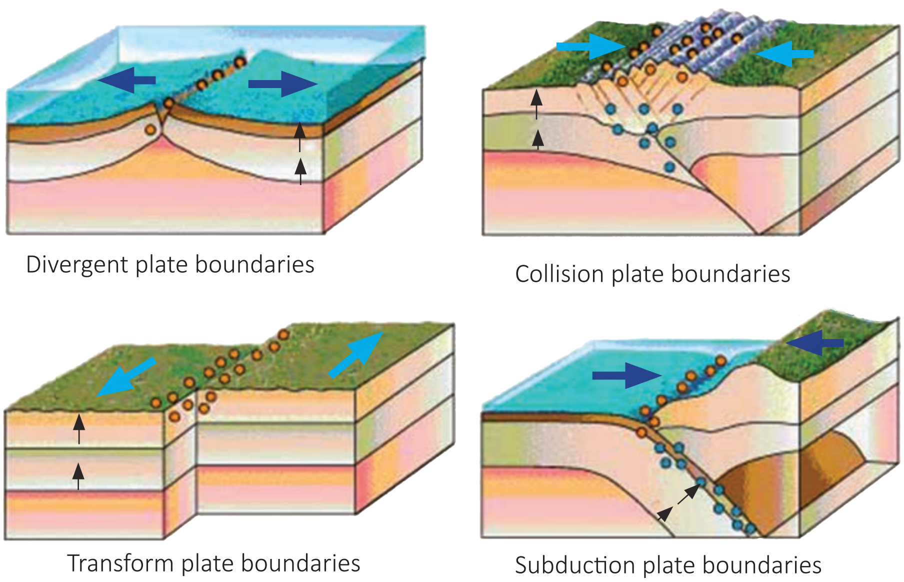


Figure 7.3. Types of Plate boundaries

Divergent plate boundaries are zones where two plates move away from each other. In such cases, the lithosphere is in a state of tensional stress forming rift valleys and oceanic ridges. The fracturing movement of lithosphere causes the earthquake. Most divergent plate boundaries are at the bottom of the oceans. Earthquakes that occur along such boundaries have low magnitudes.

Convergent plate boundaries are zones where two plates run into each other. Thus, they tend to be zones where compressional stresses are active. There are two types of convergent plate boundaries, subduction and collision boundaries (Figure 7.3). At the subduction boundaries, the tectonic plates are pushed down into the mantle, resulting in the formation of deep oceanic trenches. Due to this compressional stress, the subducted plate fractures and generates an earthquake. While in the collision boundaries, the two continental plates collide resulting in the formation of fold-thrust mountain belts; for example, formation of the Himalayan belts. This collusion generates seismic waves.

Transform plate boundaries are the plate boundaries where two lithospheric plates slide-pass one another in a horizontal fashion. Earthquakes along these boundaries have high magnitude.

Activity 7.1. *Understanding impacts of an earthquake*

Instruction:

Read the information provided in Table 7.1 and answer the questions that follow.

Table 7.1. Impacts of earthquake

Duration	**Social impacts**	**Economic impacts**	**Environmental impacts**
Short-term (immediate) impacts	Loss of life and injuries. Destruction of structures, homes, transport services and communication. Contamination of water, scarcity of food, psychological trauma, etc.	Hinders office, shops and business progress. Property loss. Damage to transport and communication links can make trade difficult. Increase in price of goods.	Change in landscape. Fire outbreak, gas pipe leakage and explosions causing destruction to forest land, animals and plants. Prompts pollution, landslides, flood, avalanche, Tsunamis in coastal areas.
Long-term impacts	*Increase in health hazards, increase in unemployment which could be due to destruction of industries.*	*Increase in cost of rehabilitation. Decrease in country's revenue and GDP.*	*Loss of Habitat and biodiversity.*

Questions

1. How do environmental impacts lead to social and economic impacts?
2. How different is the long term effect of earthquake from the short term effect?
3. In 2009, Bhutan experienced earthquake that measured 6.7 in magnitude. What were its impacts on society, economy and environment?

(ii) Volcano

Figure 7.4. Volcano

Volcano is the eruption of molten lava, rock fragments, hot vapour, ash and gases through crater or vent of a mountain or a hill. Volcanoes are generally found where tectonic plates are diverging or converging. Magma is generated at the converging plate boundaries where subduction occurs. The sinking plate melts as the plate descends into the asthenosphere. This generates magma, which rises through the other plate to form volcanoes. As magma travels through the Earth's mantle, more magma is generated due to the further melting of plates.

At diverging plate boundaries, when the plates are pulled away from each other, the magma rises upward from the underlying mantle along the gap between the two plates causing volcano. A volcanic eruption can be extremely damaging to the environment, particularly because of molten lava and toxic gases such as sulphur dioxide, carbon dioxide, hydrochloric acid, hydrogen sulphide, etc. being released. Carbon dioxide emitted by volcanic eruption increase the natural greenhouse effect, and sulphur dioxide forms sulphuric acid and causes acid rain.

Lava flows can wipe out the flanks of mountainsides, destroying biodiversity. Volcanic ash can blanket the landscape for miles, and ash clouds can cause cooling effect on the land due to reflection. If the ash is dense, it can make breathing difficult. The ash contains silica which causes silicosis, a disease resulting in lung impairment.

b. Hydro-meteorological hazards

They are potential threats posed by hydrological phenomenon in the form of flood, tsunami, and cyclone affecting the lives and the environment.

(i) Flood

Flood is the inundation of a normally dry area due to the rising water in an existing waterway, such as a river, stream, or sea due to torrential rain, storm, and melting snow, or volcanic eruption in the sea and earthquake. Flooding is a longer term event than flash flooding. It may last days or weeks whereas, flash flood is a short term event caused by heavy or excessive rainfall. Flash floods are usually characterised by raging torrents after heavy rains that rip through river beds, urban streets, or mountain canyons sweeping everything before them. Flash floods are sudden and unpredictable. Therefore, if it occurs in the vulnerable communities, it is far more devastating than the normal flood. Flash floods can also occur due to bursting of dam and outburst of glacial lakes.

Figure 7.5. Flood

Flooding is generally due to the climate change, which causes the changes in frequency and severity of storms, and patterns of rainfall. The heat waves of global warming cause the rapid melting of snow; thus, increasing the chances of floods.

Flood can have devastating consequences and effects on the environment, economy and people. Some of the impacts are given in Figure 7.6.

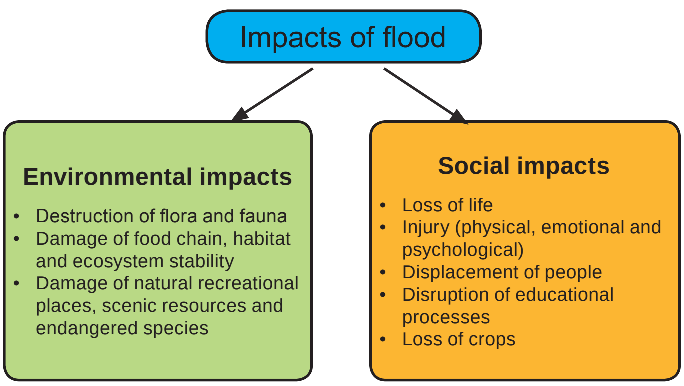


Figure 7.6. Impacts of flood

(ii) Landslides

Figure 7.7. Landslides

Landslide is a sliding movement of mass of soil, rocks and debris down a slope, mainly due to increase in water content in the landmass. Landslides can be triggered by both natural and man-induced changes in the environment. It can be due to intensive deforestation on steep slopes, construction of roads and other structure without proper planning thereby making land vulnerable to landslides. It can also be triggered due to weaknesses in the composition or structure of the rock or soil, topography of the land, heavy rainfall, and seismic and volcanic activities.

Landslide disrupts transportation and communication networks and even causes loss of lives and properties. It also creates temporary dams in some places with potential flash floods.

(iii) Avalanche

Figure 7.8. Avalanche

An avalanche is a sudden and often rapid mass movement of snow and ice down a mountainside. An avalanche occurs when the load that the mountain can hold exceeds its limit. However, a single event or a trigger is usually needed to start the process, such as earthquakes or tremors, a sudden increase in snowfall, skiers stepping onto the fragile snowpack, snow vehicles causing vibrations, or high velocity winds.

Avalanches can be slab avalanche which involves large blocks of snow fracturing away from the main plain of the mountainside, or powder snow avalanche where the top layers of the snowpack mixes with the moving air forming a cloud of snow. Avalanche can make its way very quickly, sometimes at more than 300 km/hr, down the hillside with up to about ten million tonnes of snow. In a mountainous terrain, avalanches are among the most serious natural hazards to life, property and environment.

Reprint 2022

(iv) Tsunamis

A tsunami is a series of massive sea waves generated by sudden undersea tectonic plate movement or earthquake, or even volcanic activities. Tsunami propagates across thousands of kilometers over the ocean and smashes onto coast land with powerful high waves causing devastating impacts on lives, properties and environment.

Figure 7.9. Tsunami

Tsunamis are initiated by sudden vertical deformation of the tectonic plates in the sea floor. This deformation displaces a large volume of water that travels as waves towards the shore.

Tsunamis pose no threat in the deep ocean because the height of the wave is low, but as the wave approaches the shore, waves slow down due to friction with the shore resulting in increase in height of the waves as shown in Figure 7.10.

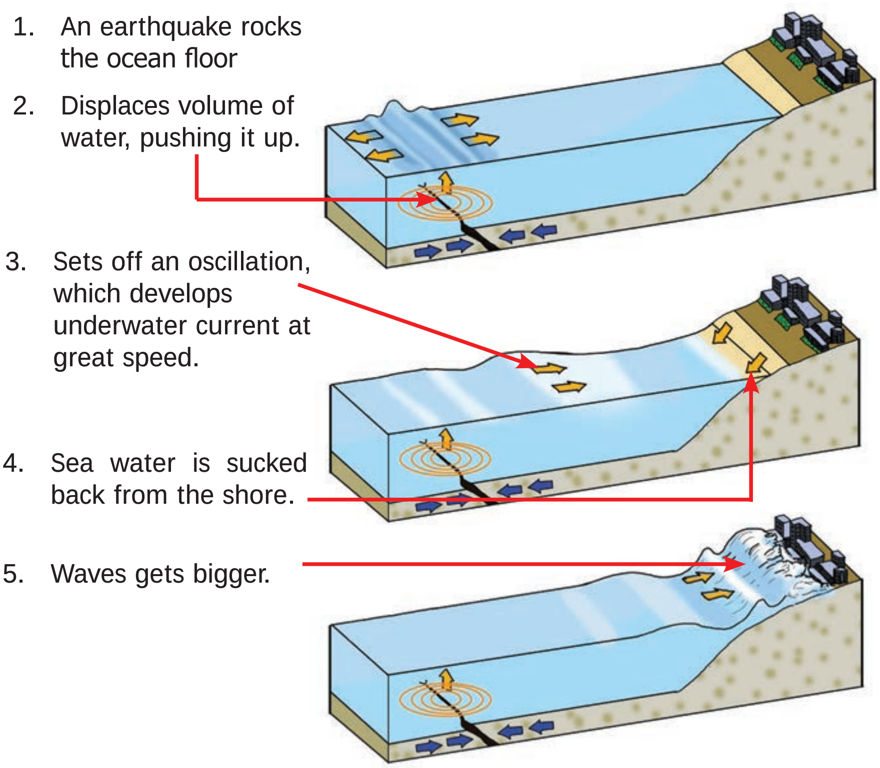


Figure 7.10. Tsunami Formation

The effects of a tsunami depend on the characteristics of the seismic event that generated it, the distance from its point of origin, its magnitude and the depth of water in oceans. A small wave of only 30 cm high in the deep ocean may grow into a huge monster wave of 30 m high as it sweeps over the shore causing devastating damages, such as loss of life, pollution, destruction of boats, buildings, bridges, cars, trees, sewage, fresh water supplies, telephone lines, power lines, and roads.

(v) Cyclones

Cyclone, hurricane and typhoon are different names for the same phenomenon. Cyclone is a large scale air mass that rotates around a center of low pressure. Cyclone circulates in anti-clockwise in Northern Hemisphere and in clockwise direction in the Southern Hemisphere.

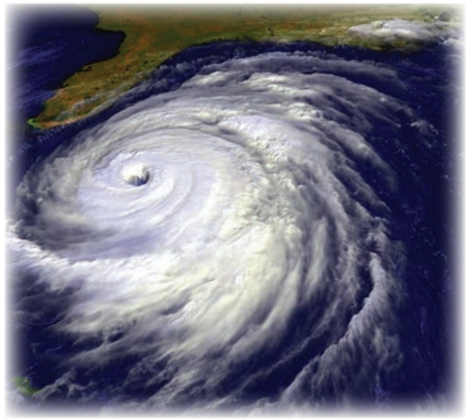


Figure 7.11. Cyclone

Cyclones are storms formed when the temperature of the sea water rises above 26 degree Celsius. The warm moist air evaporates from the surface of the sea creating an area of low pressure. The surrounding air rushes in to fill the low pressure area, but because of the spinning of the Earth, the air is bent inward which then spirals upwards with a great force. As the warm moist air rises, condensation takes place forming massive cumulus cloud. The heat released during condensation further lowers the pressure and strengthens the force and amount of the air rushing in, speeding up the rate of rotation. This forms a huge circle of moisture loaded cumulus cloud spinning at a very high speed with a calm cloudless centre called "eye". These storm systems can result in severe thunderstorms, violent winds, heavy flooding, and devastating waves.

Since the heat and moisture of the warm water is the source of energy for the cyclone, it weakens rapidly when it travels over the land or colder ocean where the heat and moisture is less.

c. Climatological hazards

Stable climatic condition is essential for healthy vegetation, adequate water supply and food for livelihoods. Extreme changes in climatic conditions over a long period of time can result in drought, floods and even wildfires.

Reprint 2022

(i) Droughts

Figure 7.12. Drought

Drought is an extreme climatic event characterised by below normal precipitation over a period of months or years. Hot dry winds, shortage of water, high temperatures and high rate of evapotranspiration.

It leads to severe water shortage, drop in crop yield, food supply and decline in thousands of livestock and its productivity due to dramatic shortage of water and fodder. The change in food production situation has a deep impact on the world food prices. The abnormal shortage of water adversely affects ecosystem services, employment, migration and health and hygiene of communities.

(ii) Wildfire

It is the fierce fire that spreads rapidly, destroying vegetation and animal species. Wildfires are caused by lightning, or by humans, either deliberately or due to their negligence. Wildfire leads to environmental changes such as vegetation and ground cover, air quality, alteration of soil properties and disturbance of hillside stability. These changes brought about due to wildfire can directly or indirectly have hazardous impact on the lives of people, properties and the environment.

Figure 7.13. Wildfires

(iii) Heat waves

A heat wave is a prolonged period of excessively high temperature which is usually accompanied by high humidity. It is measured relative to the usual temperatures of an area. It occurs when air pressure rises at a height of about 10,000 to 25,000 feet above the ground and blocks the warm air rising from the ground. At this level, the warm air cools and becomes dense. This cold dense air acts as a dome, capping the atmosphere and trapping heat instead of allowing it to rise. Without the rise of hot air, there is little or no chance of convectional rain. Therefore, there is excessive increase

Figure 7.14. Heatwave

in temperature and buildup of moisture, and if this situation persists for a longer period, it results in heat waves.

Heat wave causes hyperthermia in people, by which people suffer from fatal conditions, such as fatigue, dizziness, headache, nausea, vomiting, muscle cramps, sweating and even heatstroke. It also causes environmental damage and impacts all the life forms in the affected area. For example, in year 2015, a scorching heat wave claimed more than 1,500 people in India as temperatures soared above 47 degree Celsius.

d. Biological hazard

Biological hazard is a devastating effect caused by an extensive spread of diseases and sudden growth in population of certain kind of plants, animals or insects. Biological hazard may be epidemic or pandemic. Epidemic is an outbreak of disease like cholera, plague, etc., that spreads very quickly affecting large number of individuals within the population, community or region during the same period of time. On the other hand, pandemic is a widespread epidemic that spreads across a continent or even worldwide, for example, spread of AIDS, swine flu, etc.

Figure 7.15. Pest infection

e. Extraterrestrial Hazard

Celestial bodies such as asteroids, meteoroids and comets sometimes fall on the Earth's surface with tremendous force. Such incidents have the potential to cause catastrophic effect on humans and environment. This is termed as extraterrestrial hazard.

The extraterrestrial hazards can lead to disasters on the land, which depend on the sizes of the celestial bodies reaching the Earth. The heat emitted during the impact with the Earth's surface causes serious damages to the environment. In addition, the collision can cause earthquakes, tsunami, wildfires, and very poor visibility due to dust and soot.

Figure 7.16. Extraterrestrial disaster

Reprint 2022

f. Man-made Hazard

The advancement in technologies and industrialisation has increased the number of structures, such as tall buildings, dams, oil refineries and chemical factories, and nuclear power plant. They pose potential risk to the lives and the environment through leakage of toxic chemicals, or explosion. Some of these hazards have long lasting impact on human life and the environment including the biogeochemical cycle of the Earth.

(i) Industrial hazard

The leakages of toxic chemicals, harmful radiation, fire or explosion in the course of industrial activity, storage or transportation of hazardous chemicals pose potential threats to the people and environment in the industrial areas and nearby regions. These events can cause illness, injury, disability or death in human beings, often in large numbers, and can result in extensive damage to the environment with considerable human and economic loss.

Table 7.2. Toxic heavy metals, their sources and effects on human health

Pollutants	Major Sources	Effect on human health	Permissible level (mg/L)
Arsenic	Pesticides, fungicides, metal smelters	Bronchitis, dermatitis, poisoning	0.02
Cadmium	Welding, electroplating, pesticide, fertilizer, Cd and Ni batteries, nuclear fission plant	Renal dysfunction, lung disease, lung cancer, bone defects (Osteomalacia, Osteoporosis), increased blood pressure, kidney damage, bronchitis, gastrointestinal disorder, bone marrow cancer	0.06
Lead	Paint, pesticide, smoking, automobile emission, mining, burning charcoal	Mental retardation in children, development delay, fatal infant encephalopathy, congenital paralysis, sensor neural deafness and acute or chronic damage to nervous system, epilepticus, liver, kidney and gastrointestinal damage	0.1
Manganese	Welding, fuel addition, ferromanganese production	Inhalation or contact causes damage to central nervous system	0.26
Mercury	Pesticides, batteries, paper industry	Tremors, gingivitis, minor psychological changes, acrodynia characterised by pink hands and feet, spontaneous abortion, damage to nervous system, protoplasm poisoning	0.01

Zinc	Refineries, brass manufacture, metal plating, plumbing	Zinc fumes have corrosive effect on skin, cause damage to nervous membrane	15
Chromium	Mines, mineral sources	Damage to the nervous system, fatigue, irritability	0.05
Copper	Mining, pesticides production, chemical industry, metal piping	Anemia, liver and kidney damage, stomach and intestinal irritation	0.1

For example, the 1984 Bhopal gas tragedy of India is considered as one of the world's worst industrial disasters. Over 500,000 people were exposed to methyl isocyanate gas and other chemicals which caused death and severe injuries to several thousand people.

The radiations from the nuclear power plants are also sources of hazards for humans and environment. The radioisotopes from the nuclear power plants fuse with the dust and dirt, and slowly fall down to the Earth's surface as radioactive fallout.

The radiation has more harmful effects in the long run than the present short term benefits. When human body is subjected to radioactive radiations, large scale health hazards like cancers, deformations and mutations occur. Radiation also affects the soil microbes, growth of plants, water ecosystem, etc.

(ii) War

The environmental repercussions of war include diversion of resources for military spending, destruction and pollution caused by toxic chemicals in weapons and ammunitions. Human deaths, loss of properties and destruction of environment are some of the immediate consequences of war. The long-lasting effect of toxic chemicals used in ammunitions results in loss of habitat and biodiversity, contamination of land and water, death of terrestrial and aquatic animals, decrease in agricultural production and increase in various kinds of diseases.

Activity 7.2. *Exploring human-made disasters and their impacts*

Instruction:

1. Work in six groups. Each group will select a topic from the list provided. (You can also select any topic to substitute the listed topics).

Reprint 2022

a. *The Bhopal gas tragedy of 1984: An environmental disaster*
b. *Seveso: Italian Dioxin Crisis of 1976*
c. *Brazil: The 1998 Roraima Wildfires*
d. *Lebanon-Jiyye Oil Spill of July 2006*
e. *The Gulf War (1990-1991)*
f. *Fukushima Nuclear disaster of 2011*

2. Use internet facilities or other sources to gather information on the topic assigned.
3. Each group prepares a power point presentation. Support your presentation with relevant illustrations and photograph as evidences.
4. When one group presents to the class, other group members complete the Table 7.3.

Table 7.3.

Name of the disaster	Description of disaster	Impacts caused			Your opinion on mitigation measures that could have reduced the impact
		Human	Environment	Economy	

Questions

1. Why do you consider these disasters human-made?
2. What are the causes of the above human-made disasters?
3. Frame certain policies and discuss them to mitigate the above disasters.
4. What roles can the social and cultural values play in preventing such disasters?

Questions

1. How would vulnerability, hazard and coping capacity determine the risk of the disaster?
2. Disaster is not always due to a natural cause. Justify the statement.
3. How does radioactive fall-out affect the vegetation?
4. Explain two hazards that has potential to bring disasters in Bhutan.

2. Disaster Risk Reduction

Learning Objectives

On completion of this topic, you should be able to:

- discuss the instruments and technological innovations that help reduce disaster.
- analyse the mitigation strategies of GLOF in Bhutan.

The impending natural disaster cannot be prevented but measures can be taken to minimise the possible risks by adopting disaster mitigation strategies, early warning systems, first aid services and rehabilitation after a disaster.

The early warning system is the provision of timely and effective information that facilitates individuals exposed to hazard to prepare for effective response.

A. Disaster monitoring tools

Disaster management is a systematic plan which requires tools and professionals for monitoring and predicting different types of natural calamities.

a. Earthquake monitoring system

(i) Global Positioning System (GPS)

The Global Positioning System is one of the widely used tools for studying the Earth's crust movements. By repeatedly measuring the distances between specific points on the Earth that move, geologists can determine movements along the faults or the plates (Figure 7.17).

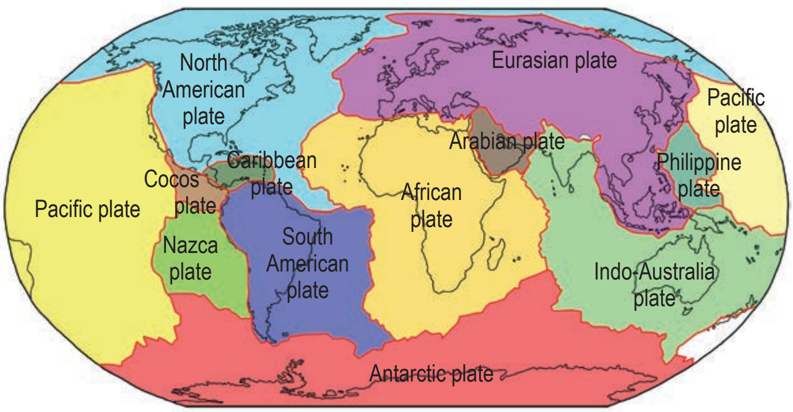


Figure 7.17. Tectonic plates

The plate movement information is used to predict the events that may build up to earthquakes, volcanic eruptions and tsunami. GPS relies on dozens of

Reprint 2022

navigational satellites that orbit the Earth. These satellites continuously transmit radio signals to the Earth which are detected by GPS receiver on the ground to determine the receiver's precise position on the Earth in terms of longitude, latitude, and elevation.

Figure 7.18. Global Positioning System

(ii) Seismograph

Most of the earthquakes occur along the plate boundaries when the two or more tectonic plates slide releasing a wave of energy known as seismic wave.

Seismograph is an instrument that detects the presence of an earthquake and measures its magnitude. A typical seismograph consists of a base that is anchored into the ground so that it moves with the ground during an earthquake. When the Earth shakes, the stylus that rest on the roll of the rotating paper records the vibration in the form of graph. This recording is called seismogram.

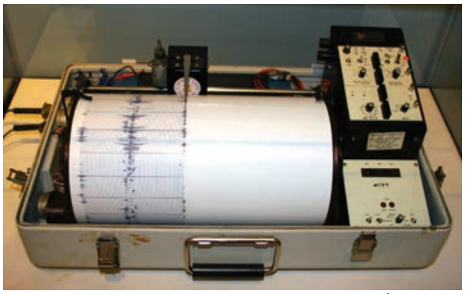


Figure 7.19. Seismograph

The magnitude of earthquake can be measured by using different scale on the seismograph. Richter scale and Mercalli scale are the most commonly used by geologist for measuring the severity of an earthquake. The Richter scale has scale from 1 to 10. It detects the magnitude of an earthquake by measuring the size of the seismic wave generated at its epicenter. Higher the value, stronger is the tremors. The Mercalli scale has a scale from 1 to 12, it measures the intensity of earthquakes.

Table 7.4. The classes of earthquakes (United States Geological Survey)

Class	Magnitude
Great	8 and above
Major	7 to 7.9
Strong	6 to 6.9
Moderate	5 to 5.9
Light	4 to 4.9
Minor	3 to 3.9

(iii) Creep Meter

A creep meter is an instrument that monitors the slow surface displacement of an active geologic fault in the Earth. A creep meter works with a wire stretched across a fault line (Figure 7.20). On one side of the fault, the wire is anchored to a post. On the other side, the wire is attached to a weight that can slide up along the scale when there is fault movement. The scale measures the magnitude of the fault movement.

The measurement range of a creep meter is usually limited to 10 mm to 30 mm. Installing the creep meter across an active fault allows geologist to understand the fault creep and to predict where an earthquake may be likely to occur due to the movement of the fault.

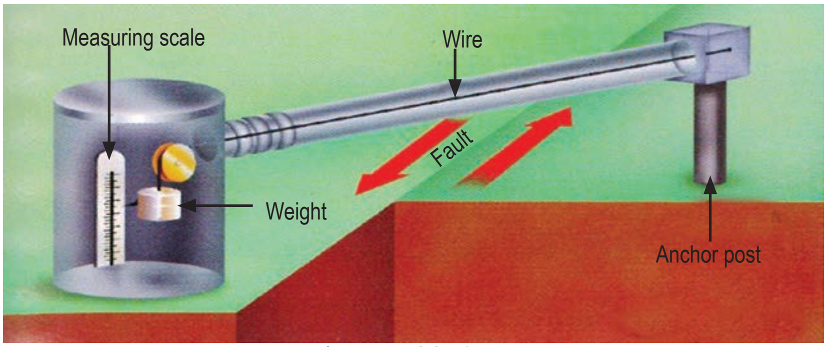


Figure 7.20. Creep meter

b. Volcano monitoring system

The volcanic activity brings about topographical changes on the land surface. The changes or the deformation of the volcanic surface can provide clues about what is happening below the surface. While monitoring the volcanic activity, an accuracy of a few centimeters or less is extremely vital for detecting the buildup of stress and pressure caused by magma rising towards the surface. Monitoring is done by installing a network of deformation detection instruments around the volcanoes. These instruments are integrated with the satellite-based technologies, such as GPS (Global Positioning System) to help geologists understand the volcanic activity and provide eruption warning.

By detecting the seismicity, geologist work around the clock to give early warning information to people. For this, a number of seismometers are installed within the vicinity of 20 km of a volcano and couple of them are placed on the volcano itself. The monitoring of volcanic gases can be helpful in predicting eruptions. For instance, an increase in CO_2 and SO_2 concentrations emitted from fumaroles may indicate increasing magmatic activity beneath the volcano. These changes are used as monitoring information to give warnings about eruptions.

c. Tsunami warning system

It is impossible to predict tsunami. Once tsunami is formed, the warning system detects it by using seismic sensor, water level gauges (pressure recorder), buoys (tide gauges) and communications infrastructure to predict the time a wave will hit the land. Accordingly, timely alarms are relayed for evacuation of people living in the vulnerable coastal areas.

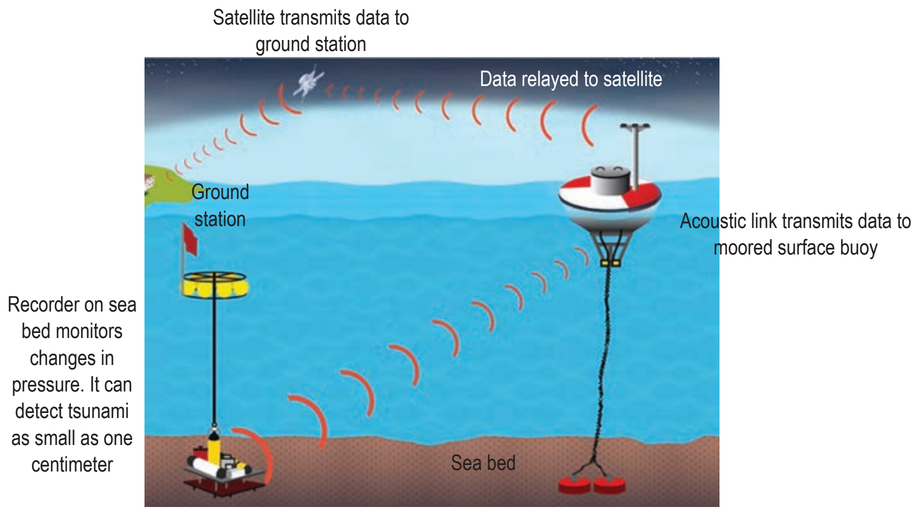


Figure 7.21. Tsunami warning system

Seismic gauge can detect the earthquakes or volcanic eruptions which may cause a tsunami. The pressure recorders in the deep sea bed measure the weight of the water above it, which varies according to the wave height and sends its data to a buoy on the surface.

The buoy monitors the surface conditions and sends the data to the satellites, which is relayed to the receiving stations for identifying a possible tsunami threat, and accordingly warn people living in the coastal areas. The advantage of this system is that it can detect tsunami far out in sea and give enough time to warn countries in the region.

Activity 7.3. *Underlying Vulnerabilities of Disasters in Bhutan'*

While Bhutan is exposed to a wide range of natural and climate related hazards, it is the underlying vulnerabilities that translate physical exposure to hazards into disaster risks. These include poor construction practices, inadequate enforcement of building by-laws, rapid urbanization, environmental degradation awareness on disaster risk reduction and planning. The limited availability of safe land for construction in mountainous region, scattered settlement patterns and irregular climatic conditions further aggravate vulnerabilities.

a. Unsafe construction practices:

Bhutan has a strong tradition of vernacular houses, made ofstone, rammed earth and timber. However, safety of traditional constructions has suffered due to the loss of traditional safe construction practices and techniques and lack of adequate masonry skills, particularly in the rural areas. The past two earthquake events caused extensive damages to rural homes all over Bhutan demonstrating high vulnerability of traditional buildings to earthquakes and other natural hazards. There is a strong need for research and consolidation of indigenous knowledge related to traditional structures that would help strengthen and conserve traditional construction practices. The lack of incorporation of adequate disaster risk reduction elements beginning with safe locations, disaster resilient building designs and construction, renders physical infrastructure in both public as well as private domain susceptible to natural hazards. Inadequate monitoring and quality check of construction materials and buildings are also important issues.

b. Rapid and unplanned urbanization:

Bhutan witnessed a spurt of urbanization in the last few decades. Increasing population, built structure and other demographics have increased exposure and risks to hazards in urban centers like Thimphu and Phuentsholing and other emerging townships. The continuation of developmental activities in hazard/red-zone areas, for example in the GLOF red zone areas in Punakha and Wangdue valleys is a serious concern. These kind of development lead to increasing exposure and higher vulnerability resulting in irrecoverable losses during disasters. There is also insufficient and slack enforcement of building by-laws and codes in the urban areas. Weak enforcement of building by-laws and codes in the urban areas due to lack of expertise and trained human resources to enforce the same is a major factor contributing to the vulnerability of the built-form.

Reprint 2022

c. *Socio-economic factors:*

Socio-economic conditions compel socio-economically disadvantaged sections to live in unsafe and hazardous areas such as steep slopes or flood-prone riverbanks and adopt livelihood patterns that increase their vulnerability to hazards and expose them to a high degree of risk. This can be attributed to the inadequate land use planning policies, hazard zonation mapping in settlements and the high migration rate to urban settlements. The disintegration of joint family structures and the erosion of community ties and social practices could affect the resilience of individuals and families to disasters.

d. *Inadequate levels of awareness:*

There is a need for sustained awareness and advocacy efforts at all levels. At the decision making level, there is a need to develop a common understanding on the existing hazards, the level of risk and the priority actions needed to be implemented; at the sector and local government level there is a need to understand the importance of mainstreaming DRR and enhancing preparedness and response capacities; and at the community levels, both urban and rural, there is a need to help identify hazards and risks and take actions for safety and resilience. There has been significant progress in the education and health sectors, however, knowledge and awareness levels are low at community level, both rural and urban. There is still a need for all stakeholders (government, parliamentarians, businesses, civil society organizations, etc.) to understand that disasters good coordination, dialogue and mainstreaming in the pre disaster phase leads to risk reduction and effective response during any disaster.

e. *Vulnerability of Critical Infrastructures:*

It is imperative for key facilities such as health centers, schools, disaster management facilities and key public and administrative buildings to be disaster resilient to ensure their functionality during emergencies. There is a need to prioritize vulnerability assessments of these key facilities (including critical disaster management and telecommunication facilities) to enable systematic and mandatory incorporation of seismic resistant and other hazard resilient features particularly for schools, hospitals and other health centers and important cultural heritage sites and buildings.

f. *Lack of Risk Transfer Mechanisms:*

A well-designed risk financing program enables a disaster-prone country to avoid major economic disruptions following natural disasters by meeting its post-disaster funding needs without resorting to major budget reallocations, additional taxation, or external borrowing. There is need for Bhutan to have a well-designed risk- financing program to ensure post disaster funding needs are fulfilled, as well as to facilitate means to build back better in the aftermath of a disaster.

g. Environmental degradation:

Environment conservation is an important crosscutting theme for Bhutan and the Constitution mandates sixty percent of Bhutan's land mass to be under forest cover for all times to come. However, the increasing population and rapid urbanization in major cities and towns is putting a strain on the surrounding environment due to inappropriate infrastructure planning and construction. Development of roads require cutting into the fragile mountain sides leading to landslides and similarly mining activities lead to rapid degradation and denudation of hills causing landslides, flash floods and siltation in river systems. Deforestation due to forest fires, over-grazing and fuel wood collection also exacerbates such hazards. Timely interventions are necessary to curtail or mitigate environmental degradation before the situation becomes precarious.

Questions

1. List all the disaster monitoring tools which are relevant for Bhutan.
2. Explain the importance of monitoring disaster.
3. Is it necessary to install Creep meter in Bhutan? Justify your stand.

Exercise

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

   i. Forest fires are destructive to the environment and organisms. Which of the following is not the destructive consequence of forest fire?

   A. Exacerbate the levels of carbon dioxide in the atmosphere.

   B. Growth of fire resistant plants and other invasive species.

   C. Enhance micro bacterial activity in the soil and make useful nutrients.

   D. Land becomes susceptible to erosion by wind and running water.

   ii. The radiations from the nuclear plants due to leakage and accidental explosions are very hazardous to human health since

   A. explosions of nuclear plant bring very high casualty.

   B. radioactive gases cause adverse effects after exposure.

   C. radiation causes mutation and has long term effects.

   D. nuclear leaks pollute land, water and air.

   iii. The magnitude of energy released by an earthquake is measured using

   A. tectonic scale.

   B. creep meter.

   C. seismograph.

   D. Richter scale.

   iv. Which of the movement of plate boundaries cause tsunami?

   A. Divergent plate boundaries.

   B. Convergent plate boundaries.

   C. Transformed plate boundaries.

   D. Subduction plate boundaries.

v. The region of initiation of seismic energy within the Earth is called

A. epicenter.

B. hypocenter.

C. area of greatest building damage.

D. area of least building damage.

2. ***Fill in the blanks with the correct form of word(s).***

i. Earthquake, volcano and tsunami are caused due to distortion occurring at ……………….

ii. At a seismic station the first waves to arrive are ……………….

iii. Conversion of ground motion into the form of graph is done by an instrument called …………......

iv. The point where an earthquake originates is called the focus, or hypocenter, while the point on the Earth's surface directly above the focus is called ………………….

v. Richter scale detects the magnitude of an earthquake and the ………….. scale measures the intensity of an earthquake.

3. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in correct forms.***

i. Making the main entrance into the school building strong and wide is hazard prevention activity.

ii. In this present world, climate change is a potential source of hazards.

iii. The National Environmental Commission is responsible for the disaster management in Bhutan.

iv. The Richter scale and Mercalli scale measures the same quantity of the earthquake tremor.

v. The destruction of crops by army worm in Bhutan is an example of biological disaster.

Reprint 2022

4. ***Answer the following questions.***

   i. Name the locations A, B, C and D as labeled in Figure 7.22.

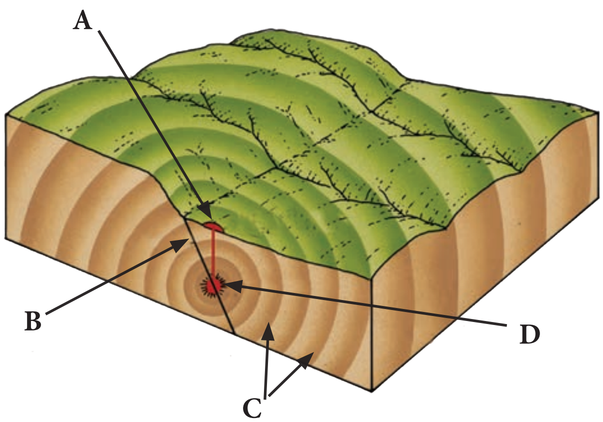


Figure 7.22.

   ii. There are several heavily populated communities living downstream, mainly dependent on fertile plains for crops and livestock. Their agricultural land is primarily irrigated by a big river sourced by several glacier lakes present upstream. Hence, it is the hub of trade of agricultural products for other adjacent communities away from the plains.

      a) Identify some of the hazards and vulnerabilities in the above situation.

      b) Relate the above identified hazards and vulnerabilities with the risk of the disaster.

      c) Suggest some of measures to mitigate the risk.

   iii. Write about some of the potential hazards in Bhutan as demanded by the Table 7.5.

Table. 7.5.

Hazard	Examples of the disaster	Impacts

iv. Categorise the following options under appropriate components of disaster risk in the flow chart given in Figure 7.23. Options can be repeated if required.

a) Extreme climate change

b) Mitigation

c) Economy

d) Early warning system

e) Chemical industries

f) Physical environment

g) Property

h) Awareness

i) Community action

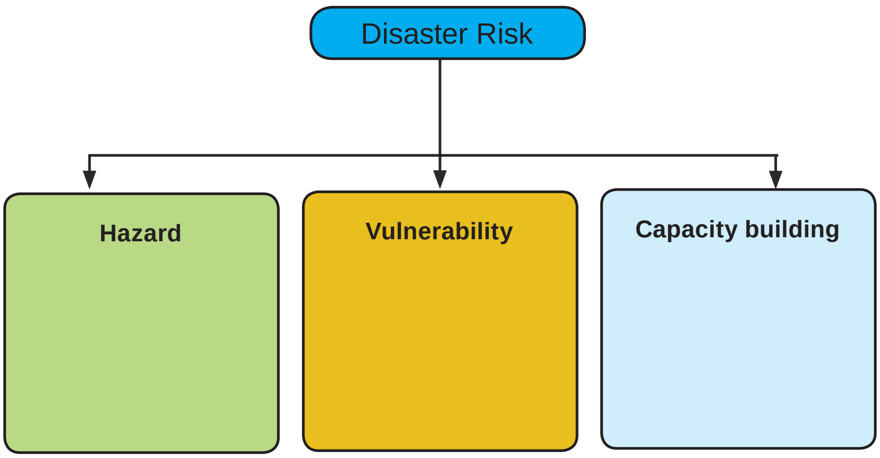
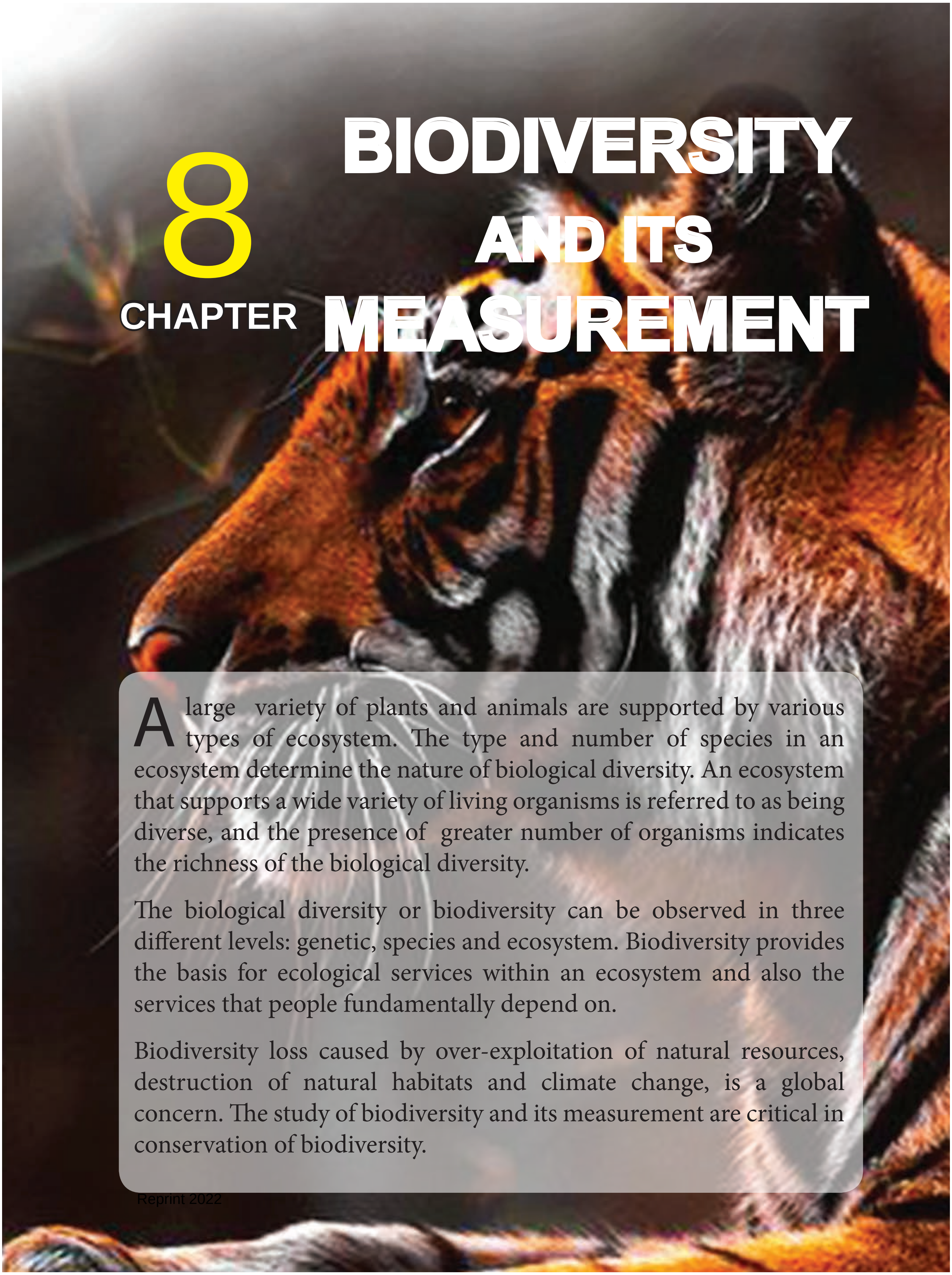


Figure 7.23.

v. Differentiate between hazard and disaster. Give one example each.

Reprint 2022



CHAPTER 8

BIODIVERSITY AND ITS MEASUREMENT

A large variety of plants and animals are supported by various types of ecosystem. The type and number of species in an ecosystem determine the nature of biological diversity. An ecosystem that supports a wide variety of living organisms is referred to as being diverse, and the presence of greater number of organisms indicates the richness of the biological diversity.

The biological diversity or biodiversity can be observed in three different levels: genetic, species and ecosystem. Biodiversity provides the basis for ecological services within an ecosystem and also the services that people fundamentally depend on.

Biodiversity loss caused by over-exploitation of natural resources, destruction of natural habitats and climate change, is a global concern. The study of biodiversity and its measurement are critical in conservation of biodiversity.

1. Biodiversity and Ecosystem Services

Learning Objectives

On completion of this topic, you should be able to:

- explain biodiversity.
- describe the levels of biodiversity.
- explain the importance of biodiversity.
- describe the relationship of biodiversity with ecosystem services.

A. Biodiversity

Biological diversity or biodiversity refers to the variety of life forms in a geographical area. It is expressed as the number of species or the number of genetic types in an area. An ecosystem which has a greater biodiversity are more stable and healthier than the one with lesser biodiversity. When a variety of animals and plants live in an area, the supply of food increases, which generally decreases the competition. This increases the survival of plants and animals even during the habitat destruction, disease outbreaks, etc. An area that has multiple ecosystems provides varieties of habitats for organisms to survive. The biodiversity is determined by species, genetic and ecosystem diversity.

a. Levels of Biodiversity

The variability among the living organisms in an ecosystem is observed under three levels, which includes the diversity within genes, species and ecosystems as shown in Figure 8.1.

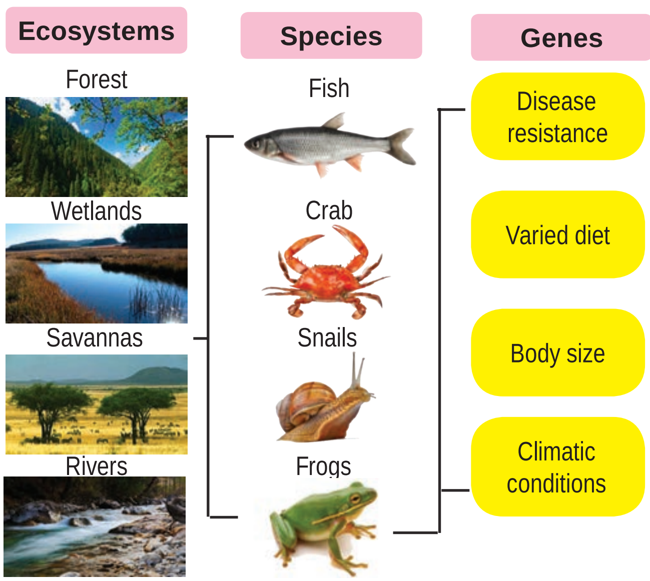


Figure 8.1. Levels of biodiversity

Reprint 2022

(i) Genetic diversity

Figure 8.2. Genetic variations

Genetic diversity refers to the variations amongst the organism of the same species. It is caused by the presence of smaller variations in their genetic composition. The members of a species exhibit individual differences due to the variations in their genetic composition. These variations are expressed as differences in their physique, behaviour, food habits, etc. For example, domesticated dogs belong to the species Canis lupus familiaris, however, different breeds like German Shepherd, Beagle, Poodle, etc., as shown in Figure 8.2., show distinct variations in their body characters and behaviours.

High genetic diversity in a species indicates greater differences and greater ability for some individuals to adapt to the environmental changes. Some of the individuals may inherit traits making them resistant to certain diseases or tolerant to extreme temperatures. Others may possess different traits like high rate of reproduction and versatile food habits that increase their chances of survival.

In nature, the organisms that are most fit survive and reproduce. Darwin termed this process as natural selection. If there is an outbreak of a disease that threatens to wipe out an entire species, then the species with more genetic variation has the highest chance of survival. Genetic variations are brought about by processes like mutation, polyploidy and hybridisation. Genetic diversity is responsible for speciation, i.e., the formation of new species. The rich global biodiversity have resulted due to speciation.

Mutation

Mutation is defined as a process of alteration of DNA (Deoxyribonucleic acid) or chromosome. DNA is made up of nucleotides arranged together to form genes. The sequence of nucleotides in DNA and shape of chromosomes are more similar in organisms that are related. Alteration in DNA or chromosome cause

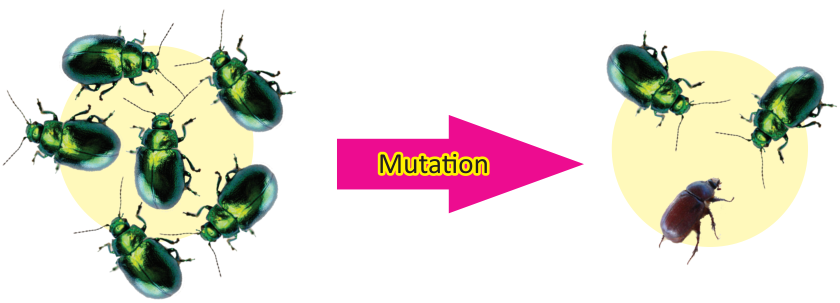


Figure 8.3. Genetic variation due to mutation

appearance of new characters that increases variation amongst the individuals of the same population. For example, in Figure 8.3., the population A is a parent population of beetles that are all green in colour. However, in population B, one of the beetles has undergone mutation, which has caused the change in its colour to brown.

Polyploidy

Organisms inherit chromosomes from their parents. Most organisms have two sets of chromosomes, inheriting one set from each parent and such organisms are called diploid. Polyploid individuals have more than two sets of chromosomes. They arise through irregularities during cell division, or through the fusion of abnormal gametes in organisms. The polyploid organisms cannot reproduce with the species of their parent population but can reproduce with other polyploids.

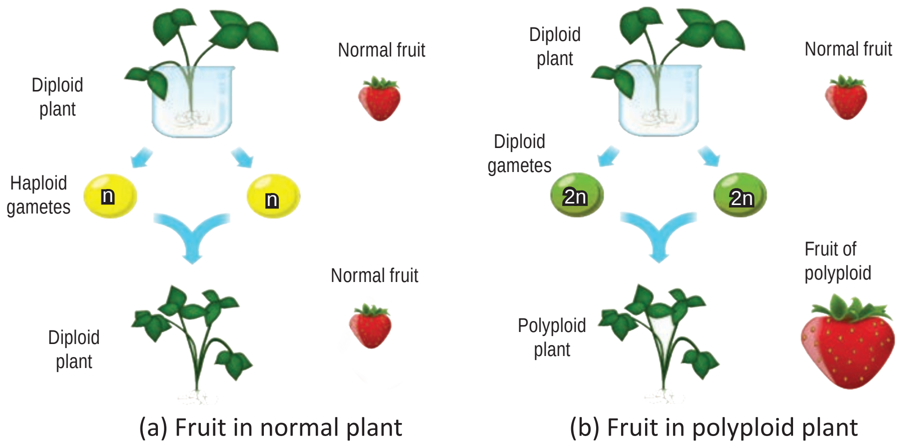


Figure 8.4. Genetic variation due to polyploidy

For example, under normal conditions, a normal plant produces haploid gametes that combine to form a diploid plant and the fruit produced is of normal size as shown in Figure 8.4 (a). However, in Figure 8.4 (b) the diploid gametes are produced, which combine to form a polyploid species with four sets of chromosomes. The fruit produced by this plant is larger than that of a normal plant.

Hybridisation

It is a process in which organism of one species breeds with other species to form a new species called hybrids. This process of interbreeding results in organisms that are genetically distinct from either of the parents. For example, interbreeding between female horse and male donkey produces a mule. Mule has a lot of distinct superior traits in terms of appearance, strength and physique as shown in Figure 8.5. Hybridisation in plants occurs due to cross-pollination.

Reprint 2022

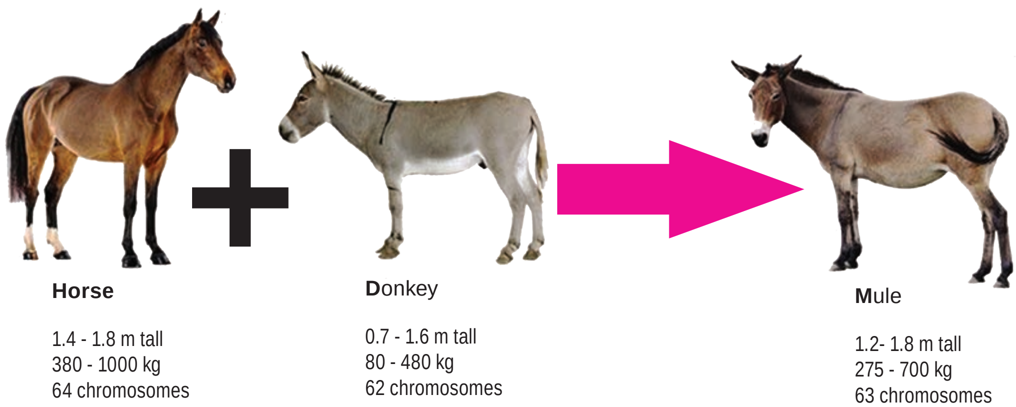


Figure 8.5: Production of mule by hybridisation

(ii) Species diversity

The variety of species and their relative abundance in a given area is called species diversity. The elements of species diversity include species richness, species evenness and species dominance.

Species richness is the count of different species in a given ecosystem, region or any particular area. The species richness does not consider the abundance of the species. For example, if there are three different organisms living in an area, the value of species richness is three irrespective of the population of each species. More the species present in an area, richer is the species diversity of an area.

Species evenness is defined as the relative abundance of individuals of different species that live in an ecosystem. It is a comparison of the number of individuals amongst the species living in an ecosystem.

For example, in Figure 8.6., both the communities have four species (A, B, C and D). Community 1 has an equal number of all four species, while in community 2, species A dominates others. The communities have the same species richness, however, community 1 is comparatively even.

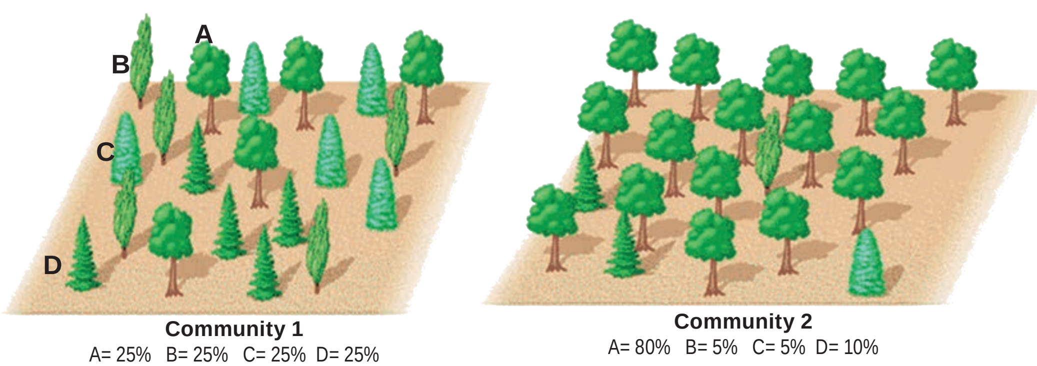


Figure 8.6. Comparing species richness and species evenness

Species dominance is the degree to which a species is more in number than other species in an ecosystem. For example, in the Sonoran desert of North America, saguaro, prickly pear (Figure 8.7) and barrel cacti are some of the most common vegetation while acacia trees and eucalyptus dominate Australian deserts. Similarly, in Figure 8.6, species A is dominant in community 2.

Figure 8.7. Prickly pear

Each species has a role in the ecosystem. For example, plants are the main source of food, and predator regulates the population of prey. If an ecosystem has more diversity, then its ability to provide food and other ecosystem services improve.

Each species is like a thread that holds the fabric of ecosystem together. If one species disappears, the whole ecosystem gets affected. Thus, species diversity is crucial for the health of the ecosystem. More the species diversity in an area, greater is the biodiversity and healthier the ecosystem.

Genetic diversity leads to the acquisition of new characters in an organism, which gradually leads to the formation of newer species from a single population. It is generally termed as speciation. Speciation is of allopatric, sympatric, peripatric and parapatric types which as shown in Figure 8.8.

Allopatric Speciation

Allopatric speciation occurs when the individuals of the same species are separated by mountain formation, island formation, habitat fragmentation, etc., that prevent genetic interchange among species. The separated populations may gradually develop distinct characteristics different from the original population and evolve into new species. For example, the evolution of Darwin's finches from native finch in the Galapagos islands occurred due to the separation of those islands by the water bodies.

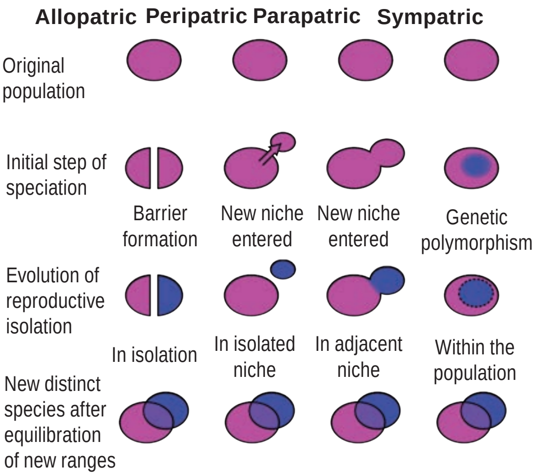


Figure 8.8. Types of speciation.

Sympatric Speciation

Sympatric speciation occurs amongst the individuals of a population living in the same habitat due to the sudden change in their genome. This results in incompatibility in inbreeding leading to reproductive isolation. Those individuals that are reproductively isolated evolve into new species. For example, hexaploid wheat (Triticum aestivum) formed by sympatric speciation as shown in Figure 8.9. It is formed by polyloidy and is reproductively isolated from other native forms of wheat.

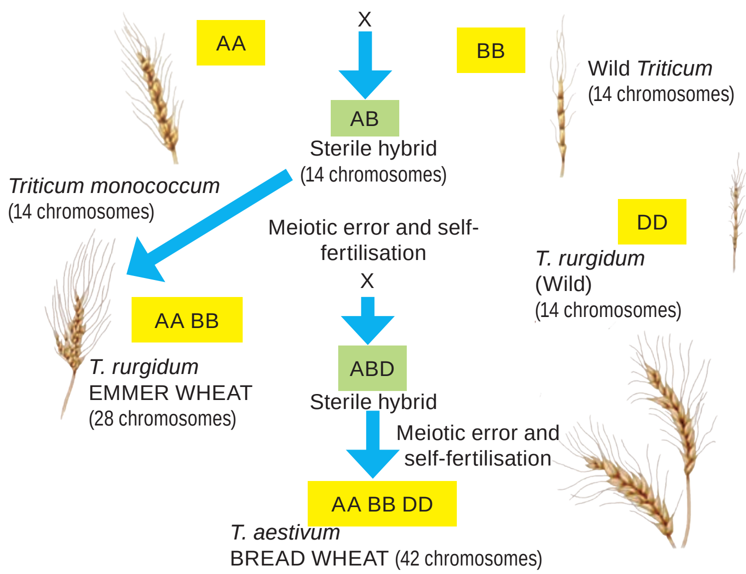


Figure 8.9. Sympatric speciation in wheat

Parapatric Speciation

Parapatric speciation occurs in individuals of a species living in the same ecosystem but occupying different distinct habitats. The organisms occupying one type of habitat are more likely to interbreed as compared to the individuals of same species living in another habitat. Therefore, as a result of parapatric speciation new species evolve in the ecosystem. For example, the Carrion crow and Hooded crow have evolved due to parapatric speciation.

Peripatric Speciation

Peripatric speciation occurs in smaller populations that live in the periphery of the main parent population species. The smaller populations gradually evolve into new species which exhibit some differences amongst each other and with the parent population. For example, paradise-kingfisher has differentiated into several distinct species in the islands around New Guinea.

(iii) Ecosystem diversity

An ecosystem provides many kinds of habitats. The biotic and the abiotic environment interact constantly in a simple or complex ways. Organisms cannot survive in isolation and have to interact with its environment.

Figure 8.10. Ecosystem diversity

Ecosystem diversity refers to variation in ecosystems in terms of biotic and abiotic components, and physical size. An ecosystems can be as simple as a pond, a piece of log or as complex as a tropical rainforest, desert and grassland. Some of the important ecosystems found are forest ecosystem, aquatic ecosystem, agricultural ecosystem, marine, grassland, desert, tundra, etc., as shown in Figure 8.10. For example, Bhutan has greater ecosystem diversity as its ecosystems has vegetation ranging from alpine to subtropical region.

In Bhutan, the forest ecosystem is the most dominant one with the largest percentage of the total land area under forest cover. Forest mainly comprises of ecosystems like lake, fresh water ecosystem, etc.

Ecosystem diversity helps to produce more productive and stable communities, which can tolerate various stresses due to anthropogenic and natural pressure. Complex ecosystems with a wide variety of plants and animals tend to be more stable. A highly diverse ecosystem is a sign of a healthy environment.

Reprint 2022

B. Patterns of biodiversity

Biodiversity is not same across the Earth. In some region, biodiversity is rich while in others, it is poor. This unevenness in biodiversity is due to spatial variation and temporal variation.

a. Spatial variation of biodiversity

The distribution of plants and animals across the globe is determined by geological and geographical differences such as differences in weather, habitat, soil formation and landscape. Generally, similar species are found in geological regions that are similar in conditions, however, the number of species may vary. This pattern of uneven distribution of species is termed as spatial variation of biodiversity.

Ecologists and bio-geographers suggest that a geographical area can be mapped with latitude, temperature and salinity to derive useful patterns of biodiversity distribution. This pattern can be used to estimate the existence of species in both terrestrial and marine ecosystems.

Some of the regions identified by spatial distribution of biodiversity are:

(i) Biodiversity hotspots

It is a bio-geographic region with a significant reservoir of species that are under threat from human activities.

A region qualifies to be a hotspot, if it contains at least 0.5 percent of the world's plant species as endemic species, and it should have lost at least 70

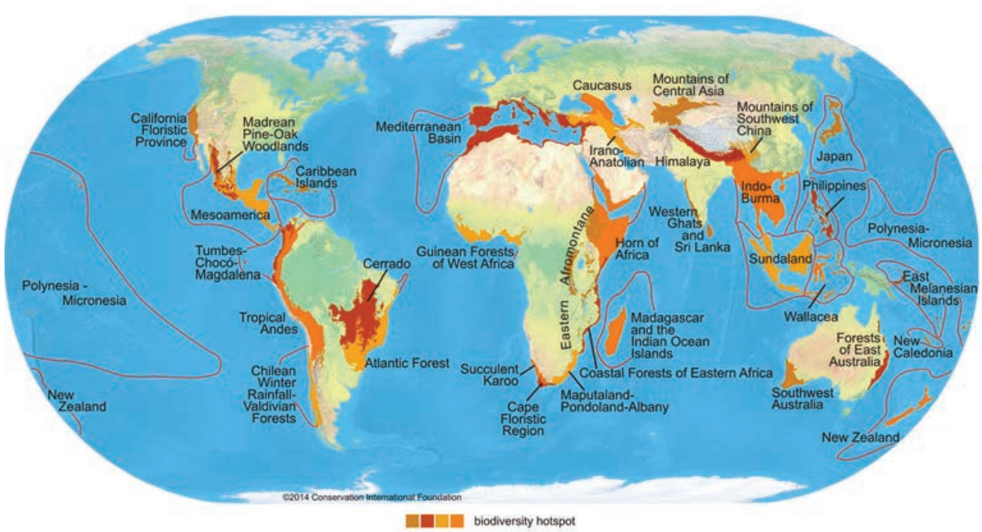


Figure 8.11. Biodiversity hotspots of the world.

percent of its primary vegetation. In other words, two factors that qualify a geographical area as hotspots are:

- high density of endemic species; and
- significant habitat impact and alteration from human activities.

There are 34 biodiversity hotspots around the world (Figure 8.11), and Bhutan is a part of the Eastern Himalayan region which contains part of three global biodiversity hotspots.

(ii) Biomes

Biomes are ecological areas that have similar climatic conditions in which similar types of plants and animals are found. There are different types of biomes (Figure 8.12), and each classified based on abiotic factors such as climate and geology. Biomes are grouped into two main categories: terrestrial biomes and aquatic biomes. The major climatic factors that contribute to terrestrial biomes are temperature and precipitation. Aquatic biomes are characterized by freshwater or saline water bodies.

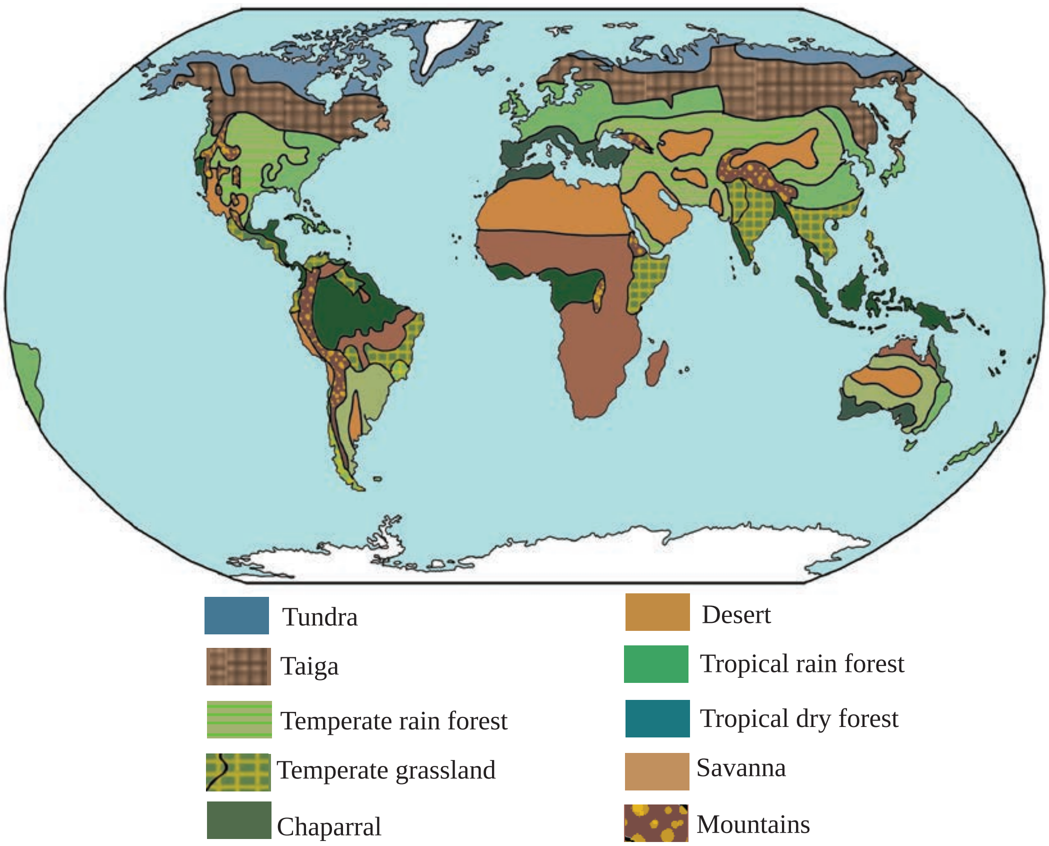


Figure 8.12. Distributions of Biomes

The flora and fauna in a particular biome have similar adaptive features. For example, the Tundra is characterised by the presence of dwarf shrubs like mosses, grass species, sedges and not by trees because the ground is usually covered with snow. On the other hand, the desert biome is mainly covered with drought-resistant shrubs like sage bush and creosote bush, and succulents like cacti, due to scanty water supply.

(iii) Bio-geographic realms

These are geographic regions where groups of species evolve and disperse. Species migrate from these regions depending on niche requirements, reproductive success, competition, and climatic and topological barriers.

There are eight major bio-geographical realms, each of which is characterized by the presence of unique plants and animals. These eight bio-geographical realms are shown in the Figure 8.13.

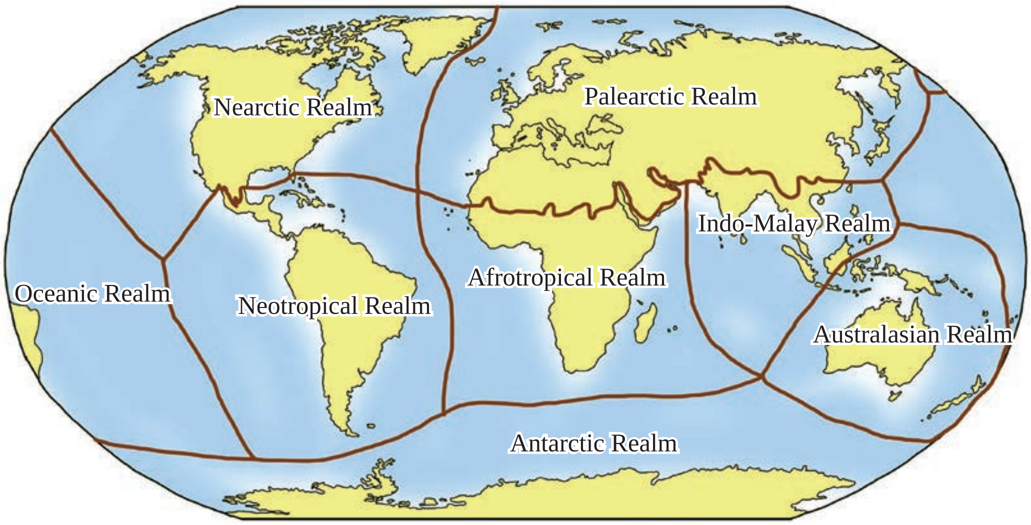


Figure 8.13. Biogeographical realms of the world

Each of the bio-geographic zone supports several biomes. For example, under the Nearctic realm, tundra, grassland, deciduous and coniferous forest, chaparral, and desert biomes are found. Similarly, Indomalayan realm consists of tropical and subtropical moist broadleaf forests.

(iv) Ecoregions

These are areas that have similar climate, geology and soil conditions. These conditions determine the type of plants and animals seen in the ecosystem. For instance, even if two places or more are very far apart but share similar ecoregion, we can predict existence of common species of plants and animals.

b. Temporal variations of biodiversity

The biodiversity of an ecosystem can change over time. This time-based variation in the richness of biodiversity of an ecosystem is called temporal variation. Temporal variation is caused by processes that bring changes in the population structure of the ecosystem. Processes like migration, food availability, predation, speciation, extinction, etc., lead to a temporal variation of biodiversity in an ecosystem. For example, in Bhutan, the population of the Black-necked Crane (Grus nigricollis) increases during the winter and decreases during summer due to their seasonal migration.

C. Values of biodiversity

Biodiversity is a foundation for the ecosystem and socio-economic benefits of humans. Ecosystem provides goods and services that have economical, ecological and social importance. The services provided by ecosystems are:

- provisioning services, such as food, water, timber, and fibre,
- regulating services, such as the regulation of climate, floods, diseases and water quality,
- cultural services, such as recreation, aesthetic enjoyment, and spiritual fulfillment, and
- supporting services, such as soil formation, photosynthesis, and nutrient cycling.

Human well-being is influenced by biodiversity and ecosystem services. The relationship between the ecosystem services and its benefits is shown in Table 8.1.

Table 8.1. Ecosystem services

Intensity of relation	
Strong	***
Medium	**
Weak	*
Indirect	@

		Ecosystem Services			
		Provisioning (Food, Freshwater, wood, Fibre, fuel, etc.)	Regulating (Food regulation, disease regulation, water regulation and Climate regulation)	Cultural (Aesthetic, Spiritual, Educational, recreational, etc.)	Supportive (Nutrient Cycling, soil formation, Primary production, etc)
Constituents of wellbeing	Security (Security from disaster, personal safety, secure resource access, etc.)	**	***	*	@
	Basic Material for life (Sufficient nutritious foods, adequate livelihood, shelter)	***	***	*	@
	Health (strength, feeling well, access to clean air and water)	***	***	**	@
	Good social relation (social cohesion, mutual respect, ability to help others)	*	*	**	@
	Freedom of choice and action (Opportunity to be able to achieve what an individual value doing and being)	@	@	@	@

The importance of biodiversity is measured by determining the value of biodiversity. The use values of biodiversity are categorized into direct use values and indirect use values.

a. Direct Use Values

Direct use values are those values assigned to products harvested by people. Direct use value is categorized into two types, namely consumptive use values and productive use values as shown in Figure 8.14.

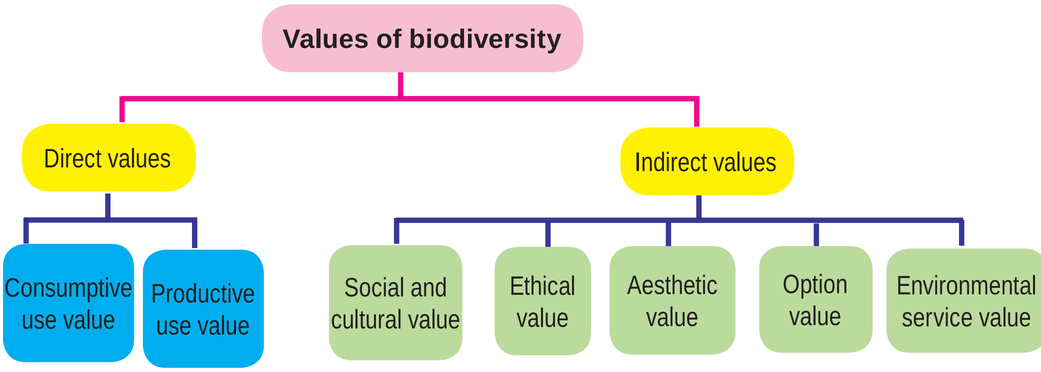


Figure 8.14. Values of biodiversity

(i) Consumptive use values:

These are values assigned to products which are consumed directly without any commercial activities. Since these products are consumed locally, these do not figure in national and international market. For example, the firewood collected from the forest for household consumption.

(ii) Productive use values:

These are values put on the products of nature which are consumed and have commercial values. For example, if we buy firewood from the market, then it is said to have productive value. Similarly, fungus Penicillin notatum has productive values as it is used to produce the penicillin drug that is sold in the market.

Figure 8.15 shows some of the medicinal plants found in Bhutan that have consumptive as well as productive use values.

Meconopsis sp.

Galium aparine

Ophiocordyceps sinensis

Herocleum dissectum

Oroxylum indica

Rheum accuminita

Terminalia chebula

Zanthoxylum alatum

Figure 8.15. Medicinal plants found in Bhutan

b. Indirect use values

Biodiversity provides values assigned to products and services that are intangible and have no specific commercial values. These values include cultural values, aesthetic values and ecological values.

(i) Cultural values:

These values are associated with the cultural, spiritual and religious aspects of

Figure 8.16. Sacred lake and black necked crane dance

human lives. Many plants and animals have religious and cultural significance. For example, in some cultures, lakes, trees, animals and mountains are considered sacred and are worshipped. Thus, biodiversity has distinctive social and cultural values attached with different societies.

(ii) Aesthetic values:

It is the value placed on environmental services that has a capacity to bring about pleasure and appreciation when viewed. The natural landscapes are a delight to watch and are inspiration for various artworks. It also provides opportunities for recreational activities like birding, photography, hiking, etc.

(iii) Ecological values:

The biodiversity provides regulating services such as:

- carbon dioxide fixation through photosynthesis.
- maintenance of essential nutrients.
- maintenance of water cycle and recharging the groundwater.
- soil formation and protection from erosion.
- regulation of climate by recycling moisture into the atmosphere.

These services that support the proper functioning of an ecosystem are the ecological values provided by the biodiversity. These services ensure the stability of the environment.

Questions

1. How does a rich biodiversity contribute in the economic growth of a community?
2. Draw a relation between diversity and sustenance of an ecosystem.
3. 'Bhutan can have manifold socio-economic growth even if half of its natural resources are extracted.' Do you agree? Justify.

2. Measuring Biodiversity

Learning Objectives

On completion of this topic, you should be able to:

- explain diversity indices.
- measure biodiversity using diversity indices.

Biodiversity measurement is used to quantify and explain the diversity of life forms and the characteristics of an ecosystem. It helps to determine the species composition, stability and the overall health of an ecosystem. It is also used in the comparison of different ecosystems..

A. Measuring three levels of biodiversity

Biodiversity is measured at different levels in terms of genes, species and ecosystem. Measurement of biodiversity at the Species level involves using diversity indices like Shannon Diversity Index and Simpson's Diversity Index. Alpha Diversity, Beta Diversity and Gamma Diversity are used to measure both the species diversity and ecosystem diversity. The measurement at genetic level includes mapping of genes and chromosomes of an individual organism. The composition of species in an ecosystem depends on resources present in the ecosystem to support the species. Factors like climate change, natural disasters, epidemics and over-exploitation of resources by human also influence the species diversity in an ecosystem. The diversity of species is measured by taking into account the species richness and evenness present in a particular ecosystem.

a. Measurement of species diversity

The common method of measuring species diversity is by recording the varieties of species observed in an ecosystem. In this method, the high or low species diversity for an ecosystem is concluded by recording the numbers of different species however, the individual species population is not considered. Shannon Diversity Index and Simpson's Diversity Index are some of the methods for measuring the species diversity. These diversity indices are mathematical functions that indicate species diversity by taking account of both species richness and evenness in a single measure.

(i) Measuring species richness

Species diversity is measured by recording the number of different species present in a particular ecosystem. In the measurement of species richness, the variety of species present is considered. For example, in Figure 8.17, Ecosystem A has

Reprint 2022

two types of species, i.e., elephant and deer, while Ecosystem B has three types of species i.e., tiger along with elephant and deer. Thus, the species richness of Ecosystem B is higher than that of Ecosystem A.

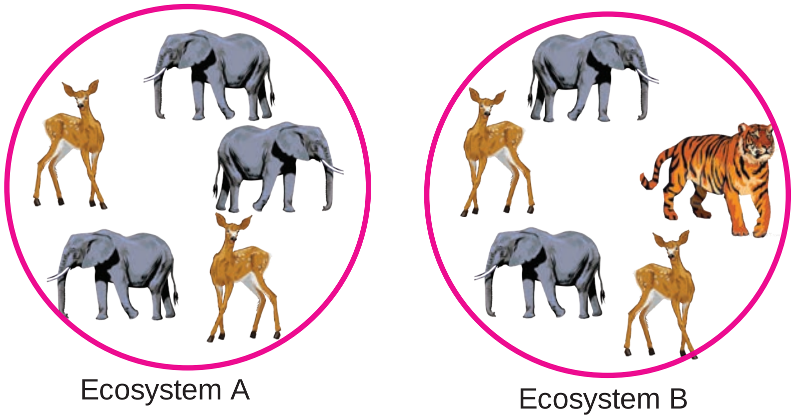


Figure 8.17. Species richness measurement

Usually, species richness and evenness are considered together for measuring the species diversity among the ecosystems. In such cases, although the compared ecosystems have the same species richness, the ecosystem that has even distribution of species is considered to have more species diversity than other ecosystem. For example, Table 8.2 presents two ecosystems surveyed for fruit tree species:

Table 8.2. Fruit tree species in two ecosystems

Fruit tree Species	Ecosystem A	Ecosystem B
Guava tree	20	20
Orange tree	18	36
Mango	23	5
Total	61	61

In both the ecosystems, the species richness is three, i.e. three varieties of fruit tree species and the total number of individuals is equal. However, in Ecosystem A, the total number of individuals of each species is evenly distributed compared to Ecosystem B. In Ecosystem B, most of the individuals are orange trees with only a few numbers of mango trees and guava trees. Therefore, Ecosystem A has more species diversity than Ecosystem B.

To determine the species richness and evenness of an ecosystem across a wide region, it is difficult to count the variety and the abundance of all species. Therefore, appropriate sampling methods and sample size are important to determine the accuracy of measurement of species diversity.

Sampling is a process of selecting a portion from a population of species. The sample represents the population in general. Various sampling methods are used depending upon the objectives of study and physical structure of the ecosystem. Some of the commonly used sampling methods in measuring species diversity are explained below:

(1) Random sampling

It is a technique of taking a large numbers of samples from different positions within an area through random selection. Random sampling is applicable when an area being studied is very large and has fairly uniform habitats, or when study needs to be carried out in a short period of time. A sampling tool like quadrat frame is most often used for this type of sampling. The quadrat frame is placed on the ground and the animals or plants inside are counted, measured, or collected, depending on the type of study. It is done many times at different locations within the ecosystem in order to get a large number of different samples as represented in Figure 8.18. Thread and wooden pegs are used instead of quadrats for sampling in those habitats, where the laying of quadrate frame is not possible.

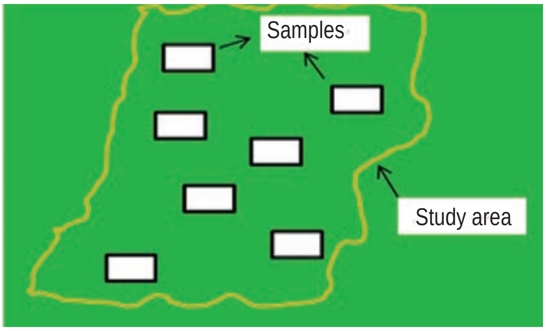


Figure 8.18. Random sampling

(2) Stratified sampling

In stratified sampling method, population or geographical area is divided into smaller units called strata (Figure 8.19.). It is applicable when the area being studied has different types of habitats. Each habitat is sampled separately to represent the diversity of the entire area. For example, to study the wildflower species in the forest consisting of woodland, grassland and bracken habitats, samples from all these habitats need to be collected in order to represent the wildflower species of the forest area.

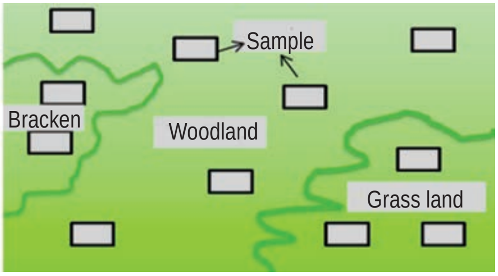


Figure 8.19. Stratified sampling

(3) Systematic sampling

In systematic sampling, samples are taken at fixed intervals of distance along a straight line called transect as represented in Figure 8.20. For example, systematic

Reprint 2022

sampling can be used to show the changes of plant species as you move from grassland into woodland.

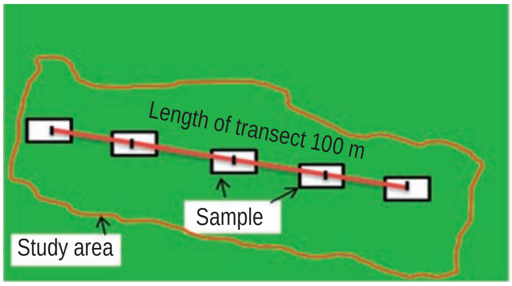


Figure 8.20. Systematic sampling

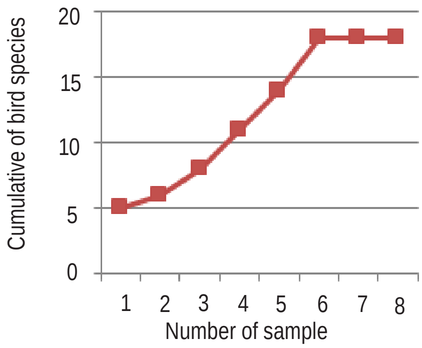


Figure 8.21. Cumulative species curve

The right sample represents the whole ecosystem and therefore gives more accurate species diversity. When measuring species diversity, the challenge is in determining when the sample collected is enough and when to stop collecting the sample. A good technique to overcome such challenge is to generate a cumulative species curve. For example, while determining diversity of bird species in Tsirang, new species are recorded with each subsequent sampling at specific area. Then a cumulative species curve is plotted with the cumulative number of bird species collected (y axis) versus the number of samples collected (x-axis) as shown in Figure 8.21. In this technique, the curve rises initially as new species are recorded in the beginning as shown in Figure 8.21. However, on subsequent sampling, the number of species remains constant therefore, the curve flattens. Once the curve levels off, there is no need to sample further. The data collected of bird species of the selected area is adequate to represent the bird species diversity for whole Tsirang.

(ii) Shannon Diversity Index (H)

The Shannon Diversity Index is a measurement of species diversity calculated by considering species evenness and species richness into a single measure. Increase in species richness and evenness increase the value of Shannon Diversity Index, thus indicating higher species diversity. The value of Shannon Diversity Index is influenced more by the change in number of species than its abundance. In other words, the measurement is more sensitive to species richness than to the species evenness.

Shannon Diversity Index (H) = - Σpiln (pi)

where; **pi**- is the relative abundance of each species i.

ln- is the natural log.

The abundance of each species **pi**=n/N, where n the is number of organism of particular species and N is the total number of organism of all species. Negative sign to the sum of Shannon Diversity Index equation is assigned to neutralize the negative result of the natural log. Positive numbers are much easier to interpret.

Shannon Diversity Index is calculated using the following steps considering an example of an area surveyed for butterfly species.

Table 8.3. Number of butterflies

Butterfly Species	***n***
Papilio polytes	12
Acytolepis puspa	5
Kaniska canace	6
Vindula erota	3
Mesapia peloria	1

(i) N = 12 + 5 + 6 + 3 + 1 = 27

(ii) **pi** = n/N. For each butterfly species the **pi** value is given in the Table 8.4.

Table 8.4. pi value of butterflies

Butterfly Species	***n***	**pi=*n/N***
Papilio polytes	12	0.444
Acytolepis puspa	5	0.185
Kaniska canace	6	0.222
Vindula erota	3	0.111
Mesapia peloria	1	0.037

(iii) The lnpi value for each species is given in Table 8.5.

Table 8.5. lnpi value of butterflies

Butterfly Species	***n***	**pi = *n/N***	lnpi
Papilio polytes	12	0.444	-0.812
Acytolepis puspa	5	0.185	-1.687
Kaniska canace	6	0.222	-1.505
Vindula erota	3	0.111	-2.198
Mesapia peloria	1	0.037	-3.297

(iv) The result obtained from proportion ***lnpi*** for each species is then multiplied with the proportion 'pi' to obtain the values of **pi** X ***lnpi*** for each species given in Table 8.6.

Table 8.6. Shanon diversity index

Butterfly Species	*n*	*n/N*	pi	lnpi	pi X *lnpi*
Papilio polytes	12	12/27	0.444	-0.812	-0.360
Acytolepis puspa	5	5/27	0.185	-1.687	-0.312
Kaniska canace	6	6/27	0.222	-1.505	-0.334
Vindula erota	3	3/27	0.111	-2.198	-0.244
Mesapia peloria	1	1/27	0.037	-3.297	-0.122

(v) The value **pi** X ***lnpi*** obtained for each species is then summed, i.e.,

$$\Sigma = -0.360 + -0.312 + -0.334 + -0.244 + -0.122$$
$$= -1.372$$

(vi) Therefore, value of Shannon diversity index (H) calculated for this ecosystem is;

$$H = -\,\Sigma \mathbf{pi} \times \mathit{lnpi}$$
$$= -\,(-1.372)$$
$$= 1.372$$

The value of H= 1.372 indicating the low species diversity in the area.

The Shannon Diversity Index value is generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. A value less than 1.5 would indicate that every species in the sample is the same and diversity is low.

(iii) Simpson's Diversity Indices

Simpson's Diversity Index is the measure of species diversity calculated by considering both species richness and evenness in a single measure. Simpson's Diversity Index is more sensitive to species abundance than the species richness.

The term Simpson's Diversity Index refers to any one of the three closely related indices: Simpson's Index, Simpson's Index of Diversity and Simpson's Reciprocal Index. All these indices determine the species diversity. The mathematical relation for calculating Simpson's Diversity Index or Simpson's Index (D) is represented by the following equation:

Simpson's Index , $D = \dfrac{\Sigma n(n-1)}{N(N-1)}$

or, $D = \Sigma pi^2$

where, pi=n/N- the abundance of each species

n - total number of organism of particular species

N- total number of organism of all species

Σ pi^2- is the sum of the values that we calculate for every species in the community.

The value of Simpson's Index (D) ranges between 0 and 1. If D = 0, it indicates higher species diversity and if D =1, it indicates no species diversity.

To make the interpretation easier and natural, Simpson's Index of Diversity is calculated in following two ways:

Simpson's Index of Diversity = 1- Simpson's Index

=1 - D

Higher the value of Simpson's Index of Diversity, more is the species diversity.

Species diversity is also calculated using Simpson's Reciprocal Index.

$$\text{Simpson's Reciprocal Index} = \frac{1}{\text{Simpson's Index}} = \frac{1}{D}$$

The value of this index starts with 1 which represents a community of single species. Therefore, higher the value of Simpson's Reciprocal Index of Diversity, more is the species communities and hence, greater the species diversity.

Table 8.7 shows data of flower species which have been used for calculating the Simpson's Diversity Index.

Table 8.7. Simpson's diversity index for flower species

Flower Species	***n***	***n/N***	***pi***	***pi^2***
Hydrangea	15	15/80	0.1875	0.0351
Gazania	21	21/80	0.2625	0.0689
Geranium	15	15/80	0.1875	0.0351
Fuchsia	12	12/80	0.15	0.0225
Hosta	17	17/80	0.2125	0.0451

Number of species = 5

N = 80

$D = \sum pi^2$

$= (0.0351 + 0.0689 + 0.0351 + 0.0225 + 0.0451) = 0.2067$

Simpson's Index of Diversity $= 1 - D = 0.7932$

Simpson's Reciprocal Index $= \frac{1}{D} = 4.837$

The value of D = 0.2067, which is close to the value zero of Simpson's Index indicates the rich species diversity. The resulted numerical values from the two different Simpson's indices - Simpson's Index of Diversity and Simpson's Reciprocal Index, represent the same biodiversity that is studied and also indicate higher diversity. It is important to ascertain which index has actually been used in any comparative studies of diversity.

Activity 8.1. *Measuring species diversity in a community*

Materials required: Calculator, plain paper and pencil.

Procedure:

1. Decide upon a type of species, either plants or animals to survey in your nearby community.
2. Visit the community and mark the places to carry out the survey using any one of the sampling methods discussed.
3. Visit the community again to carry out the survey. In each place you should record species richness and species abundance of the species you are surveying. Take photographs of species and make notes of ecosystem types you observed in each place.
4. Prepare a report and present your findings. Ensure that your presentation addresses the following points sufficiently:
   - Type of ecosystems present in the community you have visited.
   - Sampling method you have used.
   - Species richness and species abundance you have recorded.
   - Measurement of species diversity by Shannon Diversity Index and Simpson's Diversity Index.

5. Use the following format to survey:

Name:………………………………… Date of survey:…………………………

Site-location:…………………… Type of species surveyed: …………...

Survey timing – Starting time ……AM/P.M Ending Time………….. A.M/P.M

Weather: ………………………… Temperature:………^{0}C

Table 8.8.

Place	Tally of different species.	n	N	pi	pi^2	*ln*pi	pi*ln*(pi)	Shannon Diversity Index (H)	Simpson's Index (D)
Example: *1. Grassland*	*Common Myna*	*4*	*10*	*0.4*	*0.16*	*-0.39*	*-0.06*	*0.36*	*0.34*
	Spotted Dove	*3*		*0.3*	*0.09*	*-0.52*	*-0.15*		
	House Crow	*3*		*0.3*	*0.09*	*-0.52*	*-0.15*		
2.									
3.									

Questions:

1. Which of the sampled locations has the highest species diversity?
2. Why are the values for H and D different for the same location?
3. Which species is dominant in the region?

B. Measurement of ecosystem diversity

The measure of ecosystem diversity is based on species diversity. Robert Harding Whittaker in 1972 put forward the three indices: Alpha diversity (α), Beta diversity (β), and Gamma diversity (γ) that measure the species diversity in the ecosystem.

Alpha diversity refers to the species diversity within a particular ecosystem or selected habitat or sample; therefore, it measures species richness. Alpha diversity helps to assess the homogeneity of an ecosystem. Beta diversity measures the rate of increase of alpha as new habitats are sampled, or the change of species diversity

Reprint 2022

among ecosystems. Beta diversity measures the total number of species that are unique among ecosystems. Gamma diversity is a measure of the total species diversity of several ecosystems in an entire region.

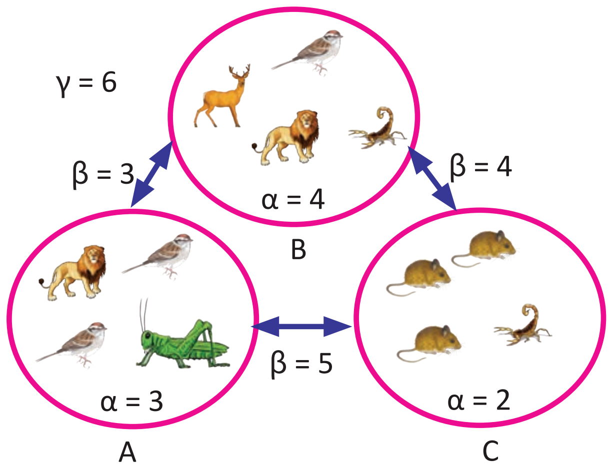


Figure 8.22. Alpha, Beta and Gamma diversity

a. Numerating alpha diversity (α)

The species diversity of a single ecosystem can be directly determined by the physical count of species present in it. Some methods, such as random sampling, stratified sampling, and systematic sampling are employed to determine the alpha diversity of an ecosystem. The Shannon Diversity Index and Simpson's Diversity Index calculation approaches are also used to determine the species richness of an ecosystem by carrying out simple numerical calculations.

Alpha diversity (α) = number of unique species in an ecosystem

b. Numerating Beta Diversity (β)

The species diversity of two ecosystems can be numerically compared using the following relationships.

(i) Beta diversity

Beta diversity is measured using following relation:

$$\beta = (S1 - c) + (S2 - c)$$

where, β = beta diversity.

S1= the total number of species recorded in the first ecosystem.

S2= the total number of species recorded in the second ecosystem.

c= the number of species common to both the ecosystem.

If β = 4, it indicates that there are four unique species present in one of the compared ecosystems. In other words, one ecosystem is richer by four species than the other.

For example:

Ecosystem A and Ecosystem B have a total of 12 species: a, b, c, d, e, f, g, h, i, j, k, and l.

In Ecosystem A, the species are a, b, c, d, e, f, g, h, i, and j.

Therefore S1 = 10.

In Ecosystem B, the species are f, g, h, i, j, k, and l.

Therefore S2=7

The common species in Ecosystem A and Ecosystem B, c=5.

$$\text{So, } \beta = (10-5) + (7-5)$$

$$= 7$$

The beta diversity of the two ecosystems is 7. This means that there are seven species which are either only in Ecosystem A or only in Ecosystem B.

(ii) Basic Beta Diversity Index

Basic Beta Diversity Index measures the similarity between ecosystems. The normalised scale of measuring Basic Beta Diversity Index is usually from zero to one. A high Basic Beta Diversity Index indicates a low level of similarity between ecosystems, while a low Basic Beta Diversity Index shows a high level of similarity.

This can be represented by the following equation:

$$\textit{Basic Beta Diversity Index} = \frac{2c}{S1 + S2}$$

For example:

If we consider the example given above under the Beta Diversity, the Ecosystem A has species richness of 10, and Ecosystem B has species richness of 7.

The common species in Ecosystem A and Ecosystem B, c=5.

Reprint 2022

Therefore,

$$\textit{Basic Beta Diversity Index} = \frac{2c}{S1 + S2}$$

$$= \frac{2 \times 5}{10 + 7}$$

$$= \frac{10}{17}$$

$$= 0.59$$

In this case, Basic Beta Diversity Index=0.59 is closer to 1, therefore, it indicates low level of similarity between the two ecosystems.

c. Numerating Gamma Diversity (γ)

Gamma diversity represents the total number of species of all ecosystems in a region. Gamma diversity can be calculated using species richness of each ecosystem and the number of species common to both the ecosystems.

$$\gamma = S1 + S2 - c$$

where, S1= the total number of species recorded in the first ecosystem.

S2= the total number of species recorded in the second ecosystem.

c = the number of species common to both the communities.

The internal relationship between alpha, beta and gamma diversity can be represented as,

$$\beta = \frac{\gamma}{\alpha}$$

Based on the formula, Beta diversity is the ratio between Gamma (regional) and Alpha (local) diversities. Therefore, it shows that Beta diversity does not only interpret the relationship between local and regional diversity, it also informs about the degree of diversity among the biological communities.

Activity 8.2. *Measuring ecosystem diversity using diversity indices*

Instruction:

1. Table 8.9 represents data collected on bird species diversity.
2. Calculate the Alpha diversity of Ecosystem A and B, Beta diversity, and Gamma diversity and answer the questions that follow:

Table 8.9.

Species	Ecosystem A (S1)	Ecosystem B (S2)
Red-vented Bulbul		
Common Myna		
Large-bellied crow		
Spotted Dove		
Rock pigeon		
Lesser-yellow nape		
Common Kestrel		
Oriental-magpie Robin		
Green-tailed Sunbird		
Alpha diversity (α)		
Beta diversity (β) $\beta = (S1 - c) + (S2 - c)$		
Gamma diversity(γ) ($\gamma = S1 + S2 - c$)		

Questions:

1. Calculate the Basic Beta Diversity Index and interpret the result.
2. Describe the possible reasons for having more species richness in Ecosystem A than Ecosystem B?
3. What is the significance of Beta diversity in ecosystem diversity?
4. How can you use these finding to guide the government in the conservation of bird species?

C. Measurement of genetic diversity

The difference in the genetic makeup of individuals of a species lead to genetic diversity. The measurement of genetic diversity involves studying of genes and chromosomes of an individual organism and compare to the genetic make-up of a

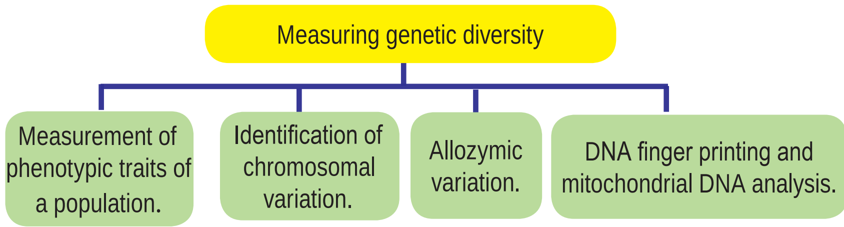


Figure 8.23. Measuring genetic diversity

larger population. It also involves the study of differences in physical appearance, termed as phenotypes, between individuals and attributing these traits to the most likely genetic roots. Individuals within the same species that have more variations in their genetic structure indicate higher genetic diversity. The techniques generally used to measure genetic diversity are shown in Figure 8.23.

Genetic diversity measure is used to observe and manage populations of organisms, and to help in selective breeding of the most desirable traits.

Questions

1. Why are species richness and evenness useful in the measurement of biodiversity?
2. How does species abundance contribute in the measurement of species diversity?

Exercise

1. Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.

   i. Although species may have the similar phenotypic traits, variations exist within the same species. This variation is called

   A. biotic diversity.

   B. species diversity.

   C. genetic diversity.

   D. ecosystem diversity.

   ii. Sonam, a class XI student surveyed different species of flower in two areas of his school garden. The data collected are presented in the Table 8.10. Which one of the following is the correct conclusion for flower diversity in the school garden?

   Table 8.10.

Place	Flower Species	Abundance
A	*Gladiolus*	15
	Gerbera	18
	Euphorbia	18
B	*Gladiolus*	42
	Gerbera	4
	Euphorbia	6

   A. More species diversity in place B.

   B. Place A has higher genetic diversity.

   C. Species abundance is different.

   D. More species diversity in place A.

   iii. Which one of the following is not the basis of biodiversity?

   A. Genetic

   B. Species

   C. Population

   D. Ecosystem

Reprint 2022

iv. Alpha diversity of two Ecosystem 'A' and 'B' is 5 and 7 respectively. If common species between the two Ecosystems is 3, what will be the Gamma diversity?

A. 9

B. 12

C. 15

D. 35

v. What is the objective of measuring the biodiversity?

A. Discovery of new species.

B. Conservation of biodiversity.

C. Know the population of species.

D. Application of biodiversity measurement indices.

2. Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.

Column A	Column B
1. Simpson's Index(D) of an ecosystem is D = 0.9	a. high level of similarity between the ecosystems.
2. Simpson's Index(D) of an ecosystem is D = 0.1	b. low species diversity
3. Beta Diversity $\beta = 5$	c. high species diversity.
4. Basic Beta Diversity Index = 0. 7	d. five species are common between the two ecosystems.
5. Basic Beta Diversity Index = 0. 2	e. low level of similarity between the ecosystems.
	f. five species are unique between two ecosystems.

3. Fill in the blanks with the correct form of word(s).

i. Harvesting medicine from a biodiversity is ....use value.

ii. Rural communities in Bhutan depend on biodiversity for food directly from the nature. This is an example of .... value of biodiversity.

iii. Biodiversity scale ....diversity represents the species richness of particular ecosystem.

iv. Organisms having more than two sets of chromosomes is called ....

v. The presence of Indian and African varieties of elephants is the example of .... speciation.

4. Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct form.

   i. Birdwatching, scientific research, hiking, are examples of productive values.

   ii. Variations in a population exists only in the presence of mutation.

   iii. Simpson's Index (D) value of 1 indicates no species diversity.

   iv. Shannon diversity takes into account only the species richness to measure species diversity.

   v. An area has three elephants, two mango trees and a crow. Then, the species richness of the area is 3.

5. Answer the following questions.

   i. Figure 8.25 represents two different habitats in a region. Use it to solve the following questions:

      a) Which habitat has more species richness?

      b) Calculate the

         1) Beta diversity.

         2) Basic Beta Diversity Index

         3) Gamma diversity

   ii. What could be the reasons for the increased extinction rates? Explain the following terms:

      a) ecoregions.

      b) biodiversity.

   iii. How is peripatric speciation different from sympatric speciation?

   iv. Write down the differences between Shannon Diversity Index and Simpson's Diversity Indices.

   v. 'Mutation contributes to the increasing chances of survival of a species during natural disasters.' Support the statement with an example.

Reprint 2022

CHAPTER 9 BIODIVERSITY CONSERVATION

The natural world is composed of biotic and abiotic constituents. Its health is largely dependent on the existence of varieties of flora and fauna and their interactions amongst themselves and with their physical world. All life forms depend on biodiversity for various purposes, including the flow of genes. The changing anthropogenic and natural events threaten the health of the biodiversity.

The biodiversity conservation is about saving life on the Earth in all its forms and keeping the natural ecosystems functioning. Biodiversity conservation ensures that natural landscapes with their range of ecosystems are maintained, and the species, populations, genes and the complex interactions in the natural world continue into the future.

Reprint 2022

1. Threats to Biodiversity

Learning Objectives

On completion of this topic, you should be able to:

- explain species loss as a threat to biodiversity.
- state some of the factors that cause biodiversity loss.
- identify the threatened species of flora and fauna in Bhutan.
- describe the consequences of biodiversity loss.

With ever increasing human population and changing lifestyle of people, more and more land is being used for agriculture, housing, transport, industries, dams, bridges and other developmental activities. Enormous quantities of unmanaged waste are also discharged into the environment. The deterioration of environmental conditions, pollutions, disappearance of forest, over-exploitation of natural resources and loss of natural habitats are endangering the species. In some cases, species of plants and animals have become extinct, decreasing the biodiversity of an ecosystem.

A. Causes of biodiversity loss

The loss of species in terms of variety and abundance due to several causes is a threat to the biodiversity. The following factors are some of the threats to biodiversity:

(i) Habitat loss and fragmentation

All life forms need suitable habitats and have specific niches in the environment. These habitats, sometimes, are threatened and are lost due to natural calamities, such as volcanic eruption, forest fire and climate change. However, most destruction of habitats are due to anthropogenic activities in which large areas of vegetation are cleared for urbanisation, agricultural expansion and construction of dams, etc. This generally leads to habitat fragmentation.

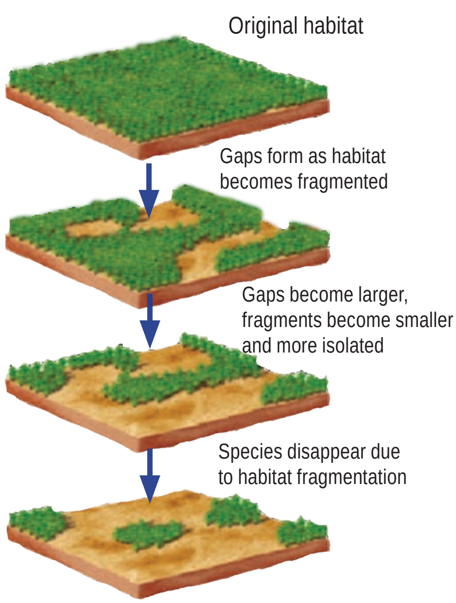


Figure 9.1. Habitat fragmentation

Habitat fragmentation is the reduction of habitats into small, isolated patches of habitat as shown in

Figure 9.1. Due to fragmented habitat, animals which require large territories such as lion, tiger, elephant, etc., are greatly threatened.

When habitats are destroyed, organisms that occupy the habitats migrate, or there will be population decline due to the reduced carrying capacity, making organisms vulnerable to extinction. For example, in Bhutan, constructions of Puna Tsang Chhu and Mangde Chhu hydropower plants have severely affected the natural habitat of the valued golden mahseer (Tor putitora), a fish species in the region. They have adverse impact on the spawning and migration resulting in the decline of its population. If the effect prolongs, it might result in the extinction of this fish species.

In fragmented habitats, the separation of organisms limits the gene flow among species due to inbreeding. The population of those affected species become isolated making the survival of the population more vulnerable which may lead to extinction of the species.

(ii) Wildlife exploitation

The illegal hunting, killing and capturing of wildlife for food, medicine and recreation or for other purposes is known as poaching. Some of the species targeted are musk deer, sloth bear, tiger, elephants, rhinoceros, etc., for musk, bile, skin, tusks, rhino horn, etc. (Figure 9.2) Poaching of species affects genetic, species and ecosystem diversity, disrupting the balance in the ecosystem. Similarly, many plants are also exploited for various purposes. Some of the commonly exploited plants are sandalwood, cordyceps, Paris plant, ginseng, etc. as all these plants have medicinal values.

Figure 9.2. Poaching and illegal trading of wildlife

(iii) Invasive species

Species that are introduced into a new geographical area or in an ecosystem, accidentally or deliberately, from other habitats are called exotic species. Although exotic species bring about genetic diversity in an ecosystem, they might become invasive in absence of any natural predators, and through fast breeding they take over the new habitat. For instance, in 1859, rabbits were introduced in Australia for sport shooting. Due to the favourable environmental conditions and decline in the population of natural predators, the population of rabbit exploded. This led to the destruction of vast areas of rangeland affecting the native wildlife like kangaroos and wombats, and sheep ranches.

Some unintentionally introduced species may cause spread of diseases or become pests or parasites. For example,white clover (Trifolium repens) shown in Figure 9.3a was originally introduced as fodder, but has now become a widespread alien invasive species. Similarly, crofton weed or sticky snakeroot (Ageratina adenophora) shown in Figure 9.3b is an invasive species of plant that spreads into landscapes.

a. Trifolium repens

b. Ageratina adenophora

Figure 9.3. Invasive plants in Bhutan

The practices of growing genetically modified (GM) crops and monoculture sometimes result in disappearance of the indigenous genetic diversity of plants and other organisms that depend on it. The gene within the Genetically modified organism (GMO) enters into competition with the gene of natural occurring species. The spread of gene within the GMO to wild weeds results in evolution of resistant weeds through hybridisation. Ultimately, weeds become dominant over other species causing loss of biodiversity in a given habitat.

(iv) Climate change

Species evolve to adapt to certain climatic conditions like high or low temperature or precipitation. When the climate change is gradual, species may have time to adapt or migrate to a more suitable location. When climate change is relatively abrupt, many organisms are unable to respond before the conditions transcend their tolerance limit. Global climate change has affected species distributions, population sizes and the phenology.

The climatic conditions influence the life cycle, physiological activities, and behaviour of organisms prompting them to migrate, bloom and mate in asynchrony with the environmental conditions. These lead to the mismatch of the timing of migration and breeding with availability of food.

Melting of polar ice caps has reduced the habitats of polar bears, penguins, and other Arctic creatures. Reduction in abundance or loss of these species alters the structure and functioning of ecosystems. In addition, drought has caused severe dryness in certain region of the world directly killing most of the plant or driving animals out from their habitat. For example, in Africa, pressures from longer dry periods due to climate change have threatened elephant population. Climate change has induced migrations in humans in many countries. For instance, the increasing impacts of climate change in Bangladesh have become an important cause of cross-border migration to other countries.

(v) Pollution

Human activities lead to the production of pollutants that are released into the environment. These substances bring undesirable changes in the environmental elements, such as land, water and air, making them unsuitable to support the organisms. For example, the chemical fertilizers used for agriculture leach into water bodies that leads to eutrophication, killing some organisms in aquatic ecosystem.

Pollutants are a major source of concern to ecosystem as they can alter the physical and chemical properties of the abiotic components. Once the pollutants enter a food chain, bioaccumulation occurs which is fatal to all the organism of that chain resulting in loss of biodiversity.

Activity 9.1. *Studying the causes of biodiversity loss*

Instruction:

Draw a concept map that shows the relationship among the factors that cause biodiversity loss using the following key words:

human activities habitat destruction pollution
climate change invasive species species extinction
greenhouse gases emissions hydro-power plants
exotic species poaching waste generations
habitat fragmentation biodiversity loss

Questions

1. Based on your concept map, how do climate change, habitat destruction and invasive species cause biodiversity loss?
2. Identify one of the factors in your concept map that has the greatest impact on the biodiversity loss.
3. Collection of medicinal plants may cause biodiversity loss. Justify.

B. Threatened and extinct species

The International Union for Conservation of Nature and Natural Resources (IUCN) maintains a document called Red List or Red Data Book of the species that are facing the risk of extinction.

The IUCN has recognized the following nine red list categories:

1. ***EXTINCT (EX)***
   A species is Extinct when there are no more individuals of that species alive anywhere in the world.
2. ***EXTINCT IN THE WILD (EW)***
   A species is Extinct in the Wild, when exhaustive surveys in known or expected habitats have failed to record an individual, or the known species is surviving only in captivity.
3. ***CRITICALLY ENDANGERED (CR)***
   A species is Critically Endangered when it faces an extremely high risk of extinction in the wild in immediate future.
4. ***ENDANGERED (EN)***
   A species is Endangered when it is not critically endangered, but faces a high risk of extinction in near future,
5. ***VULNERABLE (VU)***
   A species is Vulnerable when it is not endangered but faces a high risk of endangerment in the wild.
6. ***NEAR THREATENED (NT)***
   A species is Near Threatened when it is found in small population localised in certain geographical areas or habitats or is thinly scattered over extensive range. The species is not evaluated and do not satisfy the criteria for critically endangered, endangered or vulnerable, but because of its small size may have high risk of entering into these categories.
7. ***LEAST CONCERN (LC)***
   A species is Least Concern when it is evaluated but does not qualify as threatened or near threatened.
8. ***DATA DEFICIENT (DD)***
   A species is Data Deficient when there is inadequate information to make a direct or indirect assessment of its risk of extinction.
9. ***NOT EVALUATED (NE)***
   A species is Not Evaluated when it has not yet been evaluated against the criteria.

Source: http://www.iucnredlist.org/technical-documents/categories-and-criteria/2001-categories-criteria#categories

Reprint 2022

Species with small world population that are present, not endangered or vulnerable, but at risk, are called rare species. These species are usually localised within the restricted geographical areas or habitats, or are thinly scattered over a more extensive range. Example, Tarsiers, Okapi, Sao Tome shrew,etc.

Activity 9.2. *Knowing threatened animals and protected plants of Bhutan*

Instruction:

1. Divide yourself into groups and select a topic from the following:
   A. Globally threatened mammals of Bhutan (5-10 mammals)
   B. Threatened birds in Bhutan (5-10 birds)
   C. Totally protected plants of Bhutan (5-10 plants)
2. Search for the information by using internet facilities, library, and other sources.
3. Acknowledge the sources of information in correct forms.
4. Record the information in Table 9.1.

   Table 9.1.

Sl. No.	Common Name	Scientific Name	Global Threat Category	Reasons

5. Share your findings with the class.
6. Make personal notes of the presentations of each group, and answer the following questions:

Questions

1. From your lists, which organism do you think Bhutan should preserve? Why?
2. Why are some organisms critically endangered?
3. Suggest two to three strategies to prevent organisms from becoming extinct.

D. Biodiversity loss is a concern

Biodiversity has several values such as utility, ecological services, aesthetic and spiritual well-being of people, and the health of an ecosystem. Loss of biodiversity has negative impacts on several aspects of human well-being, such as availability of food, energy resources and clean water supply. It also makes human vulnerable to natural disaster. Biodiversity loss has direct impact on interaction amongst the biotic and abiotic constituents of an ecosystem, consequently, affecting all life forms on Earth.

(i) Ecological balance

Ecological balance is the harmonious coexistence of organisms, plants and animals including human with their environment. In an ecosystem, the diverse biological species are interdependent whereby, the degradation of one species may trigger off a chain reaction that negatively impacts the food chain. This disruption in food-web generally endangers the subsistence of the other living organisms in the ecosystem. Therefore, biodiversity loss disturbs the balance of ecosystem.

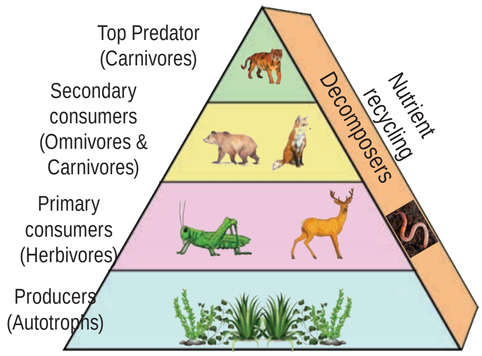


Figure 9.4. Ecological pyramid

(ii) Ecosystem services

Biodiversity provides many key benefits to human well-being. The ecosystem services are provisioning services, regulating services, supporting services and cultural services. Loss of biodiversity hampers these ecosystem services.

(iii) Social services

The natural world is of cultural and spiritual significance to many communities because of its aesthetic values and its influence on the belief system and cultural practices of the society. For instance, many communities worship trees, lakes, mountains, animals, etc., which brings people and communities together. Songs, dances and festivals on nature, animals and crop harvests are a part of culture for many societies for their well-being and unity. Natural world and its landscapes are aesthetically pleasing and provide recreational opportunities such as hiking, cycling, bird watching and nature photography. Disturbance in the biodiversity leads to the loss of these opportunities.

There are other reasons for concern of losing biodiversity. Biodiversity serves as the laboratory in enhancing the scientific knowledge on life forms and their interactions with the environment that shape the ecosystems.

Questions

1. What is Red List? What is its role in conservation of biodiversity?
2. It is often reported in Kuensel that Punatsangchhu Hydropower Project is one factor for decline in the number of White-bellied Herons. What do you think is the main cause for this?
3. The Anopheles mosquito transmits malaria that kills thousands of people around the world. However, it is an important organism that contributes in balancing an ecosystem. Do you agree? Justify.

2. Conservation of Biodiversity

Learning Objectives

On completion of this topic, you should be able to:

- explain in-situ conservation and ex-situ conservation.
- describe conservation initiatives in Bhutan.
- analyse the government laws and policies on conservation.

Biodiversity loss has various consequences on environment and humans. It is critical to ensure the sustainability of ecosystem and the overall ecological health of the Earth.

Conservation of biodiversity is a process of protection and upliftment of biodiversity through scientific management methods. The urgency in the conservation of biodiversity in Bhutan is expressed through the adoption of Gross National Happiness (GNH), as the national development philosophy. Environmental conservation is one of the four pillars of Gross National Happiness to ensure that the socio-economic development is not at the peril of the environment.

A. Biodiversity conservation

Globally, conservation efforts include in-situ and ex-situ conservation approaches. The general biodiversity conservation initiatives through in-situ and ex-situ conservation approaches are illustrated in Figure 9.5.

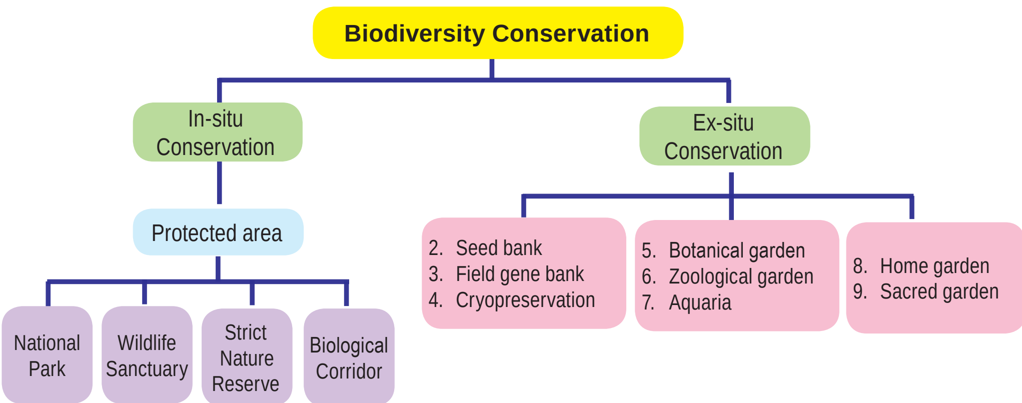


Figure 9.5. Biodiversity conservation management system

Reprint 2022

a. In-situ conservation

In-situ conservation is a strategy of conserving flora and fauna in their natural habitats. It is the protection and management of biological diversity through a network of protected areas in their natural habitats. This includes the protection of total ecosystem in the form of National Parks, Wildlife Sanctuaries, Strict Nature Reserves, Biological corridors and by declaring forests, mountains and lakes as sacred.

(i) National Parks

A national park is a large area of land used for conservation purposes in its natural state. The International Union for Conservation of Nature (IUCN) defines national park as, "large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities."

Jim Corbett National Park in India, Yellowstone National Park in the USA and Royal Park in Australia are some of the earliest national parks in the world. In Bhutan, the national parks are Wangchuck Centennial National Park (WCNP), Royal Manas National Park, Jigme Dorji National Park, Jigme Singye Wangchuck National Park and Phrumsengla National Park, covering about 12,282 sq. km.

The national parks in Bhutan protect diverse flora and fauna including some of the threatened and endemic species. For instance, Wangchuck Centennial National Park (WCNP, the country's largest park is home to about 690 vascular plants, 40 mammals and 250 bird species. Jigme Dorji National Park is a vital watershed covering almost half of the northern Bhutan, and harbours numerous species of wildlife which are endangered elsewhere in the world. The park is also famous for its flora, and more than 300 species of plants found are used in indigenous medicine, including the high-valued cordyceps.

(ii) Wildlife Sanctuaries

An area of land managed to conserve wildlife is called wildlife sanctuaries. In such areas, other activities like collection of forest products, harvesting of timber, private ownerships of land and tilling of lands are permitted as long as they do not interfere with the well-being of animals. Bumdeling Wildlife Sanctuary, Sakteng Wildlife Sanctuary, Phibsoo Wildlife Sanctuary and Jomotshangkha Wildlife Sanctuary cover more than 2500 sq. km in area.

Bumdeling Wildlife Sanctuary in north-eastern Bhutan has a rich diversity of flora and fauna, and is one of the country's two wintering spots for the endangered

Black-necked crane. Sakteng Wildlife Sanctuary harbours some endemic species such as the Eastern blue pine (*Pinus bhutanica*) and Black-rumped magpie *(Pica pica bottanensis)*. Covering an area of about 334 square kilometre between 400 to 2,200 meters, Jomotshangkha Wildlife Sanctuary is Bhutan's second smallest protected area. The sanctuary is important habitat for elephant, gaur and other tropical wildlife species. It also has the rare pygmy hog and hispid hare. Although Phibsoo Wildlife Sanctuary is Bhutan's smallest protected area, it is known for its important bio-geographic position. It is the only area in Bhutan to have Chital *(Axis axis)* or spotted deer, and the only remaining natural Sal (*Shorea robusta)* forests in the country.

(iii) Strict Nature Reserves

The IUCN defines strict nature reserve as 'strictly protected areas set aside to protect biodiversity and also possibly geological or geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure the protection of conservation values'.

The Jigme Khesar Strict Nature Reserve covering an area of about 640 square kilometre in Haa and Samtse region is a strict reserve area in Bhutan. It protects temperate forests of the country from broad leaf to alpine meadows and small lakes. Jigme Khesar Strict Nature Reserve, according to the Red List of threatened species of 2010 of IUCN, protects endangered and vulnerable species such as snow leopard, clouded leopard, red panda, Asiatic black bear, golden cat, leopard cat, musk deer, serow, takin, wild dog and Assamese macaque. It is the only protected area without permanent human residents, except for a few yak herding nomads.

In order to ensure protection of wild species and at the same time fulfill the needs and the rights of the local communities living within and around the reserves, the reserves have been zoned as shown in Figure 9.6.

1. Core or natural zone is fully protected and closed for all human-related activities. However, regulated research, monitoring programmes and staff patrolling are carried out.
2. Buffer zone surrounds the core area. The area is allowed for human activities without disturbing the conservation objectives of the core area. Experimental research and services for education, training, tourism, and recreational facilities are allowed in the area.

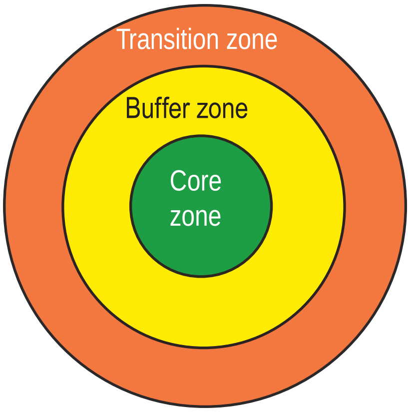


Figure 9.6. Zonation pattern of protected area

3. Transition or manipulation zone is the outermost or peripheral part of the biosphere reserve, where people live and work using the natural resources of the area in a sustainable way. An active cooperation exists between the reserve management and the activities of local people in achieving the objectives of the biosphere reserve. Hence, the zone is also called 'area of cooperation.'

(iv) Biological corridor

Biological corridors connect all the protected areas into a single uninterrupted area. The corridors act as reliable, cost effective strategy to conserve meta-populations of wide-ranging species, promote migration and gene flow for all species, and allow species to adapt to changing climate and environment. For instance, Bhutan has nine biological corridors connecting the national parks, sanctuaries and wildlife reserves. The longest corridor is the North Corridor with a length of 76 km connecting Jigme Dorji National Park to the corridors of Phrumsengla National Park and Bumdeling Wildlife Sanctuary. The shortest corridor is the one connecting Phrumsengla National Park to the North Corridor with a length of 16 km. The width of the corridors ranges from 500 m to 3 km.

The protected areas conserve Bhutan's fragile landscapes, vegetation and rich biodiversity including globally threatened mammals, avifauna, aquatic and plant species. Thus, Bhutan is listed as a part of one of the ten biodiversity hotspot in the world.

Some of the advantages of the in-situ conservation are:

a) it is an effective and efficient way of conserving biological diversity.
b) it offers a way to simultaneously preserve a large number of organisms that are known or unknown to us.
c) the existence in natural ecosystem provides opportunity to the living organisms to adapt and evolve into better life form.

b. Ex-situ Conservation

The conservation strategy in which threatened or endangered species of plants and animals are reared and preserved outside their natural habitats is called ex-situ conservation. Ex-situ conservation of wild varieties of domesticated crops provides great opportunities to plant breeders and genetic engineers to transfer desired traits in high yielding varieties. It is the source of genetic material for reintroduction to the wild and for future breeding programme of domestic species. The ex-situ conservation can be achieved by the following establishments:

(i) Off site collection

This includes development of biodiversity conservation centres, botanical or zoological gardens and aquarium. The Royal Botanical Garden and the Royal Bhutan Gene Bank at Serbithang and Takin preservation at Motithang are some examples of off site collection establishment. These facilities are used for recovery programmes of indigenous practices and diversity of flora and fauna. They are also used for research and educational purposes. They are useful to educate people about threatened status of species and factors that cause threats to biodiversity.

(ii) Gene bank

Gene bank is an institute that collects and stores genetic materials of flora and fauna. Genetic materials of animals are preserved for reproduction, genetic engineering and preservation of threatened species. Similarly, tissues and vegetative part of all native species and varieties of crops are stored for sustainable use and food security. Seed gene bank is one of the effective institutions in preserving variety of native seeds. For example, the Royal Bhutan Gene Bank was established to conserve germplasm of traditional crop varieties native to Bhutan.

Figure 9.7(a). Seed gene bank for maize (b). Seed gene bank for wheat

In seed gene bank, fresh seeds are dehydrated and then stored in special rooms under anaerobic conditions at a low temperature of -10˚C to -20˚C. At these low temperatures, the rate of metabolism slows down, which prevents the seed from germinating. These preserved seeds can germinate into plants and produce fresh seeds, even after several decades.

(iii) Tissue culture

Tissue culture technique is one of the effective methods to preserve critically endangered species of plants and animals. It is a technique used for multiplication of plants and animals by callus formation, pollen grain culture and shoots tip culture in-vitro under controlled and aseptic conditions. It is also used for those plants which are either seedless or bear recalcitrant seeds. Recalcitrant seeds are the seeds that cannot be preserved in seed gene bank as they do not survive under low temperatures. Figure 9.8 illustrates the basic procedure of tissue culture.

Reprint 2022

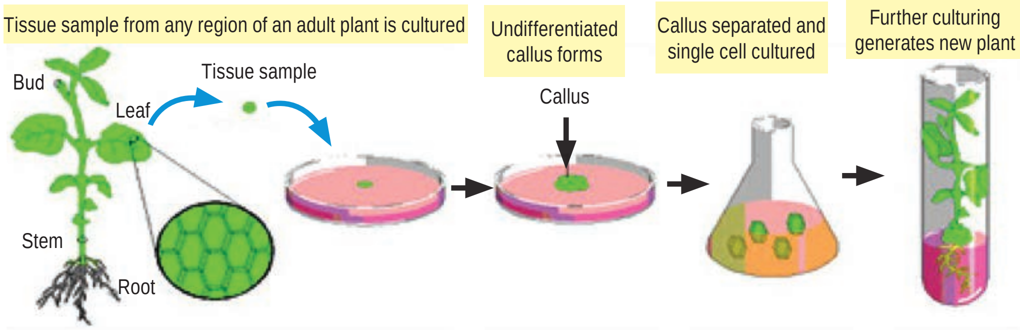


Figure 9.8. Tissue culture procedure

(iv) Cryopreservation

Cryopreservation is the preservation of biological tissue at a very low temperature of -196°C. Liquid nitrogen is used for cryopreservation. At – 196⁰C, the metabolic activities of a cell or a tissue are completely suspended for preservation. The preserved materials can be revived later when required. This method is popularly used in preservation of genetic materials of critically endangered species of flora and fauna.

Figure 9.9. Cryopreservation in liquid nitrogen

In Bhutan, the cryopreservation is used by livestock personals to preserve reproductive cells, especially semen of cattle in liquid nitrogen for artificial insemination.

Following are the advantages of using ex-situ conservation technique:

a) Increases life span of species and enhances healthy breeding activity of animals.

b) Genetic technology can be utilized in the process of conservation.

c) Breeding of endangered animals and hybrids can be successfully achieved.

d) Ex-situ centres offer the possibilities of observing and studying wild flora and fauna, which is otherwise not possible in natural setting.

Activity 9.3. *Exploring biodiversity in the Philippine Archipelago*

Instruction:

Read the extract and answer the questions that follow:

The Philippine Archipelago is considered one of the most biologically diverse countries in the world. However, the effects of indiscriminate and excessive use of its natural resources since the end of World War II have been extensive and dramatic, resulting in the rapid destruction of many of the country's irreplaceable natural treasures (Catibog-Sinha& Heaney, 2006). The Philippines is one of the 'hottest' amongst the 34 terrestrial hotspots in the world in terms of high vulnerability and irreplaceability of threatened species (Mittermeieret al., 2004). The Philippines is also on the top in the list of the 18 global marine hot spots (Roberts et al., 2002).

Since Philippine endemic species are found nowhere in the world, their extinction would mean a global loss. In response to the global call for a stronger and wider collaboration among zoos in various conservation initiatives (WAZA, 2005; WZO, 1993), the International Zoo Community has been helping the Philippines in establishing back-up populations of certain endangered endemic species in ex situ facilities. Currently, a total of 10–12 collaborative captive breeding programs are in place in the country. All of these captive breeding facilities aim to function as 'reserved gene pools' in the event of species extinction in the wild. These zoos are also involved in various aspects of in-situ conservation, such as habitat restoration and protected area management. They help develop and support national species recovery programs as an integral component of captive-breeding and reintroduction (Banks, 2005; IUCN, 2004). Improving the contribution of zoo tourism in promoting biodiversity conservation is a major challenge to the Philippines and its partner organisations.

(source:ftp://ftp.puce.edu.ec/Facultades/CienciasHumanas/Ecoturismo/ArticulosTurismo/Art%EDculos%20cient%EDficos/Ecoturismo%20y%20la%20Conservacion%20biodiversidad/2009/zoo_tourism.pdf

Questions:

1. What are the global significance of Philippine's conservation efforts?
2. What were some of the challenges faced by Philippine Archipelago in conserving wildlife?
3. Why do the international zoo community and other countries feel necessary to help Philippines establish captive breeding facilities?

B. Biodiversity conservation initiatives in Bhutan

The biodiversity of Bhutan has global significance because some of the globally endangered and threatened species are found in Bhutan. Besides, Bhutan is also home to some of the endangered endemic species.

a. National Framework for Biodiversity Conservation in Bhutan

The global conservation priorities have been developed by conservation organisations and are adopted in the National Framework for Biodiversity Conservation in Bhutan. The conservation priorities are based on the number of criteria such as nativeness, rarity, endanger status and economic values, irreplaceability and vulnerability. Irreplaceability is a measure of endemism of plant or animal species, which is based on the idea that greater the number of endemic species in a region, more the chances of biodiversity loss. Vulnerability of species is generally measured by the degree of habitat loss.

The commitment of Bhutan towards the conservation of environment is immortalised in the constitution, which has been translated into numerous policies and acts. Some of the national acts and policies are given in Table 9.2.

Table 9.2. Some of the Biodiversity-based National Policies ans Acts

Sl No.	Acts and Policies	Year of Enactment
1.	The National Forest Policy	2011
2.	The Water Act of Bhutan	2011
3.	The Biosecurity Policy of the Kingdom of Bhutan	2010
4.	The Waste Prevention and Management Act of Bhutan	2009
5.	The National Environment Protection Act	2007
6.	The Biodiversity Act of Bhutan	2003
7.	The environmental Assessment Act 2000	2000
8.	The Forest and Nature Conservation Act 1995	1995
9.	The Plant Quarantine Act 1993	1993

b. Biodiversity conservation programmes of Bhutan

Bhutan has made significant steps to ensure that the protected areas and the rest of the forest cover remain intact. Over the years, the government has issued several acts, decrees and policies that provide a legal framework for the conservation of biodiversity. The government's overall policy objective is to integrate the nature conservation into economic development plans with an emphasis on communities living within the protected areas and buffer zones.

To realize the objectives of biodiversity conservation in Bhutan, several agencies and organisations have initiated the following:

1. Community forest management
2. Afforestation and reforestation programme
3. Quarantine species management
4. Natural disaster or forest fire management
5. Watershed management
6. Enforcement of policies and acts
7. Public awareness programme

(i) Enforcement of policies and acts

The National Forest Policy 2011 ensures that Bhutan's forest resources and biodiversity are managed sustainably to provide a wide range of social, economic and environmental benefits while maintaining the constitutional requirement of a minimum of 60% of the country's total area under forest cover.

The Environmental Assessment Act 2000 directs the government to ensure that environmental concerns are taken into account when formulating, renewing, modifying and implementing any policy, plan or programme. It requires the issuance of environmental clearance as a prerequisite to the approval of any development activity.

The Pesticide Act of Bhutan 2000 encourages the practice of organic agriculture and integrated pest management with centralized system that controls and limits the import, sale and use of pesticides.

The National Environment Protection Act of Bhutan 2007 mandates the protection of forest, biodiversity and ecosystem integrity. Therefore, this Act calls for conservation of natural resources to be based on a participatory approach aimed at achieving an equitable sharing of the costs and benefits of conservation among resource users. It also calls for conservation and protection of wetlands, alpine regions, watersheds, and other vulnerable ecosystems in addition to the existing protected areas.

(ii) Public awareness programme

Many government agencies, civil society organisations, schools and institutes carry out education and awareness activities on environment. Observing important days like World Wildlife Day on March 3, Biological Diversity Day on May 22, World Environment Day on June 5, Social Forestry Day on June 2, and organising Matsutake and Black-necked crane festivals in different regions are some ways of creating awareness.

Reprint 2022

The concepts and the basic skills of managing environment are integrated into the formal school curricula through school agriculture programme and environmental science, and in non-academic curricula as nature club activities.

Activity 9.4. *Studying biodiversity conservation programmes in Bhutan*

Instruction:

1. Work in groups and choose a topic from the following:

   Group A - Community forest management

   Group B – Quarantine species management

   Group C – Afforestation and reforestation programmes

   Group D – Natural disaster/forest fire management system

   Group E – Watershed management
2. Carry out a study on the given topics in terms of biodiversity conservation and prepare a presentation.
3. Share with the class.

Questions

1. What is the common goal of all the programmes studied?
2. What are some challenges faced in achieving the goal in 1?
3. Write one benefit of each of the programme to the community.
4. What role does public awareness play in the above mentioned programmes?

Questions

1. Outline the advantages and disadvantages of protected areas for the people living nearby.
2. List down the limitations of in-situ and ex-situ conservations.
3. Describe one of the biodiversity conservation programmes in your community?

Exercise

1. Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.

   i. Poaching of animals are restricted by law due to their

      A. ecological value.

      B. economic value.

      C. legal value.

      D. aesthetic value.

   ii. The collection of Ophiocordyceps sinensis is regulated in Bhutan for

      A. protection of habitat.

      B. conservation of cordyceps.

      C. protection of livelihood of people.

      D. alleviation of poverty.

   iii. Which one of the following is related to in-situ plant conservation?

      A. Field gene bank.

      B. Gene bank.

      C. Biological corridor.

      D. Botanical gardens.

   iv. The cultivation of land and timber harvesting are permitted in

      A. wildlife sanctuaries.

      B. national parks.

      C. biosphere reserves.

      D. biological corridors.

   v. Which of the following ways would be the most effective in conservation of biodiversity?

      A. Freezing fertilized eggs of animals.

      B. Setting aside small plots of land in a variety of ecosystems, such as forests, grasslands and marshes.

      C. Creating large parks or sanctuaries in biodiversity hot spots.

      D. Maintaining a seed bank of all plant species.

Reprint 2022

2. Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.

Column A	Column B
1. Organism facing extremely high risk of extinction in immediate future.	a. Gene Bank
2. Invasive plant species.	b. National Park
3. Preservation of genetic diversity in the form of seeds or cuttings.	c. White-bellied heron
4. Protection of natural wonders and wildlife located within their environment.	d. Biological corridor
5. Facilitates the movement of species from one protected area to another.	e. Ageratina adenophora
	f. Zoo

3. Fill in the blanks with the correct form of word(s).

   i. A species of small population in localised geographical area that is not threatened belongs to ______________ category of Red List.

   ii. The drainage of the chemical constituents from fertilisers and pesticides used in vegetable garden into the water bodies will lead to ______________.

   iii. National parks, sanctuaries and biosphere reserves are common techniques applied in ______________ conservation.

   iv. Illegal hunting and slaughtering of sloth bear for bile or for meat is an example of ______________ .

   v. The process of preservation of semen of cattle for artificial insemination is called ______________.

4. Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.

   i. Species with small population which require special habitats for breeding are more likely to be extinct.

   ii. Community forest activities include afforestation and reforestation programmes.

iii. The species is known to be surviving in captivity and fail to show record of particular species in the expected habitat is most likely to be endangered.

iv. Researches and services for education are allowed in the core zone of the biosphere reserves.

v. Recalcitrant seeds cannot be preserved in gene bank as they cannot survive under high temperature.

5. Answer the following questions.

i. Conservation of environment is one of Bhutan's national priorities. How does this constrain the developmental activities in the country?

ii. How does ex-situ conservation promote biodiversity?

iii. Isolated populations of wildlife or plants are less genetically viable and at greater risk than the connected populations. Justify this statement.

iv. Does it make a difference if a biological corridor is either 1 km or 5 km wide? Explain.

v. "Death or extinction of a species from an ecosystem is a natural cause, for which people should be least concerned about it."

How does this statement impact the people's belief on biodiversity conservation?

Reprint 2022

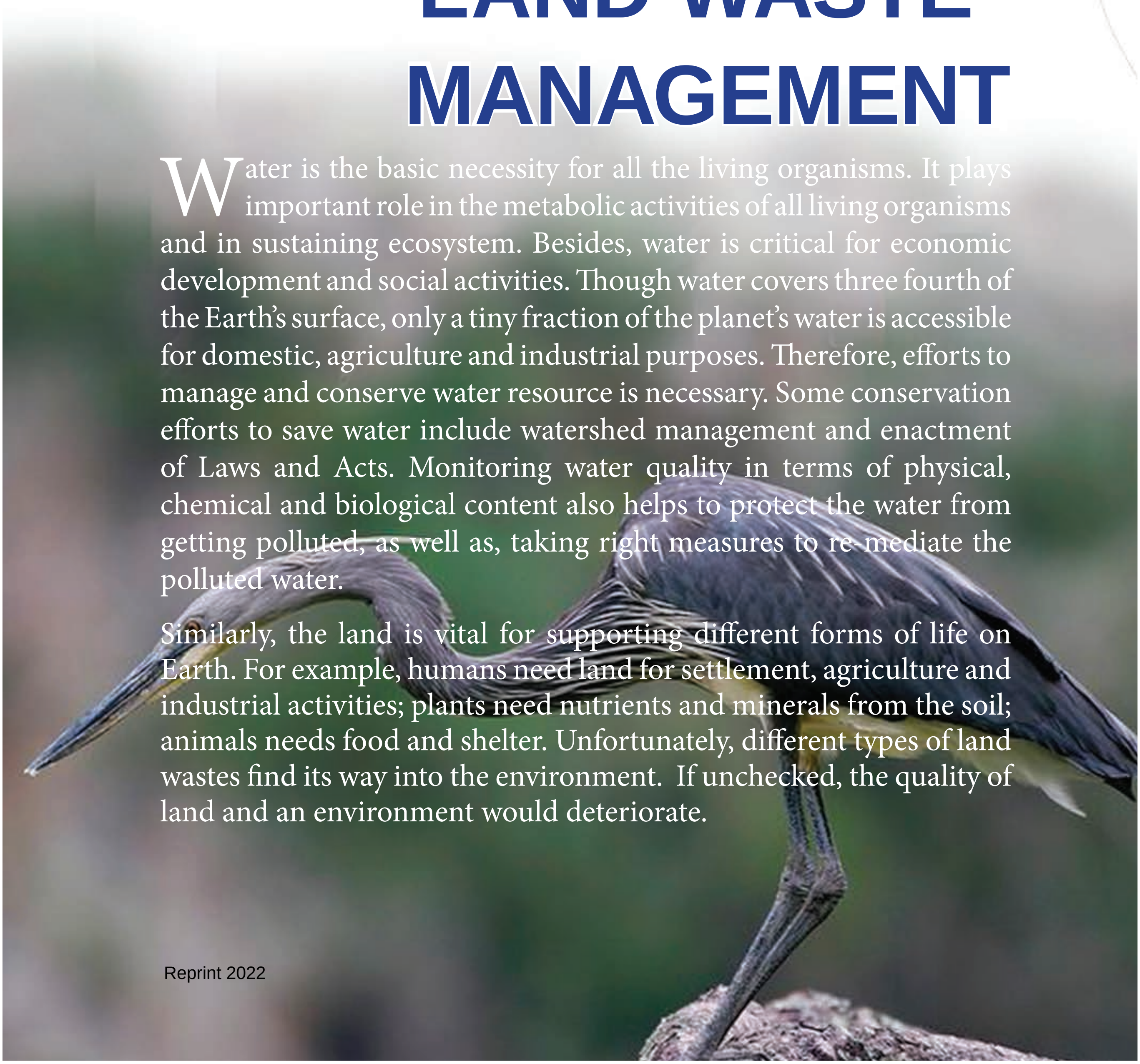
10

CHAPTER

WATER AND LAND WASTE MANAGEMENT

Water is the basic necessity for all the living organisms. It plays important role in the metabolic activities of all living organisms and in sustaining ecosystem. Besides, water is critical for economic development and social activities. Though water covers three fourth of the Earth's surface, only a tiny fraction of the planet's water is accessible for domestic, agriculture and industrial purposes. Therefore, efforts to manage and conserve water resource is necessary. Some conservation efforts to save water include watershed management and enactment of Laws and Acts. Monitoring water quality in terms of physical, chemical and biological content also helps to protect the water from getting polluted, as well as, taking right measures to re-mediate the polluted water.

Similarly, the land is vital for supporting different forms of life on Earth. For example, humans need land for settlement, agriculture and industrial activities; plants need nutrients and minerals from the soil; animals needs food and shelter. Unfortunately, different types of land wastes find its way into the environment. If unchecked, the quality of land and an environment would deteriorate.



Reprint 2022

1. Water Conservation

Learning Objectives

On completion of this topic, you should be able to:

- explain the importance of water.
- identify various water conservation practices.
- explain water conservation efforts of Bhutan.
- explain the importance of watershed management for water conservation.

With the increase in population, developmental activities, urbanisation, industrialisation and changing lifestyle of people, there is an increased pressure on water resources. These have resulted in water crises around the world. Therefore, countries around the world are emphasising the importance of water and its conservation efforts. Water conservation is the management of water resources to reduce the loss or waste of water so that everyone has access to adequate, safe and affordable water. It encompasses the principles, policies, strategies and activities to manage water as a sustainable resource.

A. Water uses and conservation efforts

Water has wide range of uses, which includes domestic, industrial, agriculture and ecological purposes. Communities conserve water by deploying appropriate methods and strategies supported by plans and policies, both at local and national levels.

Activity 10.1. ***Identifying the uses and water conservation efforts***

Instruction:

1. Visit the library, browse internet, interview professionals and conduct a field survey to collect information on water uses and conservation strategies/activities in Bhutan.
2. Record the information or observations in the format shown in Table 10.1.
3. Share the findings in the class.

Table 10.1.

Sl.No	Category of water use	Uses of water	Water conservation strategies/activities
1	Domestic		
2	Agriculture		
3	Industries		
4	Energy generation		

Reprint 2022

Questions

1. Identify and write essential roles of water in income generation.
2. How do people use water at home? What conservation activities are adopted?
3. State the importance of conserving water to humans and their environment?
4. Describe activities and strategies used for conservation of water in Bhutan.

B. Water conservation initiatives in Bhutan

Bhutan is endowed with abundant freshwater sources. The source of water in Bhutan includes glaciers, snow, lakes, rivers, streams and springs. Marshes, peatlands, peat bogs, fens and other forms of wetlands are also important sources of water. Due to the geographical location of the country, most of the water available in Bhutan is in the form of major rivers and tributaries flowing through valleys due South. Most communities depend on smaller streams, springs and lakes for domestic and agricultural uses. Increase in developmental activities and population, the demand on water resources is increasing, resulting in scarcity of water. In order to address the water scarcity in the country, Bhutan accords high priority on water conservation efforts.

a. Principles of water conservation

Our country's effort to provide adequate water to all communities is guided by the following principles as illustrated in Figure 10.1.

Principles of water conservation

- Environmental conservation: Implementing policies, acts and management plans related to water, that sustains and improve environmental condition including social, cultural and health aspects of human life.
- Integrated water resource management: Coordinated development and management of water resources to maximise the economic and social welfare in an equitable and sustainable manner.
- Sustainable use of water resources: Developing water resources to meet the demand of its people without damaging the environment and the country's unique cultural heritage so that the quality of life of future generation is not compromised.
- Economic efficiency: Recognizing that water has an economic value in all its uses.
- Equity and good governance: Equitable water use rights which respect local traditions that are founded on equity and social justice. Water administration shall be carried out by responsive, transparent and accountable institutions.

Figure 10.1. Principles of water conservation

Reprint 2022

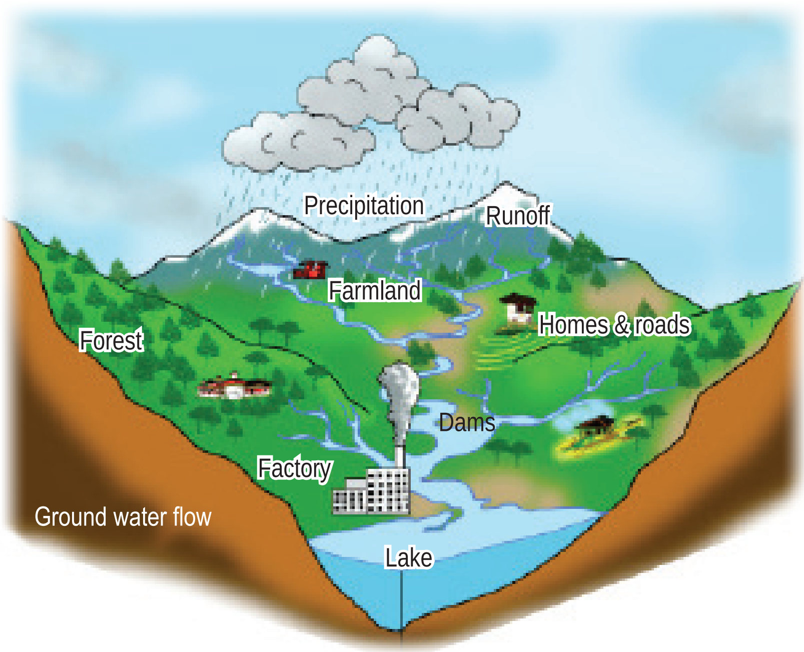
b. Water conservation initiative

Water conservation initiative refers to programmes, actions, policies and strategies designed to reduce wastage of water, and recycle wastewater for different purposes like cleaning, manufacturing and irrigation. Efficient use of water not only reduces costs and environmental impacts but also ensures abundant clean and safe water for people and animals. Water conservation initiative also makes the ecosystem more sustainable and contributes towards the overall health of the environment.

In Bhutan, one of the water conservation activities is the management of watersheds. A watershed is a geographical area, or and extent of land through which the water flows and drains into a common body of water, such as streams, rivers, lakes or oceans.

The need for Bhutan to conserve water through the management of watershed is due to its dependence on hydro-power, tourism and agrarian-based communities. It is also economically viable for Bhutan to conserve water by managing naturally occurring watersheds than investing in expensive wastewater recycling systems.

Watershed management as a system involves rehabilitating degraded landscapes, mitigating areas that are at risk of environmental hazards, encouraging communities to adopt forest and rivers, and other activities addressing impacts of climate change. The involvement of relevant stakeholders like community, business people, municipalities, NGOs and governmental agencies are essential



Reprint 2022

in management of the watersheds. Figure 10.3 illustrates the framework for watershed management involving relevant stakeholders.

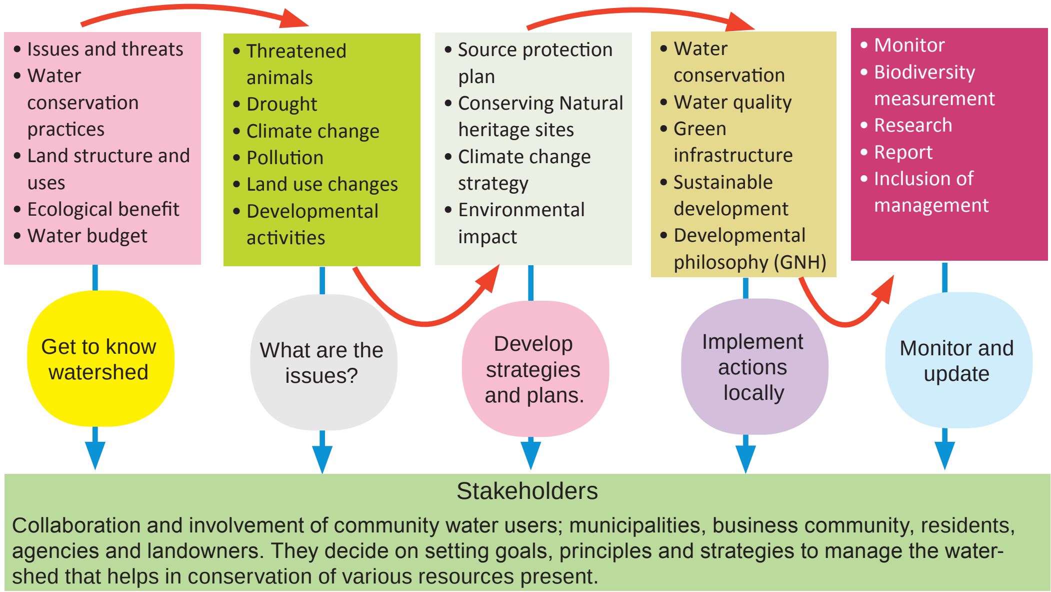


Figure 10.2. Framework for watershed management

Questions

1. Define watershed and explain its importance in context to Bhutan.
2. Explain the principle of water conservation in Bhutan.
3. 'Every household in Bhutan should have water metering devise to conserve water'. Do you agree with the statement?

2. Monitoring water quality

Learning Objectives

On completion of this topic, you should be able to:

- explain the concept of water quality.
- explain the ambient wate quality parameters, standards and significance.
- explain the importance of chemical oxygen demand in terms of water quality..
- explain the importance of testing water quality.

Water quality is a measure of the suitability of water for a specific purpose. Water should meet certain requirements regarding physical, biological and chemical characteristics for it to be useful for particular purpose. For example, drinking water should contain zero hazardous chemicals, radioactive matter and micro-organisms; be free from unpleasant colour or odour and should taste good. Government and other environment monitoring agencies also test the water for presence of contaminants, and identify the sources of pollution towards ensuring that environmental standards are being met by factories and any commercial organization that use the water. Therefore, it is important to carry out the water quality monitoring and water quality test to ensure that the water resources used for different purposes are within the permissible limit of the water quality standard of Bhutan.

A. Analysing physical content of water

The physical content of water is assessed by making observations of its physical characteristics such as the turbidity, colour, and odour.

- Turbidity is due to the presence of suspended matter such as clay, silt, and fine particles of organic and inorganic matter, plankton and other microscopic organisms.
- Colour can be caused by decaying leaves, plants, organic matter, copper, iron and manganese.
- Odour of certain nature may be indicative of organic or non-organic contam¬inants that originate from municipal or industrial waste discharges or from natural sources.

Reprint 2022

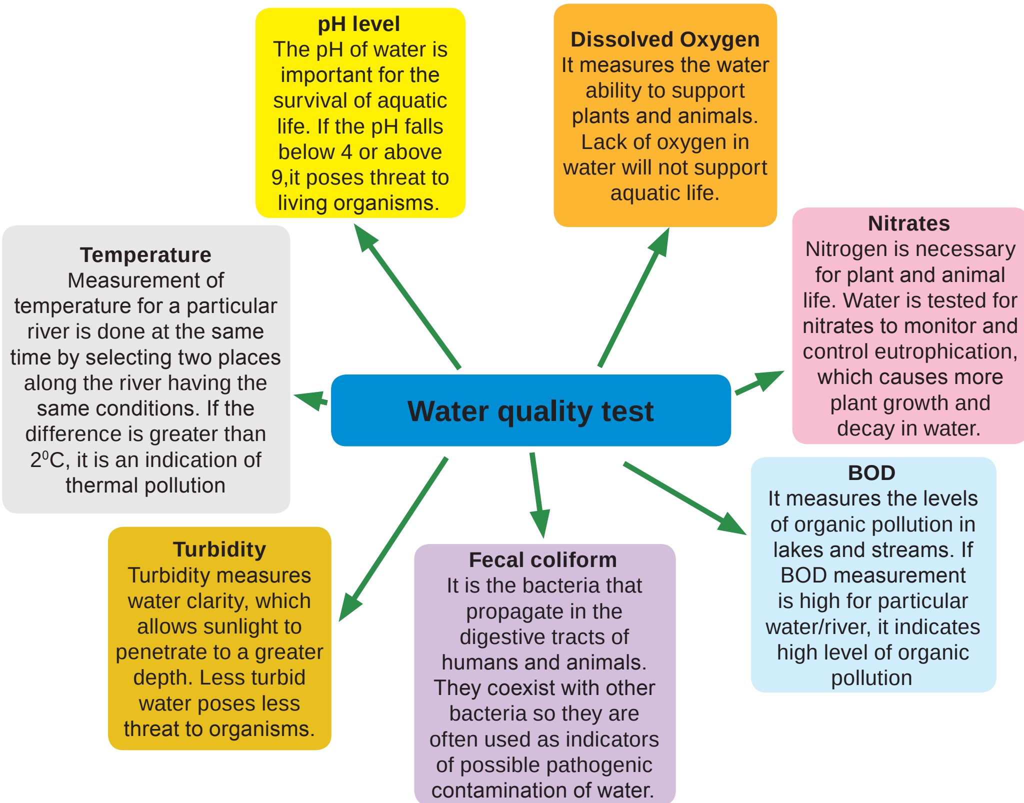


Figure 10.3. Water quality test parameters

Table 10.2 contains some of the indications of water contamination that can be made through visual observations and smell. If contamination is suspected, chemical and biological testing are used to confirm the physical observation.

Table 10.2. Possible contaminants and their indication.

Water Observations	Possible Contaminants
Foamy	Detergents
Black in colour	Manganese, bacteria growth
Brown, yellow or reddish in colour	Iron
Dark brown or yellow in colour	Tannins and pigment from leaves
White deposits or scale	Hardness, dissolved metals
Earthy, fishy, muddy, peaty odour	Organic matter, algae, bacteria
Rotten egg odour	Hydrogen sulphide
Chlorine odour	Chlorine residual from water treatment process

b. Water quality standards

Water quality standards are the provision of the state that describes the desired condition of a water body or the level of protection, and the mandates to establish the desired condition. It sets the level to prevent any harm to human beings or sets limitations on water usage. Various parameters are used to determine the standard of water quality. Some of the basic parameters are temperature, pH, turbidity, salinity, biological oxygen demand (BOD), chemical oxygen demand (COD) and total dissolved solids (Table 10.1).

Table 10.3. Water quality parameters, standards and significances

Parameter	Satndard	Significance
Temperature	------	Affects the usefulness of water. Generally, low temperature is preferred. Groundwater temperature increases with increase in depth of the aquifer.
Electrical conductivity	8.25- 14.46 µS cm-1 at 25oC	Measures the ability of water to conduct an electrical current. The magnitude of the current it conducts depends on ionic concentration, composition and degree of ionisation in water.
pH	6.5-8.5	Water with pH 7.0 is neutral and is ideal for consumption. pH <7.0 is acidic, and water will be corrosive. pH >7.0 is alkaline, and water may be corrosive.
Turbidity	Not Exceeding 1.5 NTU	Suspended particles absorb heat, increases temperature and reduce light available for algal photosynthesis. Turbidity due to suspended sediment is an indicator of erosion, either natural or human-made. Suspended sediments clog the gills of fish. Once the sediment settles, it can foul gravel beds and smother fish eggs and benthic insects. The sediment can also carry pathogens, pollutants and nutrients
Total dissolved solids	500 mg/L SMCL	It is the total amount of all dissolved mineral constituents expressed in milligrams per litre. The dissolved solids concentration is commonly called the water's salinity. Some dissolved mineral matter is desirable; otherwise, the water would have no taste. Water that contains more than 1,000 mg/L is unsuitable for many industrial uses.
COD	4 mg/L	It is the amount of oxygen required to oxidise organic matters by biochemical reactions. It determines the number of pollutants in water.

Reprint 2022

Activity 10. *Testing the water quality*

Materials required: Water quality test kit.

Instruction:

1. Conduct the activity in groups.
2. Collect water samples from different sources, such as school tap water, nearby stream, stagnant water and commercial packaged water.
3. Carry out water quality test by using water testing kit.
4. Record your observation in Table 10.2.

Table 10.4. Observation table

Parameter	Observatione	Inference
Electrical conductivity		
pH		
Turbidity		
Total dissolved solids		

5. Compare your result with the water quality standard given in Table Table 10.1 ann dconclude your findings.

Questions:

1. What is the purpose of testing quality of water?
2. Which of your water sample(s) is/are safe for drinking? Why?
3. What are some of the experimental precaution taken to get a valid result?
4. What are some of the scientific importance of this experiment?

c. Chemical oxygen demand (COD)

The chemical oxygen demand (COD) is the measurement of the amount of oxygen required to oxidise organic matter in water. It is a useful measure of water quality as it determines the amount of organic pollutants found in water. Chemical oxygen demand is related to biological oxygen demand (BOD). Both BOD and COD indicate the amount of pollutants in a water sample. Higher BOD or COD value means the discharged effluent has more oxygen absorbing capacity which is either used biologically or chemically to break down the organic matter. This reduces the dissolved oxygen (DO) level in water and causes threats to aquatic organisms.

Table 10.5. Chemical oxygen demand status

COD in mg L-1	Status
0-5	Very clear water, can be used for drinking
5-20	Fairly clean
20-100	Unfit for drinking, but can be used for washing and agriculture

Questions

1. List some of the water conservation methods that you think are appropriate for your village?
2. Harvesting rain and runoff water have many advantages. List three advantages of harvesting water.
3. Why is it important to monitor water quality even for agriculture purposes?

Reprint 2022

3. Land Waste Management

Learning Objectives

On completion of this topic, you should be able to:

- define land waste management.
- explain waste management hierarchy.
- explain the various methods of waste management.
- identify the types of waste management practices in your community.

Urbanisation, improvement in lifestyle, and the changing consumption patterns of people have increased the generation of municipal waste of various types and forms. They can be either degradable or non-degradable, hazardous or non-hazardous. If the wastes are not managed scientifically and efficiently, both environment and human society will be affected. This is a great concern for the society and the government because huge amount of resources are incurred in mitigating the environmental issues and providing health services for those affected by pollution related diseases.

Bhutan is making a good progress in waste management, mainly through the promotion of recycling and the expansion of the number of scientifically managed sanitary landfill sites throughout the country.

A. Land Waste

The waste materials that people discard which degrade the land surface are called land wastes. The land wastes are either in the form of solid or liquid. They can be hazardous or non-hazardous, degradable or non-degradable, and industrial or residential wastes. The sources and types of solid and liquid land waste are given in Table 10.4.

These wastes add toxicants into soil, water and atmosphere that cause adverse health effects to the humans, as well as to the health of the environment. For example, plastic waste contains polyvinyl chloride, phthalates, polycarbonate, and polystyrene. Chemicals present in these wastes can cause congenital disabilities, cancer, skin diseases, breathing difficulty and eye irritation. Similarly, chromium, cadmium, asbestos, arsenic, cyanide and mercury from pharmaceuticals, fertiliser and pesticide industries can cause cancer, liver damage, lung and kidney diseases. Therefore, scientific management of waste is crucial for the benefit of environment and people.

Table 10.6. Sources and types of land waste

Types of land waste	Sources	Types of waste
Solid waste	Municipal, medical/clinical, agriculture, automobile, construction / demolition, electronic, industrial, etc.	Old tires, scrap metals, broken furniture, garbage, empty cans, construction and demolition debris, e-wastes, etc.
Liquid waste (effluent)	Municipal, industrial, automobile, medical/clinical, agriculture, etc.	Stormwater, urban runoff, agricultural, horticultural, and aquaculture effluent, sewage (toilets and bathroom fixtures, bathing, laundry, kitchen sinks), oil, effluents, grey water, acids and alkalis, etc.

B. Land waste management

Waste management is a process of dealing with waste from source to its disposal. This process includes waste generation, minimisation, collection, segregation, treatment and disposal. The waste management hierarchy is nationally and globally accepted concept of waste management practices. It sets out the preferred order of waste management practices, from most to least preferred as illustrated in Figure 10.7.

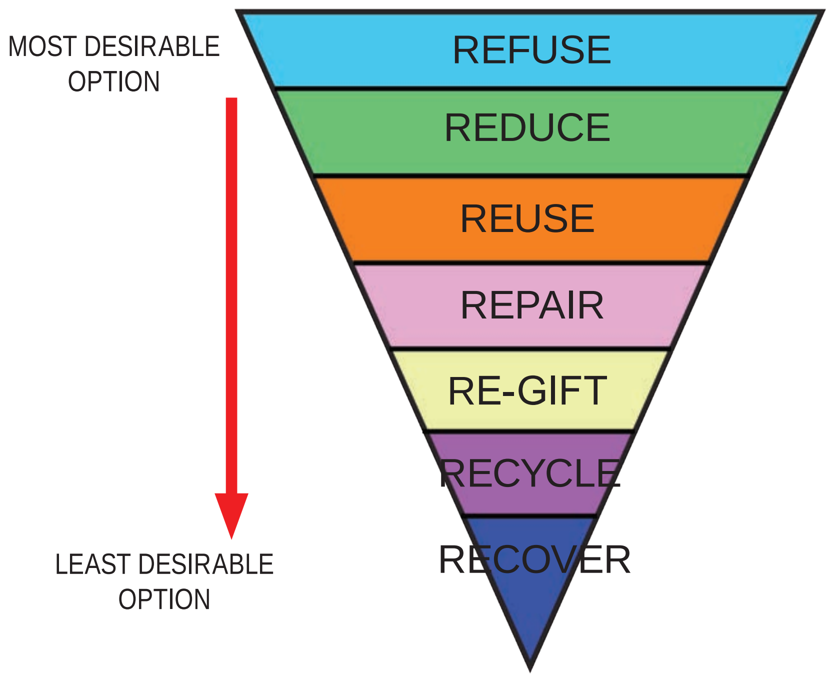


Figure 10.4. The waste management hierarchy

Some of the commonly used strategies to manage the land waste include the following:

a. Shrinking the waste stream

The steady flow of waste from domestic or industrial areas to final disposal site is called waste stream. The practice of discarding less waste means shrinking the waste stream. It is more efficient than struggling with other waste management methods like disposal and incineration. Some of the practices of shrinking the waste stream include the following options:

(i) Refuse or avoid

Refuse purchase of goods that may generate wastes. For instance, avoid buying packaged goods like biscuits, sweets, chips; refuse the use of plastic bags, instead carry personal canvas bags; and buy only the commodities that suffice one's need.

(ii) Reduce

Reduction in consumption of products minimises the production of waste. It saves energy, material and money. For instance, buying durable goods, rechargeable batteries and goods with minimal packaging materials are some of the practices that significantly reduce the consumption of goods and production of wastes.

(iii) Reuse

Reuse is the concept of using the same item several times. Instead of buying new containers, polythene containers, jerry cans, juice bottles etc., can be used several times for the same or different purposes. This practice generally reduce the amount of waste generated.

(iv) Repair

Repair means restoring partly damaged things into useable condition. Repairing significantly reduces the waste stream that goes into disposals. For example, instead of throwing, electrical devices, clothes and shoes can be repaired saving money and reducing wastes.

(v) Re-gift

Re-gift means gifting excess, used and unused goods to those who need them. For example, when the kids outgrow their clothes or toys, gift them to friends, family or relief organisations so that optimal use is derived.

Fig 10.5. Recycling with plastic bottles

(vi) Recycle

Recycling is the process of converting discarded materials into new and useful products. For example, old aluminium cans and glass bottle are melted and recast into new cans and bottles; recycled steels are made into new automobile parts and construction materials; organic waste, such as food waste, manure, leaves, grass trimmings, wood, crop residue, etc., can be converted into valuable organic fertiliser through composting.

(vii) Recover

Recover refers to the conversion of waste into resources, such as electricity, heat, compost and fuel through thermal and biological means. For example, the energy released from burning the rubbish in incinerators can be used to generate heat and electricity.

b. Disposal of waste

The disposal of waste material by burial called landfill is one of the least preferred methods in the solid waste management commonly practised in most of the countries. Landfills are convenient and relatively cheaper waste disposal options in most places. However, the increasing land scarcity, prices, demand for more landfill constructions and maintenance requirements are making this method expensive. Inspite of this, the landfill is still the preferred choice in the developing countries including Bhutan.

Based on the practice of dumping garbage, landfill can be of two types: open landfills and sanitary landfills.

(i) Open landfill

In an open landfill, household garbage, damaged appliances, old barrels, used tyres, etc. are simply piled on available land. If allowed to remain, open dumps often grow larger, and may attract dumping of both solid and hazardous wastes.

(ii) Sanitary landfill

The term sanitary landfill refers to the compacting of solid waste materials. It is a technique which uses the smallest area possible to deposit the waste, covering daily with layers of soil, and compacting it to reduce its volume. Sanitary landfill does not threaten public health as it contains the waste and prevents leaching out of potentially hazardous substances. Problems related to liquids and gases generated by the degradation of organic material are also addressed in the landfill.

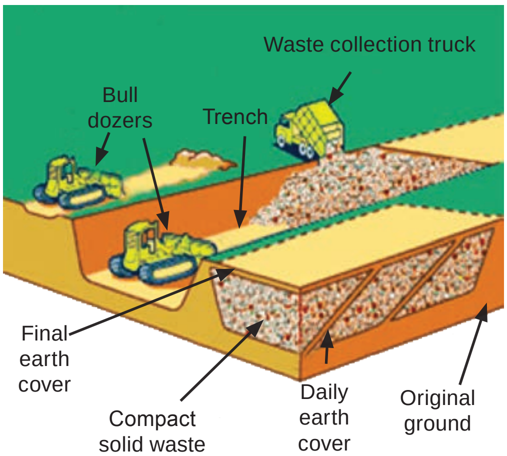
The construction and the sequence of operation in a sanitary landfill are mainly based on the topography of the land. They also depend on the source of the

Reprint 2022

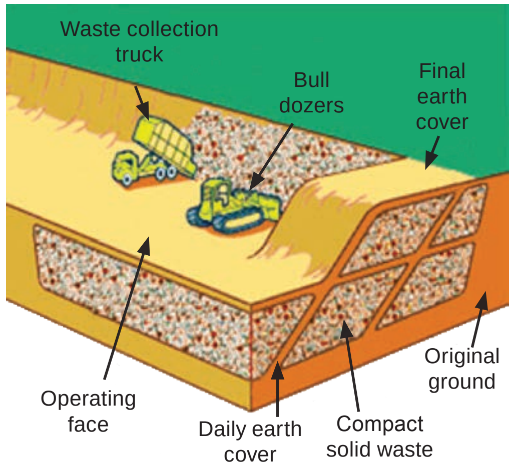
covering material and the depth of the water table. There are two different ways to construct a sanitary landfill: the trench method and the area method.

The trench method

The trench method is used in flat regions and consists of periodically digging trenches of two or three meters depth as shown in Figure 10.9(a). The width of the trench should be at least twice the size of the tractor to work. The bottom of the trench should be slightly sloped with canals built in the perimeter to collect and divert water, and to provide internal drainage. After excavation is done, the soil taken out is stockpiled for later use as covering material for a subsequent trench. Wastes are placed in the trench, spread evenly, compacted and then covered with soil. The trench method works well in areas where there are relatively little waste and low groundwater. Lands with a high water table or one very close to the surface are not suitable because groundwater would be contaminated. Rocky soil is not adequate since excavation is very difficult.



(a) Trench method



(b) Area method

Figure 10.6. Two methods of sanitary landfill

The area method

The area landfill method can be practised in flat areas where pits or trenches cannot be dug. It involves the construction of successive cells of waste that are compacted against a slope as shown in Figure 10.9(b). The cell is a completely compacted solid waste unit. The disposal pit may either be naturally occurring or excavated for the purpose of landfilling. In this method, wastes are deposited evenly and compacted forming terraces. Successive layers are built up until a depth of 9 to 12 feet is achieved. At the end of each day the waste is covered with a layer of soil. The area method is usually used to dispose of large amounts of solid waste.

Advantages and disadvantages of sanitary landfills

Advantages	Disadvantages
• Low cost of operation and maintenance. • Complete and final method, receiving all types of municipal solid wastes. • Methane gas emitted can be used as an alternative source of energy. • A sanitary landfill can begin operation within a short time. • It is flexible since it requires no permanent or fixed installations.	• The landfill may become an open dump if municipal administrators are reluctant to invest in operation and maintenance. • Contamination of nearby environment and groundwater may occur if proper precautions are not taken. • Acquisition of land is a challenge. • Construction must constantly be supervised to maintain a high level of quality.

c. Sewage Treatment

Sewage can be household waste liquids from toilets, baths, showers, kitchen and sinks. It also includes waste from industries. The process of removing contaminants of wastewater from household sewage is called sewage treatment. It is also termed as wastewater treatment which can be applied to industrial wastewater. The treatment process includes physical, chemical and biological processes.

This treatment of wastewater can be divided into three levels:

(i) Primary treatment

Primary treatment is designed to remove gross, suspended and floating solids from the raw sewage. This treatment includes screening of large solid objects and sedimentation by gravity to remove the suspended solids. A well-designed sedimentation tank reduces the biological oxygen demand (BOD) of the incoming wastewater by 20-30% in the form of settleable solids, which is about 50 to 60%.

(ii) Secondary treatment

Secondary treatment removes the dissolved organic matter that escapes primary treatment. The effluent is brought in contact with aerobic microorganism that consumes the organic matter as food and converts it into harmless substances, such as carbon dioxide, water and energy for their growth and reproduction. It is followed by additional settling tanks to remove the suspended solids. About 85% of the suspended solids and BOD can be removed with such treatment.

Reprint 2022

(iii) Tertiary treatment

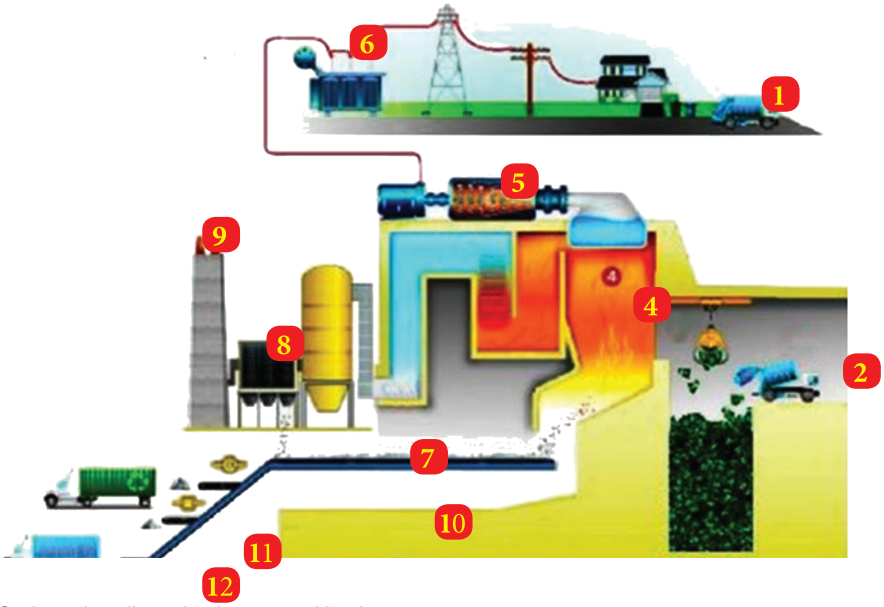
It is an additional treatment beyond secondary treatment where nitrogen and phosphorous from the effluent of secondary treatment is removed. The tertiary or advance wastewater treatment can remove more than 99 percent of the impurities to produce an effluent of almost drinking water quality. The final step of treatment is to disinfect water with chlorine but there are concerns for toxicity of chlorine residuals in the effluent. Thus, treated water is used for watering plants or flushing toilets.

Advantages and disadvantages of sewage treatment

Advantages	Disadvantages
• Removes 97% of suspended solids present in sewage. • Biological nitrification takes place successfully. • Phosphorus gets removed biologically. • Solids and liquids are separated. • Removes organic matters. • Self-sustaining system	• Cleaning is troublesome. • Minimum of three tanks required. • Temperature changes affect aerobic microbes in the tank.

d. Incineration

With increase in garbage and lack of available landfills, many cities have built waste incinerators to burn the wastes. Incineration is the act of burning waste completely, reducing the waste to ashes. The heat produced in the waste-to-energy plant is used for generating electricity; the toxic smoke produced is purified; the ashes are collected from which metals are extracted; and the leftovers are reused or disposed off in the landfills. The entire process is shown diagrammatically in Figure 10.10. The dangerous emissions are prevented or reduced by removing batteries containing heavy metals, and plastic containing chlorine before wastes are burned. Therefore, if incinerators are run properly, they are safe for the general public.



5. Garbage is collected at homes and businesses.
6. Waste is delivered to the site's storage bunker.
7. Waste is fed into a combustion chamber and burned at high temperature.
8. Heat boils water in the surrounding pipes to make steam.
9. Steam turns a turbine generator to produce electricity.
10. Electricity is used for heating plant or sent to grid.
11. Gases are fed through air pollution control equipment that cools, collects and cleans gases.
12. Gas is moved through a fabric filter to collect particulates.
13. Emission are monitored from a control area to ensure compliance.
14. Ash is collected.
15. Metals are extracted for recycling.
16. Leftover ash is reused or disposed of in landfill.

Figure 10.7. Working of a waste-to-energy plant

C. Waste management in Bhutan

Bhutan has a comprehensive waste minimisation and management regulation in place. The regulation engages various agencies and monitoring authorities in enforcing the regulatory activities. The National Environment Commission (NEC) is the apex monitoring body under this regulation. The Royal Bhutan Police, Dzongdag, Dungpa, Gup, Mangmi, Forest Officer, Park Managers and Institutional Head, Department of Roads and sanitary committee assist in achieving the full compliance. The regulation imposes fines and administrative actions on individuals or organisation.

The comprehensive regulation classifies wastes into four categories: medical waste, municipal waste, industrial waste and e-waste. The waste materials are managed to prevent their adverse effects on human health and environment and to reclaim resources from the wastes. However, waste management is challenged

Reprint 2022

by the growing urbanisation and industrialisation trends, and population increase with the consequence of increasing waste generation, especially in large cities and settlements.

Activity 10.3. *Surveying of wastes disposal scenario in the locality*

Instruction:

1. Work in small groups to conduct a survey on the waste disposal scenario in the nearby village or in the school campus.
2. During the field visit, use the following guiding questions to gather information:
   a. What are the waste produced by the community? Categorised them into degradable and non-degradable.
   b. How are the wastes managed by the community?
   b. Who is coordinating the waste management in the community?
   c. Where do the community dispose of their wastes?
   d. What do people think about the importance and practices of waste management in the community?
   e. Are there incidents of how the pollution in the community impacted the health of people and the environment in the past?
3. Scenes can be recorded with camera or mobile phone.
4. Write a report of maximum words of 500 and present it to the class. The report should be supported with adequate evidence.

Questions:

1. Give your opinion on the waste management practices in the community.
2. What changes do you wish to make to improve the waste management practices in the community?
3. How do you relate the waste generation in the community to lifestyle of the people?

Questions:

1. What are the advantages and disadvantages of an open landfill?
2. Sewage effluent is often chlorinated after secondary level of treatment. Why do you think it needs to be chlorinated?
3. What habits of goods consumption should people practise towards minimising the waste generation?

4. Entrepreneurship and Waste Management

Learning Objectives

On completion of this topic, you should be able to:

- define entrepreneurship.
- categorise the waste for recycling and reusing.
- explain the health impacts of e-waste.

The efficient and effective management of solid waste is essential in maintaining the health and hygiene of people and the environment. Generally, inappropriate treatment of waste causes major environmental degradation, while recycling contributes significantly to environmental sustainability. For instance, many entrepreneurs around the world have built substantial businesses from the waste. Some of these entrepreneurs have strikingly modern views of environmental challenges, and their scientific and engineering knowledge have benefited the management of waste across the globe

A. Entrepreneurship through waste

The process of designing a new business offering a product, process or service is called entrepreneurship. Successful entrepreneurs develop variety of skills like business, know-how, innovation, creativity and use of efficient technologies. Such entrepreneurs can provide business to people to earn profit, even from the household wastes. They also devote in making a profitable business of municipal solid waste, collecting difficult-to-recycle packaging products and re-purposethe materials into affordable and innovative products. This provides essential services of maintaining the quality of life in urban areas and ensures better standards of health and sanitation.

The solid waste can be broadly classified into three categories: organic degradable waste, such as fruits, vegetables, food and garden wastes; inorganic recyclable waste like paper, cardboard, plastic, glass and metals; and hazardous waste including medical, sanitary, electronic, solvents and chemicals. The constituents of each category are handled or disposed of through multiple technologies or processes.

In the waste-based entrepreneurship, general process includes collection, segregation of waste at source, and proper treatment for better chance of recovering valuable materials from the waste stream, and ensuring the health safety of workers. The following are types of recyclable waste:

Reprint 2022

1. Paper: newsprint, ledger paper, computer paper, corrugated cardboard and mixed paper.
2. Metals: cans, parts from abandoned vehicles, plumbing, fences, metal doors and screens, tools, machinery and other discarded metal objects.
3. Glass: glass containers and window glass.
4. Textiles: non-reusable clothing, upholstery and pieces of fabric.
5. Plastics: including beverage containers, plastic packaging, plastic cases of consumer goods such as telephones or electronic equipment, films and tyres.
6. Plant debris: leaves and cuttings, trimmings from trees, shrubs, grass, whole plants and sawdust.
7. Putrescible: including animal, fruit, and vegetable debris, cooked food, manures, offal and sewage sludge.
8. Wood: unusable lumber, tree rounds and pallets.
9. Ceramics: rock, tile, china, brick, concrete, plaster and asphalt.
10. Soils: excavated soils from barren or developed land and excess soils from people's yards.
11. Chemicals: acids, bases, solvents, fuels, lubricating oils and medicines.

B. Safety and health issue on reuse and recycle of waste

In many countries, waste pickers depend on sorting and recycling of waste materials for their livelihood. They are prone to occupational health risks due to prolonged contact with toxic materials, chemical residues, pathogenic organisms in medical wastes and batteries containing heaving metals. Exhaust fumes of waste, dust from disposal operations and open burning of waste also contribute to occupational health problems to workers and nearby communities.

Most occupational health and injury problems for waste pickers can be minimised by adopting simple safety procedures, which may include:

- use of protective gear, particularly gloves and face masks.
- daily covering and proper control of contaminated leachate of disposal site.
- rearranging the disposal layout, implementing modest sorting facilities and allowing only registered adults.
- provision of water supply for washing, sanitation and treatment.
- awareness on hygiene education for waste pickers.

The risk is greatest in developing countries where the physical contact between the waste pickers and waste is the greatest and the level of protection is the least. To complicate the exposure, their personal hygiene is often inadequate, and washing and sanitation facilities are poor at the work site. This is due to lack of education on personal and occupational health and safety practices.

Activity 10.4. *Understanding entrepreneurship of waste*

Instruction:

Read the text and answer the questions that follow:

YBI Environmental Entrepreneur of the Year 2013- *Karma Yoenten(Greener Way)*

Karma Yonten is Bhutan's first citizen to turn waste management and recycling into a business. His pioneering enterprise, Greener Way, is tackling the country's growing waste problem head-on: it collects, separates and correctly disposes of domestic waste material; manages 1,140 tonnes of recyclable matter. Karma, who was always determined to be self employed was becoming increasingly concerned about mismanaged waste and related issues such as unsightly landfills, leaching toxins and dangerous side-effects on people's health. The \$8,100 loan and mentoring assistance given to Karma by Bhutan's YBI member, Loden Entrepreneurship Programme (LEP), provided the means and much-needed guidance for Greener Way to develop and expand. Today the business employs 31 people directly, and provides an income for more than 150 'rag pickers'.

Contributing towards Bhutan's Gross National Happiness

Karma's decision to pursue a business in waste management was initially controversial. The son of a regional custom officer was expected to have a more conventional career with his Bachelor of Commerce degree. "To quit my job and take up the waste business, which is considered very low profile in Bhutan, was never welcomed," says Karma. "But I had a business dream and I was not going to let it go." Karma saw opportunity in Bhutan's neglected, mismanaged and maligned waste management sector. Karma took the initiative, researched waste management and devised a business plan before approaching LEP for assistance in 2010. The 30-year old Karma is well on his way to achieving his business goals, namely of creating gainful green jobs, safeguarding his local environment and contributing towards Bhutan's economic growth.

Reprint 2022

Building Links and Strengthening the Community

Per annum, Greener Way manages 540 tonnes of paper, 240 tonnes of PET (plastic) bottles and 360 tonnes of other plastic waste. Currently, Bhutan's recyclable waste is exported to India but there is a goal to establish a recycling unit in the country. In strong partnerships with schools, monasteries, health organisations and community groups, among others, programmes have been developed to raise awareness about the environment. Meanwhile, the business has made provisions for organic waste to be treated in a local composting plant. The end-product is safe, high quality compost which can be used by businesses, farmers and individuals.

Karma, considered an "exemplary entrepreneur and model young leader", has been invited to guest lecture at several tertiary institutions at a national and international level, including Columbia University's Barnard College. He has also participated in high-level meetings and was part of the Bhutanese delegation with the country's Prime Minister.

Greener Way has set up a fund to help educate several poor and disadvantaged children from the area. The business regularly conducts waste awareness workshops for all the sweepers of Thimphu, and it also regularly provides internships, enabling young people to receive invaluable work experience. Karma is adamant that money is not the main motivation. Instead, employment, education, awareness and waste reduction have been the primary forces behind Greener Way, which is making extraordinary strides embedding environmental awareness and preservation in Bhutan and abroad.

Adapted from: https://www.youthbusiness.org/wp-content/uploads/2013/08/Karma-Yonten.pdf

Questions:

1. List the objectives of Greener Way.
2. Karma said, "To quit my job and take up the waste business, which is considered very low profile in Bhutan, was never welcomed." What kind of challenges must have he faced?
3. What are the economical and environmental contributions of the Greener Way to the society?
4. Recycling of solid waste not only cleans our environment but also generates income. Nevertheless, most people are reluctant to collect and recycle waste. Why?
5. Based on the types of waste generated in your community, make a brief project proposal of waste-based entrepreneurship that you think would be lucrative.

C. E-waste

E-waste means discarded electronic equipment. E-waste can be broadly categorised into three categories:

a) ***Large household appliances*** - this includes electronics like refrigerators, freezers, microwaves, electric heating appliances, electric radiators, conditioning equipment etc.

b) ***Information and communications technology equipment*** – this include electronics like computers, laptops, computer accessories, printers, copying equipment, etc.

c) ***Consumer electronics*** – this include toasters, coffee machines, clocks, watches, hair dryer, shavers etc.

Figure 10.8. E-waste

Every year, large number of computer and electronic devices become obsolete or damaged and are thrown away, making e-waste one of the fastest growing municipal solid wastes. Most electronic devices contain lead, cadmium, mercury and other toxic materials which, if not taken care, contaminates the environment. Therefore, in order to avoid serious impacts on human health and the environment, it is crucial to ensure that e-waste is properly taken care of all the way from collection and handling through recycling and disposal.

Safety and health implication of e-waste

E-waste contains variety of toxic or hazardous components which are released during its processing, recycling or disposal. Heavy metals, such as lead, cadmium and mercury, and persistent organic compounds like brominated flame retardants (BRF) and phthalates are commonly found in e-waste. They pose severe risk to human health and environment. The effects of these chemical components on human health are given in Table 10.5.

Table 10.7. Chemical components and health effects

Chemical hazards found in E-Waste:		
E-waste component	**Potential hazards**	**Potential health effects from long term exposure**
Cathode ray tube (CRT) glass, batteries, solder, older printed circuit boards	Lead dust	Anemia, kidney damage, high blood pressure, nerve and brain damage, miscarriage, birth defects
Batteries, switches, thermostats, fluorescent tubes	Mercury vapor	Nerve and brain damage, birth defects
Nickel-cadmium batteries, printed circuit boards, phosphor coating on CRT glass	Cadmium dust	Kidney disease, bone problems, lung cancer
Older printed circuit boards	Beryllium dust	Lung disease, probably lung cancer
Plastic cases and parts	Flame retardant dust	Possible thyroid hormone problem

To avoid serious environmental pollution and human exposure, adequate treatment of e-waste is crucial, particularly considering the huge amounts of e-waste being produced globally.

Activity 10.5. *Studying the effects of e-wastes*

Instruction:

Read the text and answer the questions that follow:

Everyone wants the latest electronic device, but what happens when you're done with it? -*By Laura Bradley*

WASHINGTON – A rising mountain of hazardous electronic waste is putting workers in developing countries and the environment at risk. Some of the disused computers, cellphones, televisions and other products are locally generated, but the developed world – especially the U.S. – is responsible for sending many of the items.

The developed world has in the past exported an estimated 23 percent of its electronic waste to seven developing countries, according to a study published in June by the journal Environmental Science and Technology. The growing demand for electronics, and the increasingly short life spans of these devices, means e-waste isn't going anywhere. But the problem is complex, and solutions will not come quickly – or easily.

The average American household owns more than 20 electronic products, according to the U.S. Environmental Protection Agency. Several states have banned disposing of such products in the same way as conventional trash, and the EPA strongly encourages recycling. But when a person recycles a television, for instance, there's a chance it could end up exported to a country like China, India or

Nigeria, where workers at informal recycling operations often use crude, hazardous techniques to extract valuable metals from the equipment and then burn what's left.

Recycling electronics, it's been argued, could help developing nations transcend the "digital divide," as well as grow information and communications technologies in places that need to catch up. Even if devices don't work, some say recycling could provide spare parts and valuable metals like copper. But the processes to get those valuable materials often entail exposure to heavy metals like lead and mercury.

The EPA, one of the lead agencies on the Interagency Task Force on Electronics Stewardship established by the Obama administration, recognizes the potential benefits of e-recycling and encourages the practice over allowing electronic junk to pile up in landfills. But the agency also has "serious concerns about unsafe handling of used electronics, especially discarded electronics or e-waste, both domestically and overseas, that results in harm to human health and the environment," EPA spokeswoman Liz Purchia said in an email.

E-waste is exported largely for the same reason manufacturing jobs have been sent overseas: lower labor costs and fewer regulatory burdens. Handling e-recycling domestically could ensure safer procedures for the environment and workers but would come at a price, as it often costs more to process these devices than the materials are worth.

Adapted from https://www.usnews.com/news/articles/2014/08/01/e-waste-in-developing-countries-endangers-environment-locals

Questions:

1. Identify the issues of e-waste in the excerpt.
2. What do you understand by e-waste transport?
3. Why should Bhutan be concerned about e-waste?

Questions

1. Explain waste entrepreneurship.
2. Landfilling and inceneration is commonly practiced in Bhutan. Suggest an alternative method of waste disposal applicable in Bhutan.

Reprint 2022

Exercise

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

   i. If you are asked to test the water quality of a village where people are mostly suffering from diarrhoea and dysentery due to possible contamination of water, then you will check

      A. source of water.

      B. physical contents of water.

      C. chemical contents of water.

      D. biological contents of water.

   ii. Which of the following determines the total salinity in water?

      A. pH

      B. Electricity conductivity.

      C. Turbidity

      D. COD.

   iii. Generally, most of the macronutrients in the soil are readily available at pH values between

      A. 4.5 - 5.5

      B. 5.5 - 6.5

      C. 6.5 - 7.5

      D. 7.5 - 8.5

   iv. The use of aluminium and plastics decreased drastically over last two decades. This due to

      A. reusing the waste.

      B. refusing the waste.

      C. reducing the waste.

      D. recycling the waste.

v. Identify the statement which does not conform to the use of incinerators.

A. The incinerators are relatively cheap to build.
B. The incinerators can be built to generate electricity.
C. There are drastic reductions in the volume and weight of wastes.
D. The ash can contain heavy metals and other toxic substances.

2. ***Fill in the blanks with the correct form of word(s).***

i. As the amount of organic matter in water increases, the chemical oxygen demand__________ .

ii. The electrical conductivity of water depends on the concentration of ions present in water. This ion concentration in water is due to__________.

iii. A technophobe does not want to spend on a new iPhone rather repair the old one and use it. Based on 7Rs model it involves,.............................., repair and reuse.

iv. Waste items, such as batteries and fluorescent tubes are disposed of irresponsibly in water bodies. Such wastes contain ....that may be fatal to organisms.

v. Figure 10.12a symbolises reuse of water and 10.12b symbolises .... of water.

(a) (b)

Figure 10.12

3. ***Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.***

Column A	Column B
1. Most effective component of the waste hierarchy	a. Reuse
2. Refilling a purchased bottle of water with water from home to minimize the number of plastic bottles being discarded	b. Open landfill
3. The waste includes glass, newspaper, aluminum, cardboard	c. Recycle
4. Consists of periodically digging trenches	d. Rethink
5. Construction of successive cells	e. Area sanitary landfill
	f. Disposal

4. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.***

    i. The high value of chemical oxygen demand indicates that water is clean and consumable.

    ii. High value of electrical conductivity lowers the microbial activity in the soil.

    iii. Conservation of water is indispensable for the Bhutanese economy.

    iv. Natural calamities are the main causes of destruction of watersheds.

    v. The e-waste may be detrimental to human health but may have insignificant impact on the environment.

5. ***Answer the following questions.***

    i. What do you understand by waste management?

    ii. Which component of 7 Rs is the most difficult to practice. Why?

    iii. What are the safety measures you would take while participating in cleaning campaign?

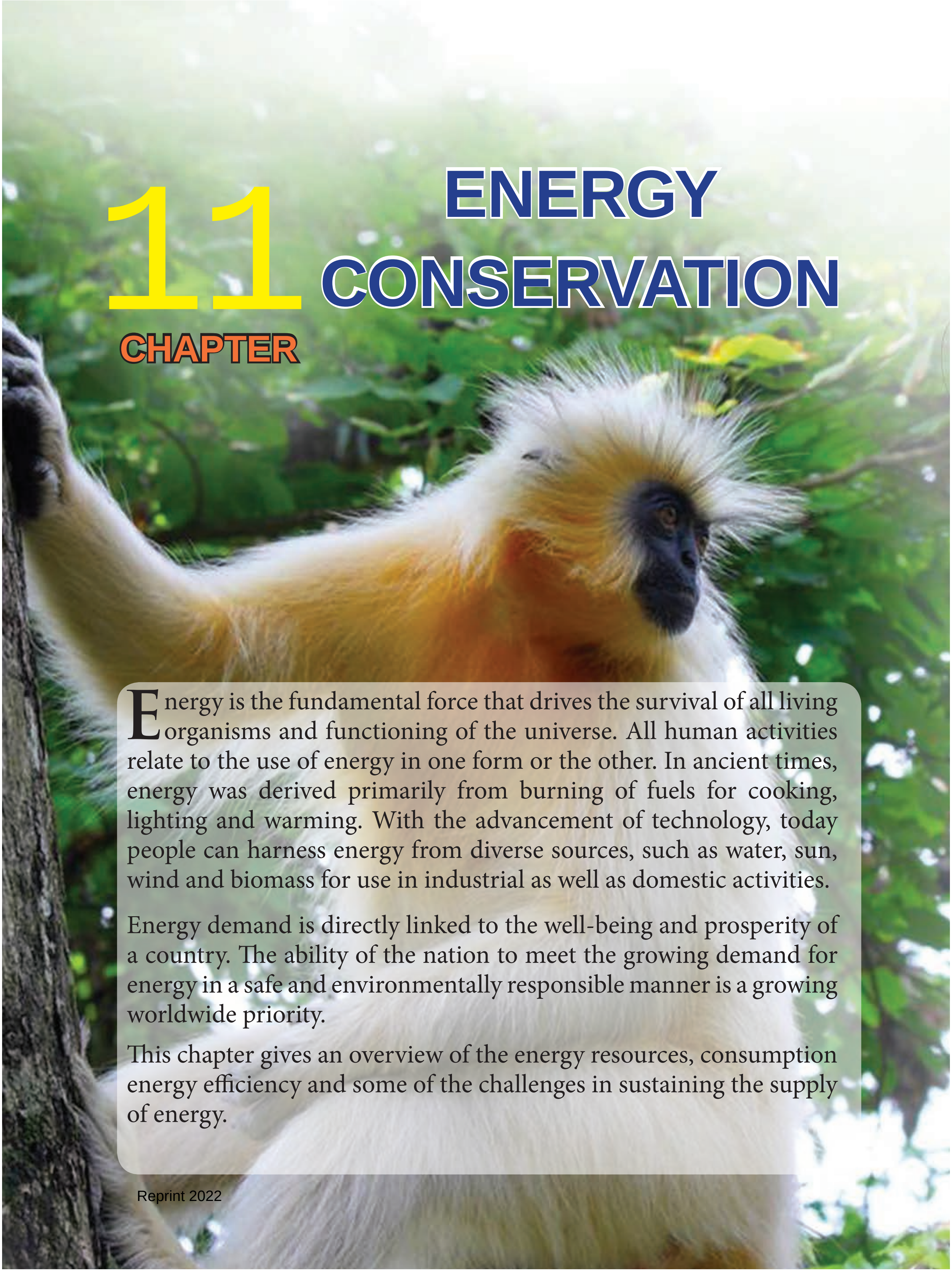
    iv. What are the challenges of sanitary landfill in the developing countries?

    v. Segregation of waste at source and recycling of waste are preferred methods as it offers a chance of recovering valuable materials from the waste stream. How can Bhutan adopt these method to minimise waste production?

    vi. Which one of the 7Rs do you practise the most? Explain.

    vii. Describe the problems associated with incineration as a method of waste disposal.

    viii. How is composting an efficient method of solid waste disposal?



CHAPTER 11

ENERGY CONSERVATION

Energy is the fundamental force that drives the survival of all living organisms and functioning of the universe. All human activities relate to the use of energy in one form or the other. In ancient times, energy was derived primarily from burning of fuels for cooking, lighting and warming. With the advancement of technology, today people can harness energy from diverse sources, such as water, sun, wind and biomass for use in industrial as well as domestic activities.

Energy demand is directly linked to the well-being and prosperity of a country. The ability of the nation to meet the growing demand for energy in a safe and environmentally responsible manner is a growing worldwide priority.

This chapter gives an overview of the energy resources, consumption energy efficiency and some of the challenges in sustaining the supply of energy.

Reprint 2022

1. Energy Sources, Production and Uses

Learning Objectives

On completion of this topic, you should be able to:

- identify different sources of energy.
- explain the trends of global energy production and consumption.
- describe various ways of using energy.

The word "energy" has its origin in the Greek word, "energia", which means activity or operation. In physics, energy is defined as the capacity to do work. Energy is necessary for all the living organisms for their metabolic activities; for humans, it is vital in driving the developmental machineries like industries, power generation, transportation, operation of social services, etc.

Energy exists in different forms which include electrical, thermal, nuclear, gravitational, etc. The energy can transform its forms but can neither be created nor be destroyed. In other words, energy is conserved in systems where the Earth acts as the storehouse.

A. Sources of energy

Solar energy, wind energy, geothermal energy, nuclear energy, tidal energy, etc., are various kinds of energy derived from sun, water, wind, fossil fuels, radioactive elements, tides, etc. All these energy sources can be broadly classified into primary and secondary energy sources.

Primary energy sources

These are energy extracted or harnessed directly from the environment, such as fossil fuels, biomass, solar energy, wind energy, tidal energy and geothermal energy. Primary energy sources can be further divided into renewable and non-renewable energy sources.

a) Renewable sources are those that can naturally replenish at a rate faster than consumption and therefore do not get exhausted over a short period of time. Renewable energy sources include solar energy, wind energy, tidal energy and geothermal energy.

b) Non-renewable sources are those that take longer time to replenish naturally upon consumption and therefore can get exhausted within a short period of time. Fossil fuels and nuclear energy are examples of non renewable sources. Fossil fuel like coal and petroleum takes millions of years to form, therefore it will be exhausted over time.

Reprint 2022

Secondary energy sources

Energy sources, such as electricity, diesel, kerosene, wax, gasoline, ethanol, methanol, biodiesel and hydrogen produced by transformation of primary energy sources are classified as secondary energy sources. For example, electricity is secondary energy source produced by transformation of various primary energy source like solar energy, geothermal energy, burning of fossil fuels or nuclear energy.

Figure 11.1 demonstrates different sources of energy. Some of the sources of energy that are gaining significant attention are discussed below:

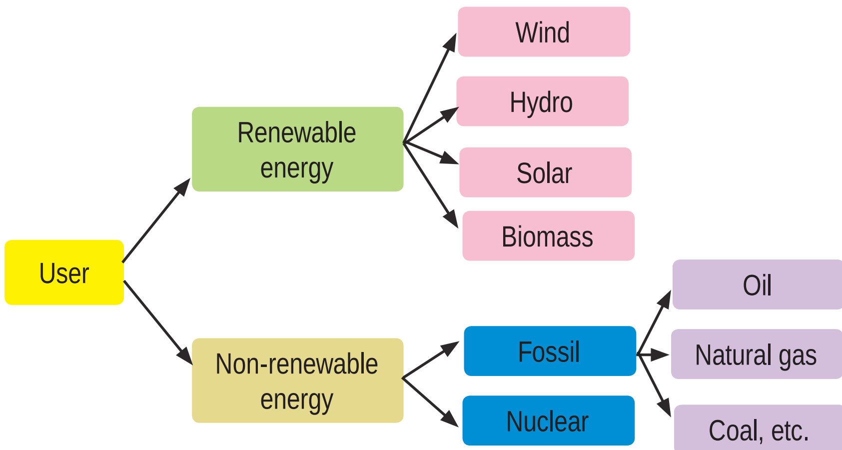


Fig 11.1. Different sources of energy

a. *Solar energy*

The Sun is the most important source of renewable energy and is available everywhere. The energy provided by Sun is called the solar energy. Solar radiation is converted into other forms of energies by using technology and devices like solar photovoltaics and solar thermal systems.

(i) Solar photovoltaic

Photovoltaic systems trap the solar radiation and convert it into electricity in a number of ways. The most common way is by using silicon panels, which generate electric current when solar radiations falls on them.

(ii) Solar Thermal Systems

The solar thermal system traps solar radiation and converts it into heat energy. This thermal energy can be used for heating water, warming rooms and also for powering solar cooling system.

The advantage of solar thermal energy is, it is a clean renewable form of energy. However, it can be installed only in places where there is high amount of solar radiation but the cost of installation is very high.

b. Biomass energy

The biomass is any organic matter which can be burnt or decomposed as a fuel to release energy. Biomass energy can be obtained from different sources, such as wood, paper, plant residues and animal waste. Nowadays, in most places in Bhutan, people have started using biogas as fuel for cooking and lighting.

Biogas which is primarily composed of methane is produced using simple principle of anaerobic fermentation. A large amount of organic waste is collected in an anaerobic methane digester at high temperature with limited oxygen supply. The bacteria breakdown organic matter anaerobically and release methane. The production of biogas is shown in Figure 11.2.

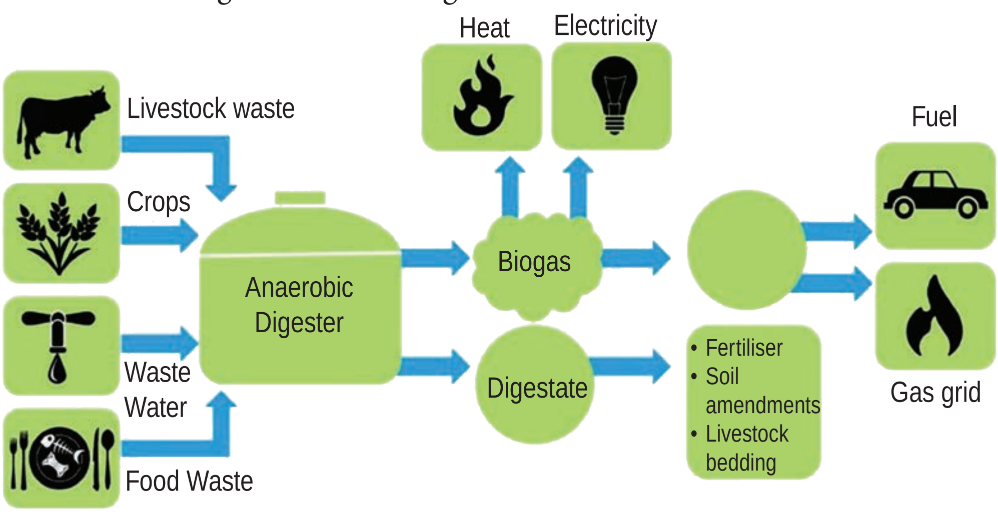


Figure 11.2. Production of biogas

There are many advantages and disadvantages of biomass energy. Can you think of a few of them and discuss in the class?

c. Geothermal Energy

The term geothermal comes from the Greek words 'geo' (Earth) and 'therme' (heat). Geothermal energy is heat from within the Earth. Huge amount of heat energy is produced continuously beneath the Earth's crust by the slow decay of radioactive particles. Rocks and water present in the crust absorb the heat and become very hot. The heat trapped in steam or hot water is used to heat buildings or to generate electricity.

Reprint 2022

Geothermal energy is a renewable form of energy because the heat is continuously produced inside the Earth and is sustainable. It is also clean and environmentally friendly. Some of the advantages and disadvantages are listed in the Table 11.1.

Table 11.1. Advantages and disadvantages of geothermal energy

Sl no.	Advantages	Disadvantages
i.	It does not produce pollutants.	Geothermal sites have the chances of running out of steam over a period of time due to drop in temperature or if too much water is injected to cool the rocks.
ii.	Geothermal energy involves low running costs since no fuels and no fuel is used to generate the power.	High establishment cost.

Apart from using renewable resources, people also use non-renewable resources of energy, some of which are explained below:

d. Nuclear energy

Nuclear energy is the energy in the nucleus of an atom. There is a huge amount of energy present in the bonds that hold the atoms together. This energy present in the bonds is released by two processes: nuclear fission and nuclear fusion. In nuclear fission, atoms split apart, releasing energy whereas in the nuclear fusion, energy is released when atoms combine together. This huge amount of energy released is used mostly to produce electricity. The advantages and disadvantages of nuclear energy are discussed in Table 11.2.

Table 11.2. Advantages and disadvantages of nuclear energy

Sl No.	Advantages	Disadvantages
i.	The production of nuclear energy does not emit toxic gases.	The cost of building the nuclear reactors and cost of maintenance of nuclear plants is high.
ii.	Even a small amount of radioactive substances can generate a huge amount of electricity.	There is the risk of using the nuclear energy for military purposes.
iii.	Produces a small amount of waste.	When atoms split to release energy, the smaller atoms that are left behind are often left in excited states, emitting energetic particles that can cause biological damage.
iv.	The generation of electricity through nuclear energy reduces the use of fossil fuels (coal and oil).	Nuclear fission chambers are cooled by water. This water is then turned into steam, which is used to power the turbines. When cooled liquid form of water is discharged into the nearby wetlands, the immense heat given off by this water can also damage the ecosystems located nearby.

e. *Fossil fuels*

Fossil fuels are formed by slow anaerobic decomposition of dead organisms under high temperature and pressure over millions of years. Fossil fuels, such as coal, oil and natural gas contain high percentage of carbon. Formation of fossil fuel involves three main steps:

i. accumulation of organic matter,
ii. preservation of organic matter to prevent from oxidation and
iii. conversion of organic matter into fossil fuels.

The advantages and disadvantages of fossil fuels are listed in Table 11.3.

Table 11.3. Advantages and disadvantages of fossil fuels

Sl No	Advantages	Disadvantages
1	A large amount of electricity can be produced using coal.	Burning of fossil fuels leads to pollution and it contributes to global warming.
2	It can be easily transported.	Due to the production of sulphur dioxide, it also leads to acid rain.
3	It is relatively cheap.	Mining coal can be difficult.

B. Energy scenario in Bhutan

The living standard of a country can be directly related to the per capita energy consumption. The per capita energy consumption is the amount of energy consumed by each individual in a region. Bhutan's per capita energy consumption is relatively high compared to other neighbouring countries because its forest resources provide an abundant and readily available source of energy. Fuel wood accounts for majority of the total energy consumption, virtually all of the non-commercial energy consumption in rural areas. Per capita consumption of fuel wood is estimated to be one of the highest in the world and is used mainly for cooking and heating.

Hydro-power is one of the main sources of energy and revenue in Bhutan. Since Bhutan has no known fossil energy reserves, such as oil and natural gas, all petroleum products such as kerosene, diesel oil, petrol, and liquefied propane gas are imported for lighting, transportation, cooking and heating.

Reprint 2022

Activity 11.1. *Exploring alternative source of energy*

Instruction:

Read the text given below and answer the questions that follow:

Hydro-power

Since the 1980s Bhutan has focused on energy generation through hydro-power, in partnership with India. Today the country exports 1,380 MW out of the 1,840 MW it generates to India. Nevertheless, due to the impact of hydro-power on environment and on flow of water in the rivers the government of Bhutan has started to lay emphasis on various ways to generate power. The Government is now exploring other forms of renewable energy like building of windmills, biogas plants, and solar power plants.

Shifting to wind and other renewable energy sources

After the successful implementation of hydro-power projects, the use of wind power is a way towards the use of renewable energy in Bhutan. The country has a vast potential of harnessing energy from the wind. The initial plan of the government was to install at least 24 wind turbines but amid public complaints about possible noise pollution, the government decided to scale down the first pilot project down to 2.

Recently government launched wind turbines in Rubesa gewog in Wangdue Phodrang. The turbines are estimated to produce 600 KW of energy, which would be sufficient to light 300 households.

Bhutan is exploring the possibility of building a 30 MW solar energy plant in Shingkhar in Bumthang. The government is also promoting other alternative

renewable energy sources such as biogas and solar plants. Though Bhutan has huge potential to generate energy from hydro-power during summer, it still imports electrical energy during winter. So,exploring other forms of clean and renewable energy like wind, biogas and solar would supplement the hydro-power shortages during the dry season. In the past few years, Bhutan's hydro-power exports have been falling, while energy imports have been increasing. According to the 2014 Druk Green Power Corporation (DGPC) report, in 2013, Bhutan exported 5,557 million units (MU) of energy worth about Nu 11 billion (USD 160 million) while it imported 108 MU worth around Nu 222 million (USD 3.26 million). In 2014, exports dropped to 5,044 MU and imports increased to 187 MU. The organisation said earlier this year that energy import had probably increased further this year. Bhutan's move to diversify its renewable energy sources had received huge support from global leaders, because Bhutan had remained committed to the use of renewable energy and would pursue a low carbon growth path.

Adapted from: http://www.thethirdpole.net/2016/02/16/bhutan-diversifies...

Questions:

1. Describe the types of potential renewable energy sources in Bhutan.
2. Why is water considered as the 'flowing gold' of Bhutan?
3. What are some of the disadvantages of hydro-power development in the country?
4. Differentiate between primary and secondary energy sources with examples.
5. Describe the pros and cons of wind turbines as alternative source of energy in Bhutan.

C. Renewable energy potentials in Bhutan

Bhutan is working on the development of strong renewable energy sources. Some of the renewable energy potentials in Bhutan are listed below:

(i) Hydro power

Water is the natural resource that is in great abundance in Bhutan. The mountainous topography and climatic conditions have endowed the country with huge hydropower potential. Hydropower potential in Bhutan is distributed according to different river basins among the districts as shown in the Figure 11.3. This distribution of river basins is due to geographic features and the landscape formation.

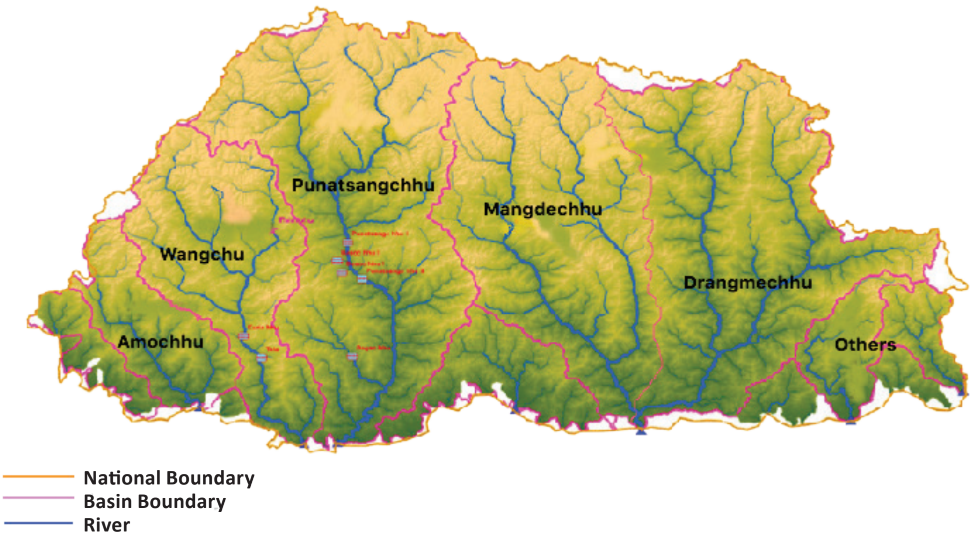


Figure 11.3. Distribution of hydropower potential across Bhutan

Since electricity generated from hydropower plants during summer is relatively higher than the domestic requirements, large amount of hydroelectricity is exported to India generating huge amount of revenue.

(ii) Solar energy

Generally, solar energy is available everywhere on the Earth, but there are differences in the amount and the duration of solar radiation of a location. Solar potentials are estimated based on the solar irradiance in specific region and the available area for harnessing solar energy.

Bhutan has high potential for solar power generation with 4 to 6 hours of sunlight per day.

(iii) Wind energy

The uneven heating of the Earth's surface by the Sun causes difference in air pressure in different regions. This results in the movement of air from an area of high pressure to the area of low air pressure as wind. The wind current is used as a mechanical energy to rotate turbine to generate electricity. Wind energy potential is area specific as it is determined by the wind speed which is influenced by topographical features, vegetation and infrastructures in and around the wind power system.

(iv) Biomass energy

The increasing price of the fossil fuels along with its negative impacts on the environment had driven many countries to shift towards low carbon, renewable sources of energy. One of the potential renewable energy sources which can reduce the dependency on fossil fuels for Bhutan is biomass energy. Bhutan has majority of it's land under forest cover which is a substantial source of biomass energy. Moreover, majority of the population in the rural areas depend on farming and backyard livestock rearing which generates large amount of cattle dung and crop residue as by-products from harvesting and processing of agricultural crops. These crop residues and cattle waste from agriculture can be processed to generate biogas and biofuels which can be used for cooking food and lighting houses.

Bhutan has come up with two projects namely Bhutan Biogas Project (BBP) and the Sustainable Rural Biomass Energy (SRBE) project to promote the use of biomass energy resources for cooking, heating and lighting in rural areas. Southern dzongkhags comprising Samtse, Sarpang, Tsirang, Samdrup Jongkhar and Chukha are rated with high potential for installation of biogas plants.

Activity 11.2. *Analyzing global energy consumption*

Instruction:

Divide the whole class into three groups. Each group must select one of the three topics. The groups should gather information on their topic based on the questions given under each topic and present to the class.

Hydropower potential

1. How many hydropower plants are there in our country?
2. How much electricity is generated currently from all the hydropower projects combined?
3. What are some of the negative impacts of hydropower plants on the environment?
4. How much electricity can we generate from all the hydropower plants combined by next decade?

Wind energy potential

1. What could be some of the possible reasons for not installing wind turbines in all the twenty Dzongkhags?
2. Why do you consider wind turbines more eco-friendly than hydro power?
3. Write one negative environmental impact of installing wind turbine.
4. Fill the table below for wind energy potential for all twenty Dzongkhags.

Sl no.	Dzongkhag	Average wind Speed at 50 m (m/s)	Wind power density at 50 m (W/m^2)
1			
2			

Solar energy potential

1. Mention two factors that will determine the amount of solar energy harnessed.
2. If all the rural households in our country have access to photovoltaic panels, how will it impact national revenue and environment?
3. Write one negative environmental impact of solar panels.
4. Fill the table below for solar energy potential for all twenty Dzongkhags.

Sl no	Dzongkhag	Productive Area (km^2)	Average Annual Solar Resource at Tilt = Latitude (kWh/m^2 per day)	Average Annual DC Photovoltaic Production (Million kWhDC/ year)	Average Annual AC Photovoltaic Production (Million kWhAC/ year)
1					
2					

Reprint 2022

D. Uses of energy

Every individual uses energy for various activities. As the population increases, the demand for energy also increases steadily. Energy is an important factor for a country's economy and development. All developmental activities and processes require some form of energy. Energy consumption can be better understood by dividing the users into residential and commercial, transportation and industrial sectors.

a. Residential and commercial

Energy is mainly used for heating, washing, cooking, operating office equipment, domestic appliances, etc. In Bhutan, residential sector is the largest energy consuming sector.

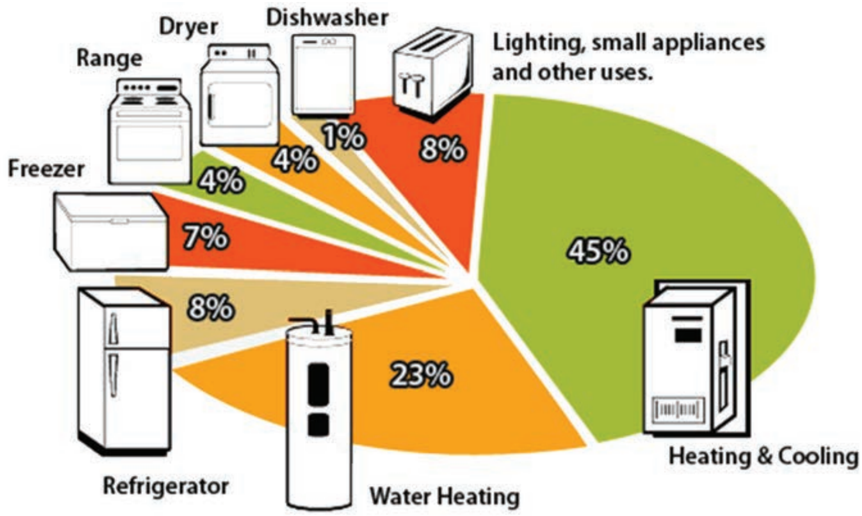


Figure 11.4. Energy use in the residents

b. Transportation sector

The transportation sector includes all modes of transportation. The energy used for transportation mostly comes from the burning of fossil fuel. In the years to come, the need for energy in the transport sector is expected to rise with the increasing demand for various forms of transport system. In order to protect the environment from green house effect and to save fuels, alternative forms of vehicles like the electric car and hybrid cars are continuously explored. In the transport sector, Bhutan has come up with some initiatives to reduce the use of energy by:

- making efficient use of public transport system.
- reducing the import of vehicles.
- introducing hybrid and electric cars.

c. Industrial sector

This sector includes agriculture, mining, manufacturing and construction industries. Industrial production of any product that people use or consume depends on energy. In Bhutan, industrial sector accounts for one-quarter of the total energy consumption. The sector-wise analysis of energy use today indicates that the industrial sector uses more energy than the other sectors.

E. Global energy production and consumption

Globally the rapid growth in population is one of the significant drivers of energy demand, along with social and economic development. The per capita energy consumption of people living in developed country is much higher than those living in the developing countries. This is due to use of inefficient technologies, increased number of vehicles and large number of industries.

Activity 11.3. ***Analysing global energy consumption***

Instruction:

Study Figure 11.5 and Figure 11.6 and answer the following questions

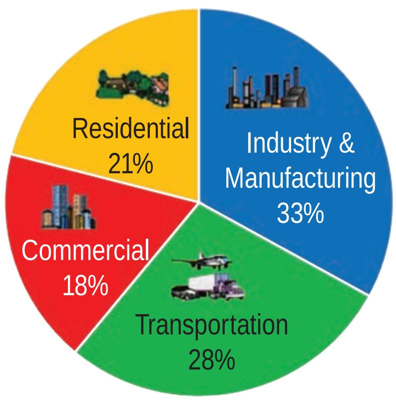


Figure 11.5. Global sector wise energy consumption

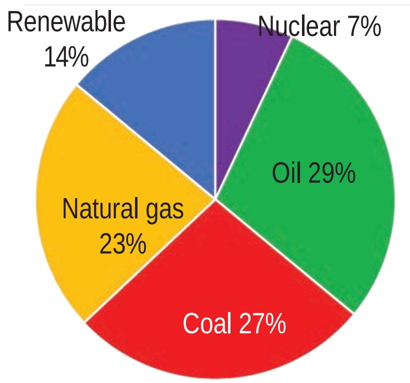


Figure 11.6. Global energy forecast

Questions

1. Which sector uses the maximum energy? Why?
2. Compare the sector-wise energy use of the world with the sector-wise energy use in Bhutan.
3. What can you predict about the change in Bhutan's energy consumption pattern? Justify your prediction.
4. Suggest a few ways to reduce the use of non-renewable resources.

Reprint 2022

Humans use various forms of energy every day to make their lives easier, productive, safer and healthier. The demand for energy is rising rapidly because of an exponential growth in the human population. The rapid increase in the energy consumption could lead to faster depletion of energy resources and will result in energy crisis if proper measures are not adopted. Many countries are exploring alternative sources of energy, using more of renewable sources of energy and shifting towards the use of lower- carbon fuels for energy security.

Questions

1. Bhutan has diversified its energy sources from hydro-power to other renewable energy sources. Support the statement with a relevant example.
2. Explain the global pattern of energy consumption.
3. List any two factors that determine the production of wind energy in an area.
4. Explain any two advantages and disadvantages of installing solar photovoltaic system in Bhutan.

2. Energy Management and Efficiency

Learning Objectives

On completion of this topic, you should be able to:

- explain energy efficiency.
- identify the ways to improve the energy efficiency at home.
- discuss steps of basic energy management system.

Energy security is essential for the economic growth of a country and the well being of its people. Rapid growth of population, inefficient use of energy, industrial development and the changing lifestyle of modern society are some of the major threats to non-renewable resources. Saving energy conserves resources and reduces expenses, and also saves the environment. Thus, there is a need for people to practice energy conservation and save the environment for future generations.

A. Energy efficiency

Energy efficiency is an effective means to provide services that reduces the wastage or minimise the overall consumption of energy. Energy efficiency uses advanced science and technology that provides same or better services with less energy consumption. Replacing an incandescent light bulb with light emitting diode (LED) bulb or light emitting plasma (LEP) is an example energy efficient practice. Investment in energy efficient practices can preserve the resources and reduce the negative impacts on the environment.

Table 11.4. Ways to improve energy efficiency

Home	Building designs	Industry	Transportation
1. Insulating home effectively to eliminate air leaks. 2. Using water-saving shower head. 3. Using modern energy efficient appliances. 4. Hanging thick curtains on window. 5. Covering the floor with carpet. 6. Using compact fluorescent lighting.	1. In cold climate, tight building design with well-sealed door, energy efficient window, well insulated wall and dark roof minimises energy used in heating. 2. In cooler climates, designing northern hemisphere buildings with south facing windows and southern hemisphere buildings with north facing windows increases the amount of sun entering the building. 3. Energy-efficient building design can include the use of low cost Passive Infra Reds (PIRs) to switch-off lighting when areas are unoccupied such as toilets and corridors.	1. Advanced boilers and furnaces can operate at higher temperatures while burning less fuel. 2. Heat that is produced as a by-product in industrial process can be captured and used for other industrial purposes. 3. Use of variable speed drive allows the motor's output to match the required load.	1. Reducing vehicle weight can reduce fuel economy. 2. Improvements in pumps and compressor can be done by better maintenance practice and installing variable speed drive. 3. Using improved aerodynamics can minimise drag and increase vehicle fuel efficiency. 4. Use of electric vehicle and bicycle for short distance journey.

Activity 11.4. *Identifying energy efficiency and energy wastage*

Instruction:

Figure 11.7 shows the activities (numbered from 1 to 14) carried out in a typical home. Classify the activities into “energy efficient” and “energy wastage” practices. Carry out the activity in groups.

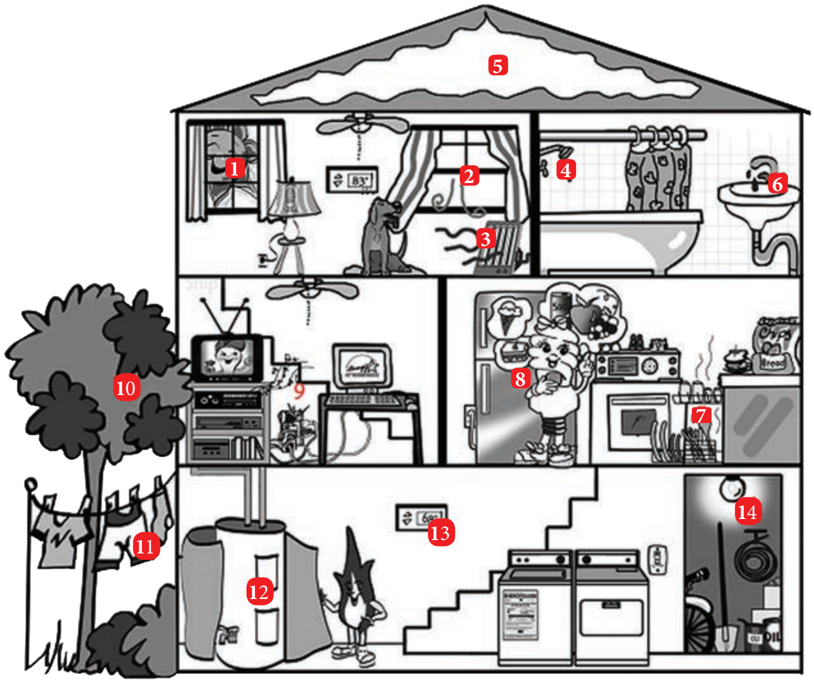


Figure 11.7. Activities carried out in a typical home

Questions:

1. List down the ways in which the energy is being wasted in Figure 11.7. How can you minimise the energy wastage?
2. How does the energy wastage at home impact the nation?
3. From this activity, what message can you share with your family members at home?

B. Energy Management System (EMS)

Energy management is the process of monitoring, controlling and conserving energy in different areas like businesses, government organisations, and homes. An energy management system is a systematic approach for continuously improving energy performance and reducing energy use or maximizing energy savings. The main objectives of EMS are to:

- *reduce energy wastage.*
- *educate the students and the public about energy management.*
- *document and publish information to achieve improvement.*
- *uphold legal requirement regarding energy use.*
- *continuously improve performance and system.*
- *effectively utilize energy efficient products and services.*

The basic EMS process is based on **Plan-Do Check-Act** continual improvement framework:

1. ***Plan (Schedule):*** Involves comprehensive analysis of energy use, establish baseline data, set target and action plan to deliver improved energy performance.
2. ***Do (execution):*** Implement energy management action plans. This step involves using or installing low energy consumption devices. Such measures are passive approach to energy management or one-time improvement plan.

Figure 11.8. Energy management model

3. ***Check (Control):*** Monitor and verify the result of action taken, compare with the baseline data. This step involves energy bill verification and helps to enhance on-going energy efficiency improvement and help maintain improved energy and cost saving over time.
4. ***Act (Action):*** Take actions to continuously improve the energy performance and EMS. This step involves energy efficiency analysis and implementation of active energy management system like automatic sensory lighting.

The successful implementation of EMS not only reduces the energy use and the cost, but also reduces maintenance and helps in mitigating climate change.

C. Energy audit

Energy Audit is a process of inspection, surveying and analysis of energy flow for conserving energy. There are three types of audits:

1. ***A Walk-through Audit*** includes a visual inspection of a building's energy systems, and a review of energy usage data.
2. ***A Computer Simulation*** are also used for energy auditing to predict system performance taking into account external factors in complicated facilities..
3. ***A Standard Audit*** assesses all equipment and operational systems, and creates a more detailed calculation of energy use. This audit identifies potential improvements, and makes recommendations based on their projected energy and cost savings.

A standard auditing is performed in three phases: pre audit phase, audit phase & post audit phase:

i) Pre audit phase

This phase involves planning, conducting awareness program, meeting and briefing departmental heads, and also to familiarise the site in order to identify the energy consuming systems.

ii) Audit phase

It involves data collection, energy consumption measurements, assessment of the efficiency of the equipment, analysis and identification of areas which has scope of saving energy consumption and finally reporting the findings to the management.

iii) Post audit phase

Based on the results outlined in the audit report, decision makers evaluate opportunities for energy savings and facilitate the implementation of energy conserving systems.

Activity 11.5. *Assessing home energy consumption*

Instruction:

There are two survey forms for energy auditing at your home or in your hostel. Read the instructions in the forms and answer the questions that follow:

Form A: Energy inventory:

Check each item at your home or in hostel, if boarder. Put '√' on the items that matches with your home or hostel and 'X' on items that does not match. Then answer the questions that follow:

- ☐ There aren't any leaks in your house toilet, sinks, shower head and taps.
- ☐ The television and lights are off, when nobody is around.
- ☐ Ceiling fans are off, when nobody is around.
- ☐ All the rooms have compact fluorescent lighting.
- ☐ When I place my hand at the edge of window or door, I can not feel the cold and warm air move in.
- ☐ All the floors are covered with carpet.
- ☐ The windows have thick curtains.
- ☐ Bathroom and kitchen have ventilation fan.
- ☐ All the electrical appliances are 3-5 star rated or energy efficient.
- ☐ There are trees planted around my place.
- ☐ When weather is sunny, clothes are dried in the sun and not in the drier.
- ☐ Boilers and geysers are put off when not in use.
- ☐ Thermo-containers are used to keep the food warm.

Form B: Energy calculation

i. Choose one room in your house or hostel for the energy auditing – the room should have at least 5 electricity consuming appliances or lights.

ii. Determine the wattage for each of the power consuming appliances or lights in your room; enter into the table using one row for each light bulb or appliance.

Table 11.5. Energy calculation

Sl.no	Appliance/light	Power (W)	Time (h)	Energy consumed (kWh)
1				
2				
3				
4				
5				

iii. Record the time that each of the power consuming appliances is on for a day

iv. Fill out the energy use table 11.5.

v. Calculate the energy used (kWh)= power(W)/1000 x time(h)

Question:

1. What type of energy auditing is used in the above survey?
2. Which mark '√' or 'X' is more? What do they indicate?
3. By looking at the energy consumption calculations in form B, which three electric appliances consume the most energy?
4. Does an appliance or device that has a high wattage always use the most energy in a day? Explain.
5. What do you think you could do to reduce the amount of energy used?

D. Benefits of energy conservation

Energy conservation has benefit on the economy, environment and a long-term availability of non-renewable resources.

i. Economy benefits

a. Reduction in cost of product

The use of energy efficient technologies in factories reduces the cost of production of goods by producing an equal amount of goods with lower energy investments. This helps to bring down the cost of goods and generate more income for the investors.

b. New job opportunities

Energy conservation usually requires new investments in more energy efficient equipment to replace old inefficient ones, monitoring of energy consumption, training of manpower, etc. This results in creation of new jobs as well as increase in number of existing jobs.

ii. Environmental benefits

a. Long-term availability of non-renewable resources

The major sources of energy used in the world today are non-renewable energy. With the increase in population and change in living conditions of people, these non-renewable sources are exploited at a very high rate. Reduction in dependency on such resources can ensure long-term availability of non-renewable resource.

b. Reduction in emission of pollutant

Fossils fuel used to generate electricity for transportation and industry emit large amount of carbon dioxide into the atmosphere. This emission may lead to global warming and acid rain. Reduction in dependency on fossil fuels and ensuring the judicial use of clean source of energy for transportation and industry can reduce emission of harmful dust and gaseous pollutants and also reduce accumulation of solid waste.

Reprint 2022

E. Initiatives and measures for energy conservation in Bhutan

With the increase in energy demand, threats to climate change, energy security, and environmental issue, there is a need to take appropriate measures that would lead to the development of indigenous and clean source of energy. Different agencies and ministries in Bhutan have taken initiatives in:

1. implementation of alternate energy program.
2. planning and coordination of rural electrification.
3. research and development on energy efficiency and conservation measures.

Currently, Bhutan's commitment towards conservation of energy can be seen in various ongoing energy efficiency activities such as formulation of National Energy Efficiency and Conservation Policy, standardisation and labelling program for appliance and building energy laboratory.

In February, 2016, the Department of Renewable Energy (DRE) launched a project to provide the public with subsidised price on LED bulbs in an effort to reduce electricity consumption. In the initial phase of the project, around 15,000 LED bulbs were distributed throughout the country and the bulbs were sold at subsidized rate of Nu.100. Further, solar LED street light pilot project has also been proposed in coming years. Mass awareness programmes on energy conservation and efficient use of energy are also conducted through various media.

Some of the important energy related policies and acts include the following: Alternative renewable energy policy, (2013), Sustainable hydro power development policy, (2008), Electricity act of Bhutan, (2001), Economic development policy of Bhutan, (2010), and Foreign Direct Investment, (FDI, 2010).

With the adoption of Alternative Renewable Energy Policy in 2013, Bhutan has embarked on a journey to strengthen its energy security and production of clean renewable energy from sources, such as wind, water and sun. These renewable sources of energy produce less pollution and have less impact on environment.

Questions

1. Why is it important to improve energy efficiency?
2. Our personal choice and habits on energy consumption can also help in conservation of energy. Justify the statement.
3. Why is energy auditing necessary in industries?

Reprint 2022

Exercise

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

   i. Replacing 60W incandescent bulb with 15W compact fluorescent bulb for the same illumination, is an example of

   A. energy management.

   B. energy security.

   C. energy efficiency.

   ii. Aum Karma's electricity utility bill is high every month. She must carry out .... to identify measures to save energy.

   A. energy efficiency test of all appliances

   B. energy management planning

   C. energy auditing

   D. energy cutting off methods

   iii. Mrs. Pema emphasizes on using fuel wood for cooking and heating purposes and water for grinding rice in the mill. The source of energy used by her is

   A. renewable energy resources.

   B. non-renewable energy resources.

   C. alternative energy resources.

   D. natural energy resources.

   iv. The pictures given in Figure 11.9 are the examples of

   A. biomass.

   B. solar energy.

   C. fossil fuels.

   D. nuclear energy.

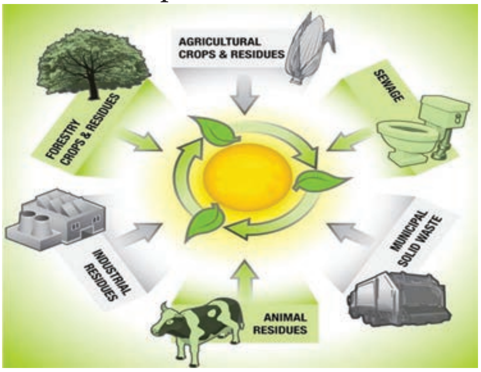


Figure 11.9.

v. The world will face energy crisis because

I. demand for energy will increase.

II. oil production will begin to decline.

III. shortage of energy will result in escalation of prices.

A. I and II

B. I and III

C. II and III

D. I , II and III

2. Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.

Column A	Column B
1. Derived from natural organic matter.	a. Renewable energy.
2. Sun and wind.	b. Energy management.
3. Fossil fuels.	c. Biomass.
4. Detail calculations of energy use.	d. Standard energy auditing.
5. Systemic approach for improving energy.	e. Hybrid cars.
	f. Nonrenewable energy

3. Fill in the blanks with the correct form of word(s).

i. The common element found in all fossil fuel is …………..

ii. Radioactive fission releases.......................energy

iii. Installation of low energy consumption devices is a ....approach to energy management.

iv. A home runs water in a closed pipe through the ground and uses heat from within the Earth to heat the water. This is an effective use of …………… energy

4. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.***

i. A walk through energy audit is recommended for a factory.

ii. Transportation sector accounts for the highest energy consumption globally.

iii. Geothermal energy comes from the energy of a falling water.

iv. Energy consumption is an indicator of a country's development.

v. Bhutan has the potential for tidal energy.

5. Answer the following questions.

i. What do you understand by the term "Clean Energy"? Why is it important to generate such energy?

ii. Study the graph provided in Figure 11.10 and answer the questions that follow:

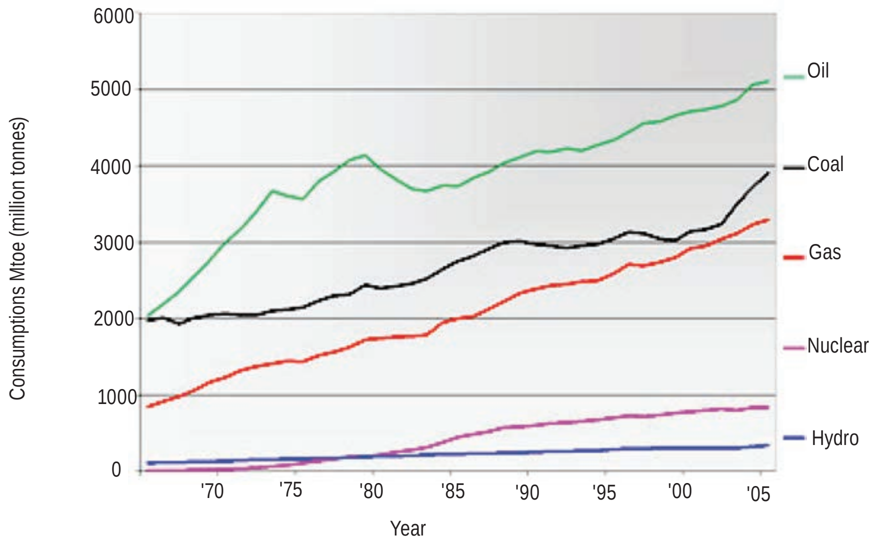


Figure 11.10. World energy consumption

a) Identify two globally least consumed energy source. Why?

b) Suggest reasons for the maximum consumption of oil and coal globally.

c) Explain the increase in consumption of nuclear energy after 1980s.

d) Suggest some of the ways to promote the use of clean energy globally.

iii. It is advised not to keep television and computers on standby mode. Justify.

iv. A farmer in Sarpang has installed a biogas electricity generator in his farm. This device generates electricity by burning methane gas produced from the decaying animal waste. Methane is a greenhouse gas. When the methane burns, carbon dioxide and water are produced.

a) The animal waste used in the anaerobic digester is a renewable energy source. What is meant by an energy source being renewable?

b) Suggest one reason why farmers are encouraged to install their own biogas generators?

c) Give two advantages and disadvantages of using the biogas generator.

v. How can energy policy help in conserving energy?

Reprint 2022

CHAPTER 12

DEVELOPMENT AND ENVIRONMENT

With the growing needs of the present generation, development is inevitable. Development in the past was measured only in terms of amount of goods and services produced. The resultant pressure on the environment was not taken into account. However, the modern holistic approach includes environmental, social, political and cultural aspects as standard measure of development. The sustainability of development can be achieved through understanding the relationship between economic growth and environment in context of the social setting.

This chapter focuses on the meaning and dimensions of the development, indicators of development, relationship between development and environment, impact of development on environment, and the changing perspectives of development over time.

Reprint 2022

1. Development

Learning Objectives

On completion of this topic, you should be able to:

- explain the term development.
- discuss various dimensions of development.
- identify the indicators of development and their limitations.

Different disciplines like Economics, Sociology, Political science, Environmental Science, etc., have different perspectives of development. Some regard economic growth as the heart of development while others perceive development as achievement of happiness.

Over time, it has led to the development of school of thought that interprets development as a multidimensional concept, which encompasses material, social, environmental, political and cultural components.

A. Development and its dimensions

The interpretation of development depends on disciplines, places and time. Different disciplines often define development from their own point of views. For example, economists define development in terms of economic progress. Economic progress is expressed in terms of increase in general productivity level, per capita income, efficiency of workers, quality of life and elimination of poverty. Sociologists focus on the social development of the people in terms of their mental relations and the institutional and structural changes in the society. Political scientist's equate development as increasing roles of government not only as promoter, but also as a principle planner.

Initially, development was considered in terms of economic growth, which is the amount of goods and services produced in a given period of time. However, economic growth alone did not satisfy the basic needs of the people and bring prosperity and harmony in the society. It was realized that economic growth alone did not lead to better food security, education, health, sanitation, etc. This required the inclusion of social, cultural, technological, human and political dimensions, as illustrated in Figure 12.1.

The World Bank defines development as a multi-dimensional process, which involves transformation in structures, attitudes and institutions as well as the acceleration of economic growth, reduction of inequality and the eradication of absolute poverty.

Reprint 2022

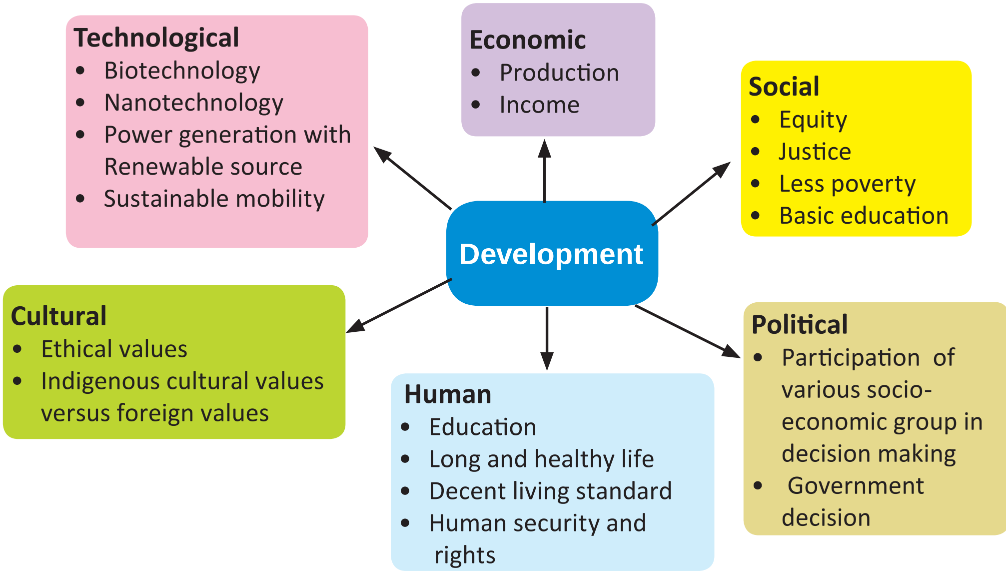


Figure 12.1. Dimensions of Development

B. Development indicators

Development indicators are measures that show a country's progress in a certain area and compare with that of other countries. They play a vital role in determining the current status of the economy in the country and for predicting the future economic developments. However, owing to more convenience in computing a nation's income, the World Development Reports indicate that the Gross Domestic Product (GDP), Gross National Income (GNI) and Human Development Index (HDI) are widely used as the development indicators.

(i) Gross Domestic Product (GDP)

The Gross Domestic Product (GDP) is the market value of all final goods and services produced within the country in a given period of time. It includes only the final value of the product. Therefore, the sale of used goods is not a part of GDP. It is calculated using its components as:

GDP = Consumption (C) + Investment (I) + Government Purchases (G) + Net Exports (X-M)

Consumption (C): It is the total spending by households on goods and services. For example, for tenants, consumption includes rent payments; for renters, the consumption includes the imputed rental value of the house, but not the purchase price or mortgage payments.

Investment (I): It is the total spending on goods that will be used in future to produce more goods. It includes spending on capital equipment such as machines, tools; structures, such as factories, office buildings and houses; and inventories, such as goods produced but not yet sold. However, investment does not mean the purchase of financial assets like stocks and bonds.

Government Purchases (G): It is all the spending on the goods and services purchased by government at the national and local levels. Government purchases exclude transfer payments, such as social security or unemployment insurance benefits.

Net Exports (X-M): It is given by exports minus the imports. Exports represent foreign spending on the economy's goods and services. Imports are the portions of consumption, investment and government purchases that are spent on goods and services produced abroad.

Activity 12.1. *Knowing more about GDP*

Instruction:

1. Work in groups. Read the scenarios given in the first column of Table 12.1 and identify the components of GDP. Mark as Consumer (C), Investment (I), Net export (X -M), or Not counted (NC) against each scenario in the second column. Provide suitable reasons for the comments under "reasons" column.
2. Comment on the effect of each transaction on GDP by writing increase, decrease, or no change in the third column. Give suitable reason for the effect on GDP for each scenario in the fourth column.

Table 12.1.

Scenario	**Component of GDP Affected** *(C, I, G, X-M, or NC-not counted)*	**Effect on GDP** *(increase, decrease, no change)*	Reasons
1. A farmer purchases a new pick-up truck.			
2. Businesses increase their current inventories.			
3. Yeshi spends Nu.200 to watch a movie.			
4. Worried about consumer confidence, vehicle company purchases less sheet metal for cars.			
5. A retired man cashes his social security check from the government.			

Reprint 2022

6. A person pays Nu. 8500 a month to rent an apartment.			
7. Worried about a recession, people begin saving more money.			
8. The Bhutan, government hires 10 Japanese–language experts from Japan to train Bhutanese tour guides.			
9. Government closes school for the month of January.			

Questions:

1. Describe a scenario each that increases and decreases the GDP, apart from the ones given in the Table 12.1.
2. The scenarios 1 and 4 both involve purchase of goods but their effects on GDP are different. Explain.
3. How does scenario 8 affect the GDP of Bhutan?

The GDP is expressed in comparison to the previous quarter or year. For example, if the year-to-year GDP is up by 3%, it indicates that the economy has grown by 3% over the last year. When a country's GDP grows, it means that the country has increased the amount of production. This indicates that citizens have higher income and there is rise in expenditure on various goods and services like healthcare, education, etc., which indicates the rise in living standard of people.

The value of GDP does not remain constant. The change is influenced by the change in the price and quantity of goods and services over time. The change in price of goods and services over time is called inflation.

(ii) Gross National Income (GNI)

The Gross National Income (GNI) is the sum of a nation's Gross Domestic Product (GDP) plus net income received from abroad.

GNI = GDP + net income received from abroad.

GNI is elaborated as the sum of value added by all producers who are residents of a nation, plus any product taxes (minus subsidies) not included in output, plus income received from abroad, such as employee compensation and property income. The GNI measures income received by a country both domestically and from overseas. In this respect, GNI is quite similar to Gross National Product (GNP), which measures output from the citizens and companies of a particular nation, regardless of whether they are located within its boundaries or overseas. Since the difference between incomes received by the country versus payment made to the rest of the world is not significant, GNI and GDP are not so different for most of the nations.

The income received from abroad is inclusive of remittance. Remittance is transfers of money across national boundaries by migrant workers. For many developing countries, money coming in from remittances is an important source of income adding to their GNI.

(iii) Human Development Index (HDI)

The Human Development Index (HDI) measures and ranks countries' social and economic development based on three indices: life expectancy index, education index and GNI index. It was introduced as an alternative to conventional measures of national development. The HDI makes it possible to track changes in development over time and to compare development levels in different countries. Different components of the HDI are represented in Figure 12.2. The HDI sets a minimum and a maximum value for each dimension and then shows where each country stands in relation to these values, expressed as a number between 0 and 1. The higher a country's HDI score, the higher its level of human development and vice versa.

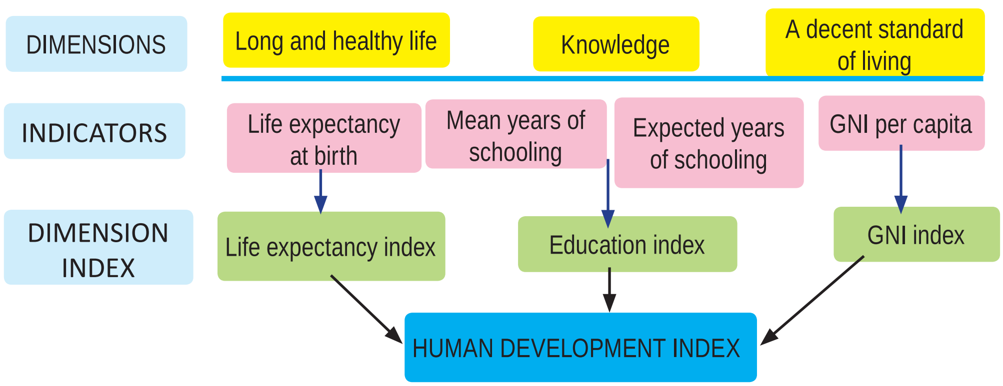


Figure 12.2. Dimensions and indicators of HDI [Source: UNDP (2010)]

Life expectancy: It measures the health of individuals in the country. Health is measured by life expectancy at birth. Life expectancy at birth indicates the number of years a newborn infant would live, if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.

Education index: This index measures the knowledge of individuals in the country. The education component of the HDI is measured by two indicators: mean years of schooling for adults aged 25 years and older; the expected years of schooling for children of school-going age. The mean years of schooling is estimated based on duration of schooling at each level of education. The expected years of schooling estimate is based on two factors: enrollment by age at all levels of education and the number of children of school-age in the population for each level of education.

The two indicators are first normalised using a minimum value of 0 and maximum value of 15 for mean years of schooling, and 18 for expected years of schooling. Since society can exist without formal education, the minimum value of 0 years is used for both education variables. Both indicators are then combined to produce an education index, which is the arithmetic mean of the two (equally-weighted) sub-indices of education.

GNI index: Income is measured by purchasing-power-parity (PPP), which is the adjusted per capita Gross National Income (GNI). It expresses the income accrued to residents of a country, including the international flows, such as remittances and aid, excluding the income generated in the country but repatriated abroad. Thus, GNI is a more accurate measure of a country's economic welfare.

The HDI also ranks countries into four categories: very high human development, high human development, medium human development, and low human development. For example, Bhutan, as per the HDI ranking of UNDP (2018), falls under medium human development category.

Activity 12.2. *Comparing developmental status of countries*

Instruction:

Study Table 12.2 (a), Table 12.2 (b) and Table 12.2 (c) representing developmental status of Bhutan and Singapore and answer the questions that follow.

Table 12.2 (a). Gross National Income per capita (in US$)

	2014	*2013*	*2012*	*2011*	*2010*	*2009*	*2008*	*2007*	*2006*	*2005*
Bhutan	*2370*	*2340*	*2320*	*2170*	*1990*	*1830*	*1750*	*1630*	*1340*	*1220*
Singapore	*55150*	*54580*	*51390*	*48330*	*44790*	*37080*	*36680*	*35660*	*32080*	*28370*

Table 12.2 (b).Gross Domestic Product (US$ in billion)

	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005
Bhutan	1.82	1.78	1.82	1.82	1.59	1.26	1.26	1.2	0.9	0.82
Singapore	307.87	297.9	286.9	274.1	236.4	192.4	192.2	180	147.8	127.42

Table 12.2 (c).Human Development (based on life expectancy)

	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005
Bhutan	69	69	69	68	68	67	67	66	66	65
Singapore	84.68	82	82	82	82	81	81	80	80	80

Questions

1. Using Table 12.2 (a), plot a GDP graph of Bhutan. What can you deduce about the trend of GDP of Bhutan?
2. What relation can you draw between GDP and GNI of Singapore?
3. Plot a graph using Table 12.2 (c) for both the countries. What can you say about the trend in life expectancy in both the countries. What could be the possible reason for the trends?

C. Limitations of development indicators

There are limitations of development indicators in providing comprehensive developmental status of a country. Some of the limitations are:

(i) Gross Domestic Product (GDP)

1. The GDP does not measure the very useful output that are unpaid and non-market values, such as parental childcare, volunteer efforts, home improvement projects.
2. It does not measure improvement in product quality and inclusions of new goods.
3. The GDP also does not include the underground economy like illegal economic activities and legal economic activities carried out to avoid taxation.
4. The harmful effects of pollution are not deducted from GDP (oil spills, increased incidence of cancer, destruction of habitat for wildlife), but it includes payments made for cleaning up oil spills and the cost of health care for cancer victims.
5. Though the per capita GDP gives information about relative living

standard in the economy, its figure does not provide informations about the distribution of income.

6. Goods and services produced but not exchanged for money (non-market production) are not measured even though they have values.

(ii) Human Development Index (HDI)

1. The HDI fails to adequately explain the differences among the industrialised and advanced countries. When the countries' income and literacy are very similar in terms of achievement, the only differences are due to small variations in life expectancy. To capture a slightly high level of development, there is the need for a more complex indicator.
2. The HDI also does not reflect the human development idea accurately. It is an index restricted to the socio-economic sphere of life, and does not take into consideration political and civil spheres, and gender inequalities and gender issues within the countries.
3. The HDI is unreliable in terms of data quality and exact construction of index. The definition and measurement of literacy are different among countries and also the data on life expectancy component are not available for a number of countries.
4. The HDI does not recommend ways to improve longevity and magnitude of importance to be given to each level of education.
5. GNI may not necessarily increase the economic welfare, it depends on how it is spent. The higher GNI per capita may hide widespread inequality within a country.

(iii) Gross National Income (GNI)

1. Production of certain goods and services is not reported to government by the producers in order to avoid taxation. Therefore, GNI gets underestimated, reflecting much less welfare than actually enjoyed by people.
2. Inequalities in income distribution reduce welfare of the people. The richer sections of people enjoy surplus.

Questions

1. Why was environment not considered as one of the dimensions of conventional development approach in the past?
2. Use the developmental indicators to explain how Gomtu cement factory at Samtse contributes to Bhutan's development.

2. Relationship - Development and Environment

Learning Objectives

On completion of this topic, you should be able to:

- draw links between environment and development.
- discuss the changing views of development.

The development of any country is directly or indirectly dependent on the natural resources. This dependency of human on the environment affects the condition of natural world. If the natural resources are not extracted scientifically and sustainably, the Earth will not be able to support the varieties of life forms; thus affecting the ecological health.

A. Economic Growth and Environment

Economic growth means the transformation of economy from the under-developed to the developed stage. This transformation is mainly reflected in a sustained and steady raise in national income and per capita income. Economic growth is related to a quantitative change only. Thus, economic growth refers to an increase in the aggregate level of national income, output and employment over a long period of time. It also refers to the increase in the quantity of goods and services produced. Economic growth can be either positive or negative. Negative growth is associated with economic recession and economic depression. In either ways, pressure on natural environment persists as long as economic activities continue.

The natural environment plays an important role in supporting economic activity. It contributes:

- ***directly***, by providing resources and raw materials, such as water, timber and minerals that are required as inputs for the production of goods and services; and
- ***indirectly***, through services provided by ecosystems including carbon sequestration, water purification, managing flood risks, and nutrient cycling.

Economic growth is important for the prosperity and well-being of the country and its citizens both in advanced economies and in the developing world. Economic growth brings many benefits, such as raising the standards of living and improving the quality of life across the world. However, it also results in the depletion of natural resources and the degradation of ecosystems. Economic activities relate to the environment in two fundamental ways : we draw resources

Reprint 2022

(both renewable and non-renewable) from the environment to produce goods and services and we emit wastes into the environment in the process of production and consumption.

There is always a debate over whether it is possible to achieve economic growth without unsustainably degrading the environment. At the same time, there is a growing realisation that economic growth at the current rate of depletion and degradation of environmental assets cannot continue indefinitely. Therefore, in order to understand the relationship between economic growth and environment, various models like Kuznets Environmental Curve (KEC) Model, Mehboobul Haq's Model and Three Stage Development Model are used to explain the relationships between development and environment.

The KEC Model is based on the hypothesis of an inverted U-shaped relationship between economic output per capita and the environmental quality, as shown in Figure 12.3.

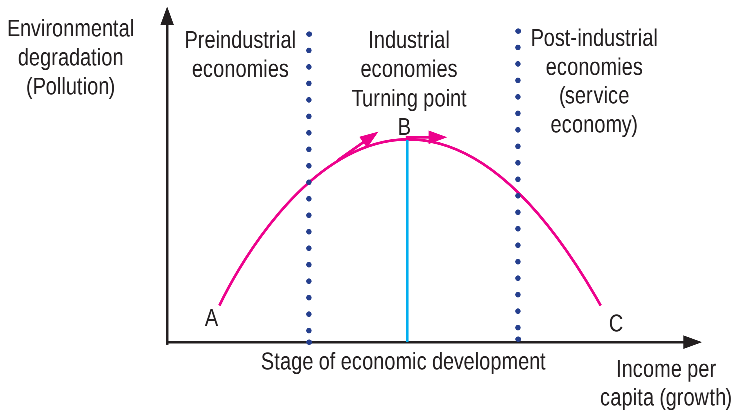


Figure 12.3. Kuznets Environmental Curve

As the GDP per capita of the country increases, there is generally proportional increase of environmental degradation (curve AB). At low incomes, the environment pollution and degradation is unavoidable as individuals value their consumption needs over the environment quality. However, beyond a certain point (B), the increase in GDP per capita leads to reductions in environmental damage (curve BC) because government begins to legislate for pollution controls and the economy moves towards service rather than industry. In addition, individuals in the society prefer improvements in environmental quality over further consumption, and thus the environmental quality begins to improve alongside the economic growth.

The KEC Model has a tendency to encourage economic growth and avoid costly environmental regulations particularly in the developed countries that have gone past their turning point. On the other hand, if a country prefers the early implementation of strict environmental regulations, it could actually harm the economic growth and cause increased environmental damage in the long run.

B. Impact of economic development on environment

For many nations, economic development is the backbone of country's prosperity and security. While economic growth boosts country's pride and people's living standard, it raises a concern as to how long a nation can continue with the same rate of economic growth. High economic growth results in more human desire for materials leading to increased environmental damage.

Activity 12.3. *How does development impact the environment?*

Instruction:

Work in groups. Draw a concept map on a chart to illustrate the impacts of development on the environment. Build your concept map using the following concepts:

- agricultural practices
- industries
- transportation
- human settlement.

These broad concepts must be supported by specific concepts linked to each other with the help of linking words. Present your group work to the class.

Questions

1. How does the development in the above-mentioned broad areas impact the environment?
2. 2. What relation do you see among these broad concepts?
3. 3. Which of the developmental activity has the maximum impact on environment? Support your answer giving suitable reason.

C. Changing perspective of development

The perspectives of development have changed over time since the era of industrialisation. The purpose of development has shifted from the materialistic well-being to holistic approach, which considers environment and social welfare as important dimensions of the development. Table 12.3 summarises the trend in changing perspectives of development.

The current global sustainable development goals accord priorities on improvement of human welfare and equity in the context of sustainable use of resources to ensure that resource meet the needs of the present without compromising the needs of the future generations.

Table 12.3. Meaning of development over time

Period	Perspectives	Meaning of development
1800s	Classical political economy	1. Achieving national power. 2. Colonisation to gain control over resources. 3. Monopoly of trade. 4. Economic development through Comparative advantage. 5. Protectionism (Elite's influence on protection of domestic economy through tariffs and other preferential laws.)
Early 1900s	Development economics	1. Faster economic growth- industrialisation.
Mid 1900s	Modernisation theory	1. Political and social growth in the European countries. 2. Accumulation of power and wealth. 3. Enlargement of people's choice.
Late 1900s	Neoliberalism	1. Economic growth- structural reforms, regulation, liberalisation and privatisations.
Early 2000	Millennium Goals	1. Eradicate extreme poverty and hunger. 2. Achieve universal primary education. 3. Promote gender equality and empower women. 4. Reduce child mortality. 5. Improve maternal health. 6. Combat HIV/AIDS, malaria & other diseases. 7. Ensure environmental sustainability. 8. Develop a global partnership for development.

2015-onwards	Global Sustainable Goals	1. No poverty. 2. Zero hunger. 3. Good health and well-being. 4. Quality education. 5. Gender equality. 6. Clean water and sanitation . 7. Affordable and clean energy. 8. Decent work, economic growth. 9. Industry, innovation, infrastructure. 10. Reduce inequalities. 11. Sustainable cities and communities. 12. Responsible consumption, production. 13. Climate action. 14. Life below water. 15. Life on land. 16. Peace, justice and strong institutions. 17. Partnership for the goals.

Questions

1. According to KEC model, the environment degradation decreases after attaining the turning point. Will the decrease in environment pressure continue in future, or must it be considered as a temporary phenomenon? Support your answer with reasons.
2. "Early implementation of strict environmental regulations could actually harm economic growth, and cause increased environmental damage in the long run." Support the statement giving suitable reasons.
3. Why should social needs be given more consideration in the developmental process?

Reprint 2022

Exercise

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

   i. What is gross domestic product (GDP)?

      A. Income earned through foreign exchange.

      B. The amount of dollars earned in industry.

      C. Income earned within a country.

      D. Goods received from the nation's local residents.

   ii. If Nike, an American corporation, produces sneakers in Bhutan, this

      A. neither contributes to US GDP nor Bhutan's GDP.

      B. contributes to Bhutan's GDP only.

      C. contributes to US GDP only.

      D. contributes to both Bhutan's GDP and US GDP.

   iii. As economic development proceeds, income inequality tends to follow a(n) ………………… curve.

      E. convex

      F. inverted U-shaped

      G. L-shaped

      H. S-shaped

   iv. The Human Development Index (HDI) summarizes a great deal of social performance in a single composite index, combining

      A. disparity reduction rate, human resource development rate and the composite index.

      B. longevity, education and living standard.

      C. minimum schooling, adult literacy and tertiary educational attainment.

      D. human resource training, research and development.

v. Which of the following are included in GNI?

I. Remittances

II. A farmer purchasing new tractor.

III. Sangay spends Nu 500 for a new pair of jeans.

IV. A retired civil servant cashes his pension from the government.

A. I and II

B. I, II and III

C. I and IV

D. I, II, III and IV

2. ***Fill in the blanks with the correct form of word(s).***

i. The human development index is based on life expectancy index, education index and ____________________ index.

ii. As per the Kuznets Environment Curve Model, environment degradation is less in _____________ countries.

iii. Expenditure on goods and service purchased by the government is known as ______________ purchases.

iv. Illegal economic activities are not included in __________ calculation.

v. Net exports is exports minus __________________.

3. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.***

i. With time, the poor nations of the world can achieve the same standard of living as that of the rich nations.

ii. The GDP includes the environmental costs of producing goods and services and is a good measure of sustainability.

iii. Highly developed countries still depend on environment for food, water and fuel.

Reprint 2022

iv. Human Development Index is a tool to measure peoples' happiness.

v. Increase in GNI at current rate gives a correct picture of economic development of a country.

4. ***Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.***

Column A	Column B
1. Colonisation to gain control over resources.	a. Neoliberalism.
2. Industrialisation for faster economic growth.	b. Development economics.
3. Enlargement of people's choice.	c. Modernisation theory.
4. Liberalisation and privatisation of economic growth.	d. Millennium development goals.
5. Ensure environmental sustainability.	e. Classical political economy.
	f. Economic theory.

5. ***Answer the following questions.***

i. Explore other models to explain the relation between development and environment. Compare it with Kuznets Environmental Curve model.

ii. Draw interrelationship between the six dimensions of development.

iii. The Human Development Index (HDI) is a composite index that measures the average achievements in a country in three basic dimensions of human development.

a) Differentiate between human development and economic development.

b) Suggest some activities that might help Bhutan to increase its HDI index.

iv. What are the main indicators of the economic development of a country?

v. How can modern technologies help in solving trade-off between economic growth and development?

vi. Why is economic growth alone not an indicator of the overall development of a country?

vii. How do Kuznets Environmental Curve Model relates economic growth with that of environmental degradation?

viii. Relate the Kuznets Environmental Curve Model to Bhutan's developmental philosophy.

Reprint 2022

13
CHAPTER
SUSTAINABLE DEVELOPMENT

There is a rise in income inequality within and among the countries. At the same time, change in lifestyle has led to exponential rise in consumption and production that has resulted in huge economic and social cost. The environmental health of the Earth is also deteriorating, endangering lives on the planet. These challenges are addressed through sustainable development that includes economic, social and environmental dimensions of development.

Bhutan's development policy is guided by the philosophy of Gross National Happiness (GNH). This ensures secure, ecologically balanced, equitable economic and social development.

Reprint 2022

1. Introduction to Sustainable Development

Learning Objectives

On completion of this topic, you should be able to:

- explain sustainable development.
- describe the dimensions of sustainable development.
- explain the inter-relationship among the dimensions of sustainable development.

The deteriorating environment due to rush for economic development has led to realisation of wide interconnections and dependency of humans on the environment. Therefore, economic development must be achieved without compromising the social and environmental state of the world.

A. Understanding sustainable development

Humans are considered dominant in the human-nature relationship. The economic development occurs at the cost of ecological health. Even with continued over-exploitation of natural resources, it has completely failed to bring improvement in economic development and eradication of poverty.

Sustainability means the ability or capacity of a system or environment to endure or maintain itself at a certain rate or level for an indefinite period. Sustainable development is a development, which maintains, manages and does justice to the change people seek without compromising the well-being of future generations.

The most recognised and classic definition of sustainable development is, "The development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The definition contains two key concepts: concept of needs, which expresses the priorities of meeting the needs of the people and concept of limitations, which states the limitations imposed by nature on the development.

The key objectives of sustainable development are:

1. protect environment through sustainable use of resources and services;
2. promote social equity through fulfillment of fundamental human rights, cultural diversity, equal opportunities and elimination of all forms of discrimination; and
3. support economic prosperity through the promotion of knowledge, innovation and competitiveness.

Reprint 2022

A set of universal goals known as the Sustainable Development Goals (SDGs) are identified to achieve the objectives of sustainable development by 2030. Since then, sustainable development has been accepted as a guiding principle for development by most of the countries around the world.

B. Dimensions of sustainable development

Human well-being can neither be sustained without a healthy environment nor in the absence of a vibrant economy. Sustainable development has been described in terms of "economic, environmental and social" dimensions. Changes in any one of the dimensions of development impacts the other two dimensions. According to the declaration of 2012 Rio+20 Summit, the sustainable development goals should "address and incorporate in a balanced way all three dimensions of sustainable development and their interlinkages" and should "be coherent with and integrated into the United Nations development agenda beyond 2015".

(i) Environment

The Earth provides raw materials and environmental services for the social and economic development. However, these resources and services are finite. The limited capacity of our environment to provide resources and services is further reduced by the changing environmental conditions due to climate change, pollution, natural disasters, etc. These changes are brought mainly due to the unsustainable production and consumption of natural resources. Therefore, equal importance must be given to protect and develop environment for sustainable development.

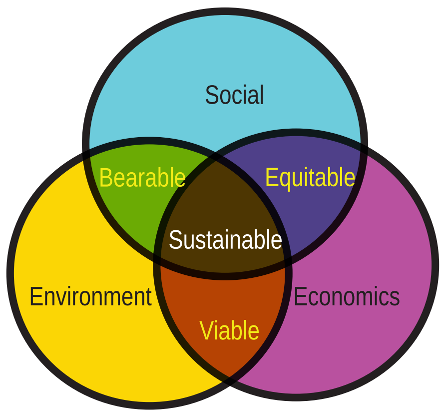


Figure 13.1. Attributes of sustainability

Development of environment means maintaining the ability of the environment to hold its capacity to provide resources and receive waste. Some of the ways by which we can protect our environment are:

- harvesting renewable natural resources at the rates that do not exceed the regeneration rate;
- substituting non-renewable energy sources such as coal, gas, and nuclear power by renewable energy sources such as wind energy and solar energy;
- managing wastes to level assimilative capacity of the environment;
- reducing pollution and emissions of greenhouse gas, using numerous green technologies.

The maintenance of ecological processes and life support system, preservation of genetic diversity and sustainable use of natural resources is indispensable in order to achieve sustainable development.

(ii) Economic

Traditionally economic development was seen as a growth in the GDP. Rush for economic growth has led to unstable society, unequal wealth distribution, depletion of natural resources, etc. Therefore, sustainable development guides economic growth to minimise negative impact on the environment, reduce inequality and eradicate poverty.

An economically sustainable system must maintain a stable resource base and also include the maintenance of biodiversity, atmospheric stability and other ecosystem functions.

For example, a sustainable business model has lower risks, improved efficiency through strengthened operations and quality products along with lasting benefits and services to the employees. Such business model provides opportunities for innovation and green technologies, which not only increases the product and services but also protects environment. Therefore, economic achievement is unattainable without taking into account the social and environmental stability.

(iii) Social

The social dimension of sustainable development focuses on social equity, social stability, social interaction, participation, safety and security of a community. A society must have fairness in distribution of opportunity, adequate provision of social services, including health and education, gender equity, political accountability, and participation. Social sustainability seeks to reduce vulnerability and maintain the health of social, cultural and environmental systems. For instance, one of the aspects of social well-being is access to quality education, thereby, enhancing people's efficiency, productivity and creativity. This could enable active participation of people in decision-making and policy development, which contributes to achieving sustainable development goals.

The three dimensions of sustainable development - economic, environmental and social, are inter-dependent and mutually reinforce each other. The interactions among dimensions are important to ensure the balanced assessment of trade-offs and synergies that might exist among the three dimensions.

A good example of the interdependence and integration of sustainable development activity is the establishment of community forest. The community forest is introduced to establish decentralised forestry extension service and preservation of resources and biodiversity for future generation. The community

Reprint 2022

forest also provides equal accessibility to timber and non-wood forest product for consumption and commercialisation by the community. The community resource capacity and sustainability of the forest depends on the community's initiative to manage through informed decision.

In the process of managing the community forest, people make decisions, draw polices, take ownership and responsibilities, which contributes to the cooperation and advancement of community. Therefore, community forest brings environmental, economic and social benefits, and ensures that the resources remain for the future generation.

C. Sustainable future

Activity 13.1. *Visioning your future*

Materials required:

Guiding questions written on chart papers, markers and mobile phone to play peaceful music in the background.

Instruction:

1. Work in groups. Each group will create the vision as, 'future of our community 50 years from now'. Use the following questions to guide you formulate the vision:.
   a) *What economic developmental activities do you foresee in your community 50 years from now?*
   b) *If you go to a nearby river, lake or stream how would it look like?*
   c) *What plants and animals will there be for you to show to your children/ grandchildren?*
   d) *How might you be living?*
   e) *What will your house look like?*
   f) *How will you and your children or grandchildren move from one place to another?*
   g) *Where will your food come from?*
2. After the vision has been set, each group will design a poster using drawings, mind map and brief write-ups on "My Community after 50 Years from now."
3. Make presentations to the panel followed by a presentation by the panel on the inferences made on the concept of sustainable development.

2. Relationship - Sustainable Development and Environment

Learning Objectives

On completion of this topic, you should be able to:

- define the term economic instrument.
- describe the types of economic instruments for environmental protection and resource management.

In economics, the environment is viewed as an asset that provides a variety of services and materials. A healthy environment provides economic services directly to the consumers. The air to breathe, soil to grow crops, water to drink, shelter and clothing for warmth and protection are all derived from the natural environment. This results in exploitation of natural resources and create two broad categories of environmental problems: overuse of renewable resources and emission of pollutants into the environment.

The damages done to the environment through unsustainable economic activities is steadily growing. The cost of consuming scarce and shared resources is borne by the environment.

A. Economic instruments (EIs)

In order to address the increasing environmental degradation issues, many countries have started implementing a policy tool called Economic instruments (EIs), which helps to reduce the impacts of human activities on the environment. The EIs are the administrative mechanisms adopted by government agencies to influence the behaviour of producers and consumers.

Economic activity to generate goods and services incurs both private cost and external cost. Private costs involve production and consumption of goods and services while external costs are the cost of pollution, depletion of natural resources or degradation of the environment. The social cost is the total cost of an economic activity arising from the production or consumption of goods and services. It includes both private cost and external costs. However, absence of secure property rights, unsustainable production and consumption and policy failures result in the underpricing of scarce natural resources and environmental assets. As a result of this gap, producers and consumers of these products and services do not receive correct signals about the true scarcity of the resources they consume or the environmental damages they cause.

EIs aim to bridge this gap between the private and social costs by internalising

Reprint 2022

all the external costs to their sources. For example, in air transport, private cost includes cost of constructing and operating airport, while the external cost includes environmental degradation due to change of landscape, noise pollution, air pollution and risk of accident to those living nearby. The external costs are often not included in prices paid by consumers and producers; they are borne by society as a whole. The failure to consider these external costs may be corrected through the use of EIs by including the external cost in private cost of goods and services. The government uses EIs to reward firms and individuals that adopt sustainable environmental management practices, such as watershed management and ecosystem conservation.

B. Types of economic instruments

Figure 13.2 shows the Economic instruments as espoused by United Nations Environment Programme (UNEP).

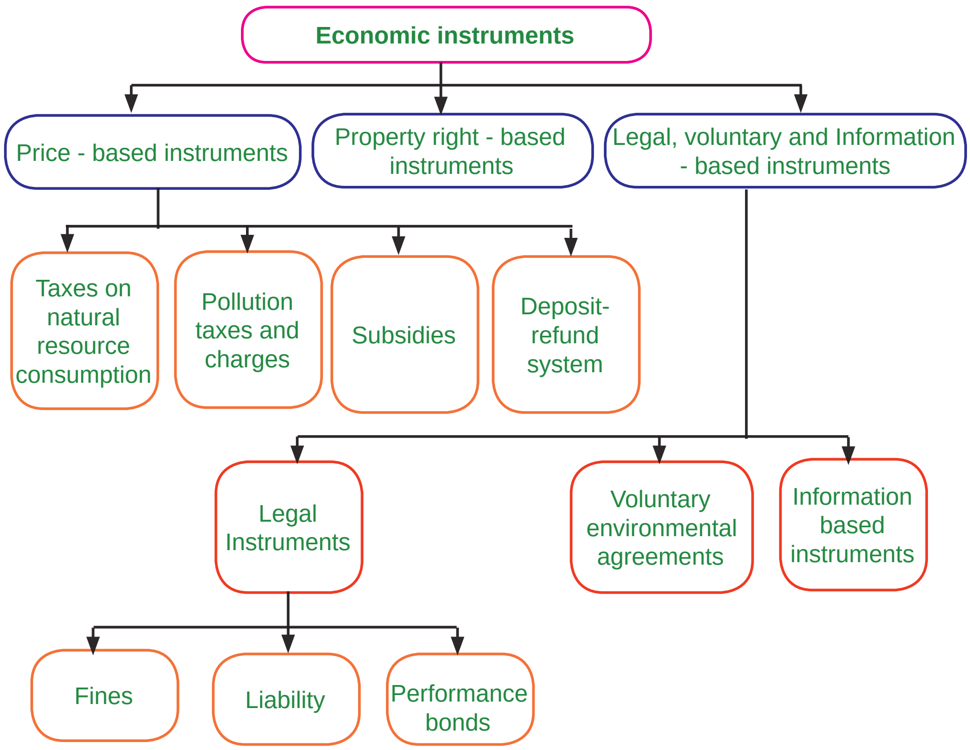


Figure 13.2. Economic instruments

a. Price-based Instrument

Price-based instrument is special government taxes, charges or fees for polluting the environment or exploiting natural resources. The charges and taxes imposed are:

(i) Taxes on natural resource consumption

Government uses price-based instruments such as mining royalties, user fees and land taxes to manage natural resources. For instance, in Bhutan, lessee pays mining royalties for mining of gypsum, dolomite, coal, etc.

(ii) Pollution taxes and charges

The taxes and charges on pollution intend to shift the costs of pollution to the polluter. The government applies taxes and charges, which include sewage effluent taxes, smokestack emissions, gasoline taxes and emission taxes.

In Bhutan, green tax is imposed on vehicles that uses fossil fuel, while electric vehicles are exempted. The green tax is meant to discourage the use of fossil fuel and encourage individuals to opt for effective and environment friendly means of transportation..

(iii) Subsidies

Subsidies are the sum of money granted from public funds to help an industry or business to keep the price of a commodity or services low. Government subsidies can compensate for the cost of environment friendly production and consumption behavior. Subsidies are useful where the government wishes to protect privately owned environmental assets (e.g. land, forests, and waterways). The subsidies are also applied on the purchase of pollution control equipment.

For instance, Bhutan provides subsidies to those establishments that provide eco-tourism services. Similarly, people get subsidies on installation of biogas plant to reduce consumption of fossil fuels and firewood.

(iv) Deposit refund systems

Deposit refund systems involve a charge on some particular item and a refund for its return, which is used to encourage environmentally appropriate recycling, or for appropriate disposal. The deposit refund approach is applied on drink cans and bottles, batteries, tyres, etc. In the United States, retailers charge \$10 as the deposit on all batteries sold. When the customer returns the used battery for recycling the deposit fee is returned, which otherwise would cause soil pollution and water pollution. Recycling batteries saves natural resources, reduces the need for landfill and saves energy.

b. Property Rights-based Instruments.

The property rights-based instruments are used to manage the environment assets by creating, clarifying and enforcing rights to a specific property. This instrument sanctions the rights to ownership and use of both tangible (e.g.

Reprint 2022

land) and intangible (e.g. permits) property. For example, in Bhutan, **tsamdro** (pasture land), which fall under the government-reserved forestland is leased to an individual household or community who owns livestock. The lessee is allowed to use the **tsamdros** for rearing cattle but has to adhere to a guideline that ensures sustainable use of pasture land.

c. Legal, Voluntary and Information-based Instruments.

(i) Legal Instruments

Legal instruments are designed to hold individuals and organisations liable for environmental damage they cause. They include penalties, fines, liability, and performance bonds.

(1) Fines

Government imposes fines when a firm or an individual violates environmental laws. The fines imposed must be large enough to deter individuals from violating laws. For example, fines are imposed for illegal dumping of waste, poaching, cutting trees, etc.

(2) Liability

Liability is a legal obligation in which one is required to pay for the natural resource damage, property damage, damage to human health or loss of life, non-compliance to environmental laws and regulations and non-payment of due taxes, fees or charges. For instance, in mining, the company needs to bear all the cost of resources damaged by mining.

(3) Performance Bonds

Performance bonds are forms of insurance required to ensure that the company is able to pay for any environmental damage caused by its activities. For example, in Bhutan, a mining operation company is required to sign a legal document to compensate for the potential environmental damage the mining operation could cause. This bond requires the company to provide financial assurance for cleanup and proper disposal of waste and reclaim the area ensuring a sustainable mining activity.

(ii) Voluntary Environment Agreements

The voluntary environment agreements are negotiated agreements among the private firms, government agencies, and non-government organisations. The agreements are designed to encourage voluntary investments to reduce negative environmental impacts, such as to limit pollution or the overuse of natural resources. The incentives for such agreements include subsidies, positive publicity or good relationship with the government. For example, under Indonesia's Clean Rivers Program, the polluters are encouraged to sign agreements to reduce water pollution over a specific time period. The government rewards those polluters who reduce pollution with publicity. This encourages public participation to join and reduce water pollution for sustainability.

(iii) Information-Based Instruments

Information-based instruments are methods of informing the public about how eco-friendly a product is. The public disclosure of information changes behavior of polluters and consumers by directly influencing the market. It is used to publicise firms or products that meet certain standards in the way they are produced or harvested.

In some countries, the pollution caused by waste discharge by factories is compared with national standards. The list of top polluters and the least polluting factories are published for public information. This drives the factories to reduce pollution and also gives choice to consumers to opt for the products with less environmental impacts.

Questions

1. Identify environmental issues in our country that could be resolved by enforcing property rights.
2. Solid waste management is becoming a major public health and environmental concern in Thimphu. Draw an agreement to be signed by public committing to dispose solid waste responsibly. Your agreement must include all the relevant economic instrument that would ensure that solid waste is properly managed.

Reprint 2022

3. GNH and Sustainable Development

Learning Objectives

On completion of this topic, you should be able to:

- discuss sustainable development in the context of GNH.
- analyse the developmental policies and strategies of Bhutan from the point of sustainable development.
- analyse the challenges of GNH practices for sustainable development.

A. Gross National Happiness and its dimensions

The Legal Code of Bhutan 1729 declares "if the government cannot create happiness (**dekid**) for its people, there is no purpose for the Government to exist." In 1972, His Majesty the 4th Druk Gyalpo Jigme Singye Wangchuck declared that Gross National Happiness (GNH) is more important than Gross Domestic Product. Since then, Bhutan has oriented its national policies and developmental plans towards achieving the Gross National Happiness.

GNH at its core comprises a set of values that promote collective happiness as the end value of any developmental strategies. The GNH philosophy is generally described as:

- ***Holistic:*** Recognizing all the aspects of people's needs, be it spiritual or material, physical or social.
- ***Balanced:*** Emphasizing balanced progress towards the attributes of GNH.
- ***Collective:*** Viewing happiness to be an all-encompassing collective phenomenon.
- ***Sustainable:*** Pursuing well-being for both current and future generations.
- ***Equitable:*** Achieving reasonable and equitable distributed level of well-being.

The greatness of the concept of GNH lies in its simplicity in giving priority to happiness. The term 'happiness' reflects the creation of enabling conditions where people are able to pursue well-being in sustainable ways.

While there is no single official definition of GNH, the widely accepted definition states that "Gross National Happiness (GNH) measures the quality of a country in more holistic way (than GNP) and believes that the beneficial development of human society takes place when material and spiritual development occurs side by side to complement and reinforce each other".

Bhutan has adopted a holistic approach to achieve a balanced and sustainable form of development within the GNH framework that comprises of four pillars and nine domains. The four pillars of GNH are: good governance, sustainable socio-economic development, preservation and promotion of culture, and environmental conservation.

Good Governance

Good governance is considered as a pillar for happiness because it determines the conditions in which people thrive. The government must reflect the opinion of the people and people must become more proactive in their involvement with the changes.

Sustainable Socio-Economic Development

All development activities in Bhutan must ensure that people continue enjoying higher standards of health care, education, and social services. Bhutan envisions higher standards of living with access to modern amenities and technologies by all citizens equally across all parts of the country.

Preservation and Promotion of Culture

Bhutan makes a sincere and respectful effort to preserve its culture. The preservation and promotion through distinct architectures, cultural events, traditions and rituals are the way of life and living for Bhutanese. This contributes to happiness and minimises the negative impacts of modernisation.

Environmental Conservation

The country's pursuit of development remains within the limit of environmental sustainability. This pillar of GNH ensures the protection, conservation and promotion of the health of the natural environment. This contributes to sustainability of natural resources, aesthetic and recreational services.

The four pillars of GNH have been further elaborated into nine domains in order to create a widespread understanding of GNH. They are also the means to analyse and measure of sustainable development and happiness of the people. The nine domains are shown in the Figure 13.3.

1. Psychological well-being

It considers how satisfied people are in various aspects of their lives. It provides an evaluation guided by emotions and feelings such as the frequency with which people experience various moods in reaction to their lives.

Figure 13.3. Domains of Gross National Happiness

2. *Health*

It takes care of both the physical and mental health because the well-being and happiness of people depends on them.

3. *Education*

The holistic educational approach ensures a deep foundation in traditional knowledge, values and skills. Creative learning is also encouraged in addition to reading, writing, mathematics, science and technology.

4. *Culture*

It takes care of distinctive culture of Bhutan, which facilitates the sovereignty of the country and provides identity to the people. The diversity of culture is manifested in forms of language, festivals, ceremonies, drama, music, dress, and traditional arts and crafts.

5. *Time use:*

This provides a comprehensive view of how individuals use their time within a 24-hour period. It takes care of paid work, unpaid work and leisure time.

6. *Good governance*

It covers the vision and goals of the country. It emphasises on the approach of governance to protect and strengthen the sovereignty of the Kingdom. This ensures peace, security, well-being and happiness of the people.

7. *Community vitality*

It emphasises on sustenance of social capital of the country through co-operative relationships and social networks within the community.

8. *Ecological diversity and resilience*

It emphasises on environmental conservation, environmental issues and human-wildlife conflict.

9. *Living standards:*

It refers to the material well-being of the people. It ensures the fulfillment of basic material needs for a comfortable living.

B. Sustainable environmental policies and strategies of Bhutan

In the early 1990s, Bhutan formulated sustainable development strategies and established the institutional framework needed for their implementation. The National Environment Commission (NEC) drafted a National Environment Strategy (NES) that envisioned a dynamic, long-term vision to achieve sustainable development through improved environmental planning, policymaking and management.

Bhutan now incorporates GNH into its planning and policymaking processes. All the initiatives of the government are divided into policies and projects. The proposed policies or projects have to undergo a GNH screening test in a systematic way that conforms with dimensions of GNH. It is to ensure that all the policies or projects are GNH enhancing or have minimal or no adverse effects on the GNH values. For example, the Mineral Development Policy has to pass not only the economic indicators but also the environmental standards and impacts on other indicators like culture.

There are environmental policies, acts and by-laws that guide Bhutan to pursue sustainable socio-economic development.

Reprint 2022

Activity 13.2. ***Analyzing the environmental policies, acts and by-laws***

Instruction:

1. Work in groups.
2. Each group must carry out research for information on any one of the environmental policies, acts and by-laws of Bhutan listed below:
   - *i. Cottage, Small and Medium Industries Policy*
   - *ii. Waste Management Act of Bhutan*
   - *iii. Forest and Nature Conservation Act*
   - *iv. Disaster Management Act of Bhutan*
   - *v. Land Act*
   - *vi. Human- Wildlife Conflict Management Strategy*
   - *vii. Water Act of Bhutan*
3. You may get help from your parents, Dzongkhag Environment Officer or other relevant people. Use the following questions to guide your research.
   - *a) What are the rationale behind the enactment of the policies, acts and by-laws?*
   - *b) List down the provisions of the selected policy, act or by-laws that ensure sustainable development.*
   - *c) How does the policy, act or by-laws mitigate the challenges of sustainable development?*
   - *d) What are some clauses that you would like to include to strengthen the policy, act or by-law?*
4. Evaluate how these environmental policies, acts and by-laws contribute to sustainable development in Bhutan.
5. Present your findings to the class.

C. GNH and Global goals for sustainable development

World leaders gathered at the UN in the year 2000 to shape a broad vision to fight poverty in its many dimensions. The vision translated into eight goals, ranging from halving extreme poverty rates, to halting the spread of HIV/AIDS and providing universal primary education as the overarching development framework for the world untill 2015. These goals were called as Millennium Development Goals (MDGs).

Bhutan has achieved most of the MDG targets, as it has successfully aligned the MDGs with national priorities and integrated them into the national development and planning framework. The development philosophy of GNH also provided an enabling environment to mainstream the MDGs. The progress made towards achieving the MDGs are:

a) Global poverty continues to decline.

b) More children than ever are attending primary school.

c) Child deaths continue to drop.

d) Access to safe drinking water has been greatly expanded.

e) Targeted investments in fighting malaria, HIV/AIDS and tuberculosis have saved millions of lives.

In September 2015, the 193 Heads of State and Government and High Representatives adopted the new Sustainable Development Goals (SDGs) to achieve the three dimensions of sustainable development till 2030 in a balanced and integrated manner that are critical for humanity and the planet. SDGs seek to build and address the unfinished targets of MDGs.

Activity 13.3. *Developing sustainable development goals*

Instruction:

1. Work in pairs. Each pair selects a country based on choice to do a mock UN session to discuss on “global goals and GNH”.

2. Each pair will enact the role of a delegate to the United Nations and attempt to solve real world issues.

3. The class will choose one student to play the role of Secretary General and four Moderators to ensure peaceful discussion and to arrive at unanimous resolutions at the end of the session.

4. Use the following sections to guide you to carry out the mock UN session:

A. *Country position paper:* It is the summary of ones country’s knowledge on the following four sections.

1. ***Background:*** Study briefly about the background of the chosen country. Identify some of the problem in the country.
2. ***Past international actions:*** List down some of the initiatives taken to solve the problems. You may visit UN website, country website, UN or NGO reports.

Reprint 2022

3. ***Country policy:*** Identify and list down the countries key treaties and resolutions meant to solve the problems.

4. ***Possible solution:*** List down the policy recommendations that you would like to change or expand on. You may create your own recommendations.

B. ***Opening Speech:*** It is the speech that each country representative will give to UN session. It is the best opportunity for a country to explain policy and key issues that UN session would like to focus on. It is important for a country to propose sustainable solutions. Use the position paper as a guide to deliver the speech.

C. ***Debates and Discussion:*** Discuss on the issues and recommendations to set 10 goals for sustainable development.

D. ***Writing Resolution:*** The country representatives should endorse the agreed sustainable development goals by signing an agreement.

Questions:

1. Compare the sustainable goals of the activity with the global sustainable development goals.
2. Categorise the SDGs under the nine domains of GNH.

Bhutan has integrated the four pillars of GNH into its entire decision-making for every developmental activity for achieving the economic, social and environmental prosperity.

In the economic realm, the application of the GNH screening tool to evaluate the policies and projects helps to keep the focus on sustainability at all times. Bhutan has adopted a policy of high value and low impact tourism. For instance, the high tariff rate for tourism services and restriction on tourist to visit certain areas are to ensure minimum damage to the environment, quality services and sustainable tourism practices.

In the social realm, GNH focuses on the initiatives to increase the life expectancy and decrease infant mortality rates in Bhutan by improving health and education facilities. This assures healthy and literate society for future.

In the environmental realm, the reforestation efforts bring about a substantial increase in country's forest cover as well as expand the protected natural areas that include corridors for wandering animals. Bhutan continues building the local capacity of citizens to manage forests and protected areas, improve awareness and public support for conservation of environment. Bhutan serves as an important carbon sink and integrates the economic development with environmental conservation to ensure a sustainable future for Bhutan.

However, Bhutan faces a few challenges to achieve the sustainable development goals:

- unemployment issues;
- pressure of managing waste;
- rural-urban migration;
- increased prevalence of non-communicable disease; and
- change in land-use patterns.

The global sustainable developmental goals and the national planned developmental activities will be critical to address the above challenges.

Questions

1. Why is economic development not the ultimate goal in the concept of GNH?
2. How does good governance contribute to the protection of environment?
3. How do you relate the sustainable development principle with the philosophy of GNH?
4. Of late, the concept of Green Economy is gaining attention of politicians and planners in Bhutan. Justify in three points, the importance of Green Economy from the sustainable development perspectives.

Reprint 2022

Exercise

1. ***Each question in this part is followed by four possible choices of answers. Choose the most suitable answer.***

   i. The sustainability of resource is defined as the ability to

      A. maximise the use of resources.

      B. maintain resource at the desired level.

      C. avoid the use of resources.

      D. produce more resources.

   ii. Which of the following can attain sustainable development?

      I. reducing consumption, increasing efficiency and using renewable energies.

      II. building large structures using stronger design and materials.

      III. building safer roads for transportation.

      IV. extracting all natural resources.

      A. I, II and III

      B. I, II and IV

      C. II, III and IV

      D. I , III and IV.

   iii. Which of the following is a characteristic of sustainable development?

      A. Meeting the needs of present generation

      B. Saving for the needs of future generations

      C. Meeting the needs of present as well as saving for future generations

      D. Creating resource to meet the needs of future generation

   iv. One of the differences between sustainable economic development and the conventional economic development is

      A. sustainable development considers equal distribution of wealth.

      B. conventional economic development generates less wealth.

      C. sustainable development is much faster.

      D. sustainable development is much slower.

v. Inclusion of GNH in every developmental policy of Bhutan is necessary to

A. maintain balanced development in all aspects of GNH domains.
B. create awareness on GNH.
C. simplify the policy.
D. guide economic developmental activities.

vi. The purpose of performance bond is to

A. discourage the use of resources.
B. generate government fund.
C. generate fund for people.
D. minimise harmful environmental impacts.

vii. Bhutan government imports kerosene and LPG from India at low price. This is mainly to

A. reduce the consumption of wood.
B. reduce the consumption of electricity.
C. help Bhutan to be self sufficient.
D. supply the surplus kerosene and LPG from India.

viii. What type of economic instrument is applied to encourage consumers to opt for public transport, cycle, walk and live closer to place of work?

A. Green tax
B. Deposit Refund Systems
C. Subsidies
D. Fines

ix. As per the GNH philosophy, happiness of a person may be achieved if the

I. consumption is high.
II. environment is healthy and resourceful.
III. government is fair and responsible.
IV. society is stable and cooperative.

A. I, II and III
B. I, II and IV
C. II, III and IV
D. I, III and IV

x. The International Day of Happiness is celebrated throughout the world every year to

A. protect the environment.
B. prioritise happiness.
C. boost the economy.
D. encourage good governance.

2. ***Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs.***

Column A	Column B
1. Environmental certification.	a. Royalties
2. Tradable emission.	b. Recyclable containers
3. Taxing natural resources.	c. Property management
4. Transferable permit.	d. ISO 14000
5. Deposit refund system.	e. Pollution management
	f. Eco-labeling
	g. Subsidy

3. ***Fill in the blanks with the correct form of word(s).***

i. The three dimension of sustainable development are economic, environment and ___________.

ii. The royalty paid for timber is __________________ economic instrument.

iii. The sustainable development is explained through the concept of need and concept of ______________.

iv. The production of **dheysho** (Bhutanese paper) from daphne plants results to destruction of the plant species and pollution of the environment; this accounts for ___________ cost.

v. Any developmental activity, private or public, must obtain clearance of the Environment Impact Assessment (EIA), which is an example of ____________________

4. ***Write TRUE or FALSE for the following statements. Rewrite the false statements in their correct forms.***

i. The ultimate goal of GNH paradigm is to achieve happiness.

ii. Spiritual and cultural values of a society have insignificant roles in the sustainable development process.

iii. One of the ways to bring global consumption patterns of products and services to a sustainable level is responsible consumers' choice, use and disposal.

iv. Economic instruments are implemented to reduce the cost of goods and services for the people.

v. The program that supports students with physical and learning disabilities is in line with economic dimensions of sustainable development.

6. ***Answer the following questions.***

i. Define sustainable development in your own words.

ii. How is environment conservation important to economic growth of a nation?

iii. One of the signs of economic growth is invention of technologies, which has led to mass production of goods. Can we conclude that invention of technologies is not a sustainable activity? Justify your statement.

iv. How is sustainable development important in combating the climate change?

v. How will the shrinkage of cultural diversities affect the individual and collective potential for happiness?

vi. How can economic instruments promote the efficient allocation of natural resources?

vii. What might be the potential challenges when using property right based instruments?

Reprint 2022

SAMPLE QUESTION

Environmental Science

Class: XI | **Time: 3 hours**

Full Marks = 100

Directions

- The first 15 minutes of the examination is for reading the paper only. Students must **NOT** start writing during this time.
- This paper has two sections A and B.
- **Section A** contains objective questions and all questions are compulsory.
- **Section B** contains extended response questions, wherein you have to answer **any** SIX out of seven questions.
- The intended marks for questions are given in brackets ( ).

Section A (40 Marks)

Compulsory: Attempt **all** *questions.*

1. For each question, there are four alternatives A, B, C and D. Choose the correct alternative and circle it. Do not circle more than ONE alternative. If there are more than one choice circled, NO score will be awarded.
(1 x 15 =15 marks)

i. Identify the correct order of biomes from the lowest to the highest range of precipitation.

A. Desert, grasslands, temperate deciduous forest, tropical rain forest.

B. Desert, temperate deciduous forest, grasslands, tropical rain forest.

C. Grasslands, desert, temperate deciduous forest, tropical rain forest.

D. Grasslands, desert, tropical rain forest, temperate deciduous forest.

ii. Classification of organisms into trophic level is based on

A. niche.

B. habitat.

C. food chain.

D. adaptation.

iii. The colonisation of human environment by plant and its consequent evolution into domesticated form is viewed as

A. parasitism.

B. domestication.

C. natural selection.

D. co-evolution.

iv. Which of the following describe carrying capacity?

I. It depends on the availability of food, water supply, environmental conditions and living space.

II. It depends on species and their population.

III. It remains constant over many years.

A. I and II

B. II and III

C. I and III

D. I, II and III

iv. The heavy metal which is the most toxic to humans is

A. lead.

B. mercury.

C. arsenic.

D. cadmium.

v. Certain gases in the atmosphere trap solar radiation and maintain the temperature of the Earth. These gases are called

A. inert gases.

B. atmospheric gases.

C. greenhouse gases.

D. natural gases.

vi. The point on the surface of the Earth where earthquake originates is called

A. hypocentre.

B. epicentre.

C. focal depth.

D. fault.

viii. Conservation of biodiversity is carried out by

A. fragmenting habitats.

B. introducing exotic species.

C. keeping animals in the zoo.

D. harvesting plants for medicines.

ix. A Giant Panda is included in the list of vulnerable species as it faces

A. high risk of extinction in near future.

B. extremely high risk of extinction in the immediate future.

C. high risk of endangerment in the wild.

D. low risk of endangerment. .

x. Incineration is one of the methods of managing waste. The disadvantage of incineration is that it

A. requires a large space for landfilling.

B. produces harmful products.

C. is an inefficient method of waste disposal.

D. disposes small amount of waste.

xi. The objective of energy management system is to

A. maximise energy cost.

B. minimise energy waste.

C. maximise productivity with same amount of energy.

D. maximise productivity with increased energy consumption.

xii. The Gross Domestic Product is developmental indicator that measures

A. the quality of goods and services.

B. income distribution.

C. non-market value of goods and services.

D. market value of goods and services.

xiii. Bhutan practises "high value, low volume" tourism to

A. restrict free trade.

B. increase the number of tourists.

C. promote sustainable development.

D. prevent overcrowding.

xiv. Bhutan has adopted carbon neutral policy to

A. reduce carbon sequestration capacity.

B. reduce pollution.

C. conserve biodiversity.

D. reduce the emission of greenhouse gases.

xv. Which interaction best illustrates the concept of mutualism?

A. Aphids feeding on rose leaves.

B. Nitrogen-fixing bacteria in root nodules of legumes.

C. Infectious bacteria living in the blood of a host.

D. Wolves and arctic foxes feeding on snowshoe rabbits.

2. Fill in the blanks with appropriate word(s) (½ x 10 = 5 marks)

i. Paying Nu 6000 as a monthly rent for an apartment is an example of ______________ component of GDP.

ii. The__________ level in sewage is reduced by 20-30 % during primary sewage treatment process.

iii. Ecosystem services that ensure the stability of environment are called _________ services.

iv. Rice cultivation and raising livestock emit _________, which is a greenhouse gas.

v. A toxic chemical that causes cancer is called ____________.

vi. The relationship between a brightly coloured pea flower and the pollinator represents____________.

vii. The boundary between the troposphere and the stratosphere is called ________.

Reprint 2022

viii. The impact of severe destruction of natural environment due to human activities is termed as ____________.

ix. The potential hazard for the people living in the coastal region falling within the seismic zone is____________.

x. In a graph depicting the relationship between exploitation and carrying capacity, the sudden fall in carrying capacity indicate____________.

3. Match each item of Column A with the most appropriate item of Column B. Rewrite the correct pairs by writing the number and the corresponding alphabet in the spaces provided. (½ x10 = 5 marks)

Column A	Column B
i. Ratio between national average yield and world average yield	a) Fault Re-gift
ii. Average productivity of different land type of a country	b) Primary treatment
iii. Formation of soil due to continued weathering of rocks and minerals	c) Reuse
iv. The increase in temperature with increase in height in the stratosphere	d) El Nino
v. The value assigned to ecosystem services that are extracted to be used directly at homes	e) Secondary treatment
vi. The value of ecosystem services which can be viewed but not removed	f) Trench method
vii. Climatic condition of a periodic warming in sea surface temperature across the equatorial Pacific.	g) Consumptive use value
viii. The process of removing suspended particle by mechanical processes	h) Yield factor
ix. Gifting excess, used and unused goods to those who need them	i) Indirect use value
x. Construction of successive cells of waste that are compacted against a slope	j) National average yield
	k) Pedogenesis
	l) Equivalence factor
	m) Negative lapse rate

n) Area method

4. Write TRUE or FALSE against the following statements. Rewrite the false statements in the correct forms. (1 x 5 = 5 marks)

i. Clouds block the UV radiation from reaching the Earth.

ii. A pyramid of energy shows that there is an increasing amount of energy available at each successive trophic level.

iii. Innate affinity of humans to the ecosystem is termed as ecocide.

iv. Good governance emphasises on the economic conditions of the people.

v. Electricity produced by burning coal is classified as primary source of energy.

5. Answer the following questions briefly. (1 x 10=10 marks)

i. Bacteria and fungi are important component of food chain. Support this statement.

ii. Acid rain is more common in the industrial area. Justify.

iii. How is weather different from climate?

iv. Why do you measure biodiversity?

v. Why is disposal of e-waste in landfills prohibited?

vi. According to KEC model, the environmental degradation decreases after attaining the turn-out point for economic growth. What is the reason for the decrease?

vii. Why is tax levied on vehicles in Bhutan?

viii. Tundra biome is also called an arctic desert. Justify.

ix. How is peripatric speciation different from parapatric speciation?

x. Compare hazard and disaster.

Section B (60 marks)

Answer any **SIX** *questions.*

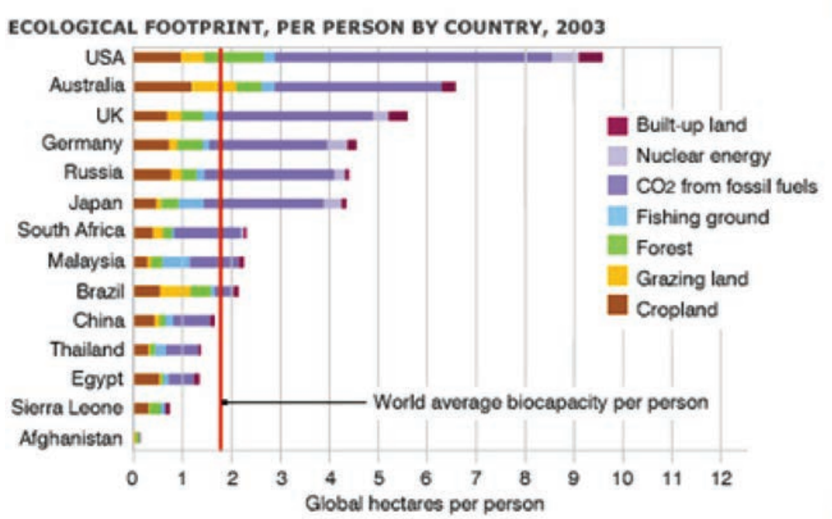


Figure 1.1

Question 1 **(10 Marks)**

i. Study Figure 1.1 and answer the questions that follow:

a) Describe different parameters taken into account in the above figure to determine the Ecological Footprint. (2)

b) Identify a country that is likely to increase its Ecological Footprint in future. Give reasons. (1)

ii. Study Figure 1.2 and answer the following questions:

a) Explain the phenomenon caused as a result of increase in the concentration of carbon dioxide and other greenhouse gases? (2)

b) Explain the anthropogenic activities that increase the concentration of carbon dioxide in the atmosphere. (2)

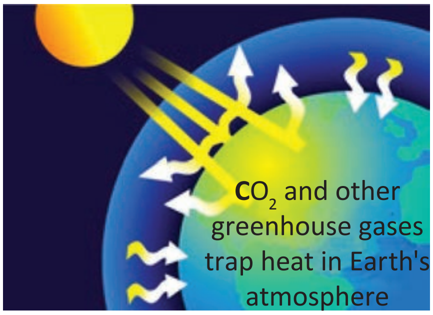


Figure 1.2

iii. How does Bhutan incorporate GNH into its planning and policymaking process?(2)

iv. Why is economic development alone not sufficient to meet the needs of human being? (1)

Question 2 **(10 Marks)**

i. Tropical rain forest can support diverse and abundant life even with poor quality of soil. Give reasons. (1)

ii. How do tectonic plates influence the nature of land on the Earth's surface? (1)

iii. State two major factors that determine classification of terrestrial biomes. (1)

iv. What does each factor in the I=PAT equation indicate? How are the factors inter-related? (3)

v. Exotic species are introduced with the intention to bring about genetic diversity in an ecosystem. However, under certain circumstances they become invasive. With reference to the statement answer the following question:

   a) What are exotic species? (1)
   b) What are some of the conditions that make the exotic species invasive? (1)
   c) Is introduction of exotic species good for the ecosystem? Support your answer. (2)

Question 3 **(10 Marks)**

i. Give two examples of ozone depleting substances. (1)

ii. Explain hydro-meteorological hazard that is likely to occur in Bhutan? (2)

iii. How is GPS useful in determining the possibility of earthquake and volcanic eruptions? (2)

iv. Mention two parameters measured by Human Development Index. (1)

v. Explain at least three initiatives to minimise land pollution. (3)

Reprint 2022

vi. Why is indoor air pollution more harmful than outdoor air pollution? (1)

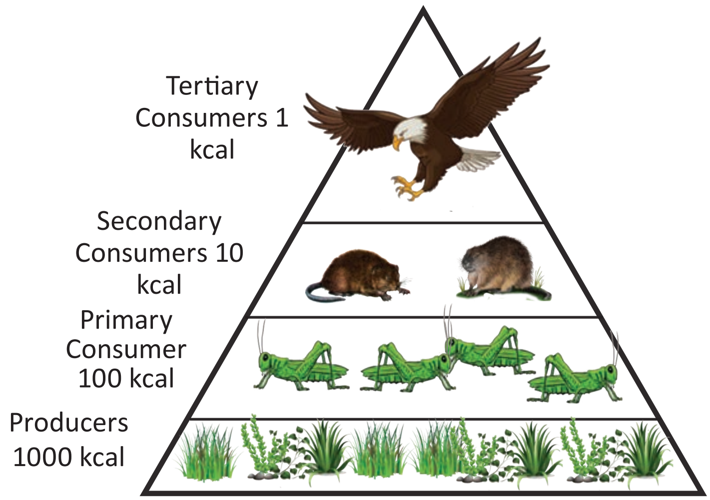


Figure 1.3

Question 4 **(10 Marks)**

i. Study Figure 1.3 and answer the questions that follow:

   a) Explain pyramid of energy based on Figure 1.3. (1)

   b) Why is the pyramid upright? (1)

   c) In a stable ecosystem, can there be more carnivores than herbivores? Explain. (1)

ii. How does fragmentation of habitat lead to speciation? (2)

iii. How does rich biodiversity help to sustain the ecosystem? (2)

iv. "Solar energy is a renewable energy source used to generate electricity". With reference to this statement, answer the following questions:

   a) What do you understand by term renewable energy? (1)

   b) Name two renewable sources of energy in Bhutan. (1)

   c) List two benefits of using solar energy. (1)

Question 5 **(10 Marks)**

i. Compare lentic ecosystem and lotic ecosystem. (2)

ii. Table 1.1 represents the water quality test carried out in one of the rivers in Bhutan.

Table 1.1

Property	Reading
pH	9
DO	4 mg/L
BOD	10.4 ppm
Coliform bacteria	150/100 mL of water (Present)

a) Relate the value of DO level to the quality of water? (1)

b) How does the level of DO in water affect the result of BOD? (1)

c) What would be the possible source of contamination of water by coliform bacteria? (1)

d) Considering the result of water test given in Table 1.1, how safe is the water for aquatic organisms? (1)

iii. Explain two key concepts embedded in the principles of sustainable development. (2)

iv. How does a country benefit through the implementation of economic instruments? (2)

Question 6 **(10 Marks)**

i. How does pollution lead to loss of biodiversity? (1)

ii. Why is a food web a more accurate depiction of nature than a food chain or pyramid? (1)

iii. Why is crop rotation a popular practice in agriculture? (1)

iv. How does the increased level of nutrients in water affect aquatic organisms? (2)

v. What is lethal dose? What is the purpose of testing the lethal dose in animals? (3)

vi. What do you understand by the term energy audit? (1)

Reprint 2022

vii. List two causes that influence the rate of species extinction. (1)

Question 7 **(10 Marks)**

i. If you are to observe the detail life cycle of a species, which method would you use? Justify. (2)

ii. How does water vapour in the atmosphere contribute to global warming? (2)

iii. Why are glass bottles preferred in packaging than plastics? (2)

iv. The data of wild animal species diversity survey conducted by an ecologist is presented in Table 1.2. Study the table and answer the questions that follow:

Table 1.2

Number of individuals of species in each habitat			
Species	**Forest**	**Grassland**	**Scrubland**
A	*4*	*15*	*0*
B	*5*	*2*	*3*
C	*4*	*3*	*0*
G	*3*	*15*	*8*
H	*6*	*12*	*0*
I	*3*	*1*	*11*
J	*4*	*0*	*0*

a) Find out Alpha diversity for each of the habitat. (1)

b) Calculate the Simpson's Index (D) for Grassland habitat and interpret the value. (3)

Annexure

Procedure for preparation of chemical reagent

Instructions

1. Manganese sulphate solution
   - Dissolve manganese sulphate
     - 480 g $MnSO_4.4H_2O$,
     - 400 g $MnSO_4.2H_2O$ or
     - 364 g $MnSO_4.H_2O$

     in freshly boiled and cooled distilled water, filter the solution and make up to 1000 mL (One litre).

2. Alkaline Iodide Sodium Azide solution
   - Take 700 g of Potassium hydroxide and add 150 g of potassium iodide and dissolve it in freshly boiled and cooled water, and make up to 1000 mL (One litre).
   - Dissolve 10 g of Sodium Azide (NaN3) in 40 mL of distilled water and add this with constant stirring to the cool alkaline iodide solution prepared.

   (If potassium compounds are not available, use 500 g of sodium hydroxide with 135 g of sodium iodide)

3. Sodium Thiosulphate stock solution
   - Weigh approximately 25 g of sodium thiosulphate and dissolve it in boiled distilled water and make up to 1000 mL. Add 1 g of sodium hydroxide to preserve it.

4. Starch indicator
   - Weigh 2 g of starch and dissolve in 100 mL of hot distilled water. In case if you are going to preserve the starch indicator add 0.2 g of salicylic acid as preservative.

Reprint 2022