ENVIRONMENTAL SCIENCE

CLASS XII

ཤེས་རིག

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

Kinga Dakpa, 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

Sonam Peldon, Teacher, Paro
Wangpo Tenzin, Curriculum Specialist, REC, Paro

Illustrations & Lay out design

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

ISBN: 978-99936-0-441-9

Reprint 2022

Contributors of Environmental Science Textbook for Class XII

Panel members:

1. Wangpo Tenzin (Curriculum Specialist), Dean, CDC, REC, Paro.
2. Surjay Lepcha, Curriculum Developer, CDC, REC, Paro.
3. Bhoj Raj Rai, Chief, STEM, CDC, REC, Paro.
4. Jas Raj Subba, Sherubtse College, Kanglung, Trashigang.
5. Prem Timsina, Nagkor HSS, Pemagatsel.
6. Changa Tshering, UWICE, Bumthang.
7. Karma Tshering, NEC, Thimphu.
8. Bhim Kumear Sharma, Damphu CS, Tsirang

Participants:

1. Tshering Lham, Gongzim Central School, Haa
2. Uma Acharya, Babesa MSS, Thimphu
3. Tshering Tobgay, Bajothang HSS, Wangduephodrang
4. Jamyang Drukda, Punakha Central School, Punakha
5. Ugyen Wangmo Tenzin, Peljorling CS, Samtse
6. Phuntsho Penjor, Tendruk HSS, Samtse
7. Mahendra Timsana, Chukha CS, Chukha
8. Jamyang Tenzin, Shari HSS, Paro
9. Karma Choedup, Punakha Central School, Punakha
10. Tshering Tobgye, Yadi CS, Mongar
11. Norbu Gyeltshen, Samdrupjongkhar MSS, Samdrupjongkhar
12. Pemsang Tamang, Chukha CS, Chukha
13. Tshering Zangmo, Punakha Central School, Punakha
14. Deo Kumar Thing, Gyelposing CS, Mongar
15. Karma Jamtsho, Nganglam HSS, Pemagatshel
16. Yeshey Nidup, Tshangkha Central School, Trongsa
17. Tshewang Dhendup, Changangkha MSS, Thimphu
18. Tshewang Dema, REC, Paro
19. Karma Tenzin, REC, Paro
20. Thinley Jamtsho, REC, Paro

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 to 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 man-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.

Kinga Dakpa
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.

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 utilization, 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,

Reprint 2022

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.

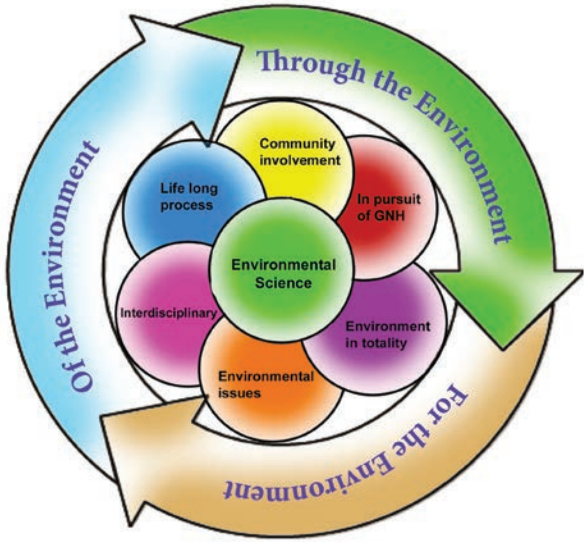


Figure. 1. Principles of Environmental Science Curriculum

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**

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

Reprint 2022

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, now 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 realize 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.

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

Reprint 2022

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 **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:

Reprint 2022

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.

Assessment Matrix								
Types of assessment	CFA			CSA			SA	
Definition	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.			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.			Assesses student's cumulative performances and achievements at the end of each term.	
Domains	Content knowledge (CK)	Environmental Processes (EP)	Environmental values and attitudes (EV)	Content knowledge (CK)	Environmental Processes (EP)	Environmental values and attitudes (EV)	CK, EP & EV	CK, EP & EV
Techniques	Quiz & debate, self & peer assessment, class presentation, homework, class work, immediate interaction with students.	Immediate interaction with students, class work, home work, experiments, exhibition, case studies	Observation of student's conduct, group work, field trip, excursion, self & peer assessment ,immediate interaction with students.	Class Test.	Project Work(PW)	Environmental Profile(EP)	Term exam.	Term exam
Assessment Tools	Q&A, checklist and anecdotal records.	Checklist and anecdotal records.	Checklist and anecdotal records.	paper pencil test (chapter end test).	Rubrics	Rubrics	Paper pencil test	Paper pencil test with:
Frequency interval (when &how)	Checklists and anecdotal records must be maintained for each topic throughout the academic year.			Chapter end test – for every chapter.	Project Work -Single PW for Classes 11 &12 but assessed each year	Environmental Profile -assessed two times (half yearly)	Once in a term.	Once in a year.
Format in Progress Report				CK	EP	EV	Mid-Term	Annual Exam
Weightings				T1= 2.5 T2= 2.5	T1= 5 T2= 5	T1= 2.5 T2= 2.5	T1=30	T2=50
NB:	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(Weightage = 80 marks).							

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

Reprint 2022

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							

Reprint 2022

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.

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.

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

Reprint 2022

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.

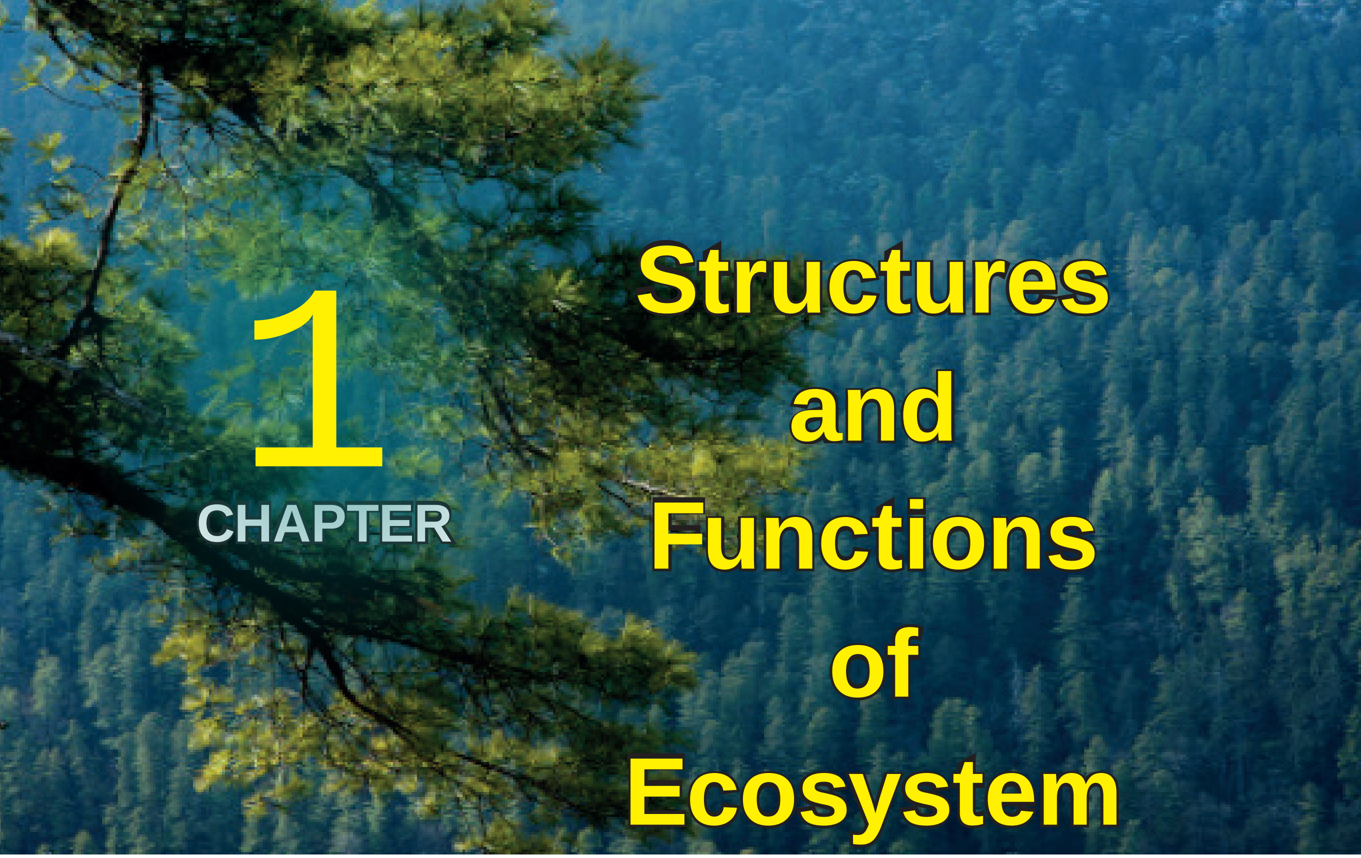
The tools used in SA are test blue print and pencil paper test. The pencil paper test may include variety of questions, such as multiple choice questions, fill in the blanks, matching, true or false, short answer questions, extended response questions, etc. These questions will test the competencies 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	Structure and Functions of Ecosystem	500.0	8%
Chapter 2	Balance of Nature	437.5	7%
Chapter 3	People and Environment	437.5	7%
Chapter 4	Natural Resource Degradation	437.5	7%
Chapter 5	Pollution	500.0	8%
Chapter 6	Climate Change	500.0	8%
Chapter 7	Disaster Management	562.5	9%
Chapter 8	Biodiversity Conservation	500.0	8%
Chapter 9	Biodiversity Management	375.0	6%
Chapter 10	Water and Land Management	500.0	8%
Chapter 11	Energy Conservation	437.5	7%
Chapter 12	Environmental Management	500.0	8%
Chapter 13	Sustainable Development	562.5	9%
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

An ecosystem is a dynamic and a complex system in which plants, animals, microorganisms and non-living elements interact as a functional unit. Within an ecosystem, organisms cooperate and compete with one another. Such interrelationships maintain the stability of the ecosystem. Ecosystems are multifunctional systems which provide humanity with many vital ecosystem services. Thus, the valuation of ecosystem services informs decision-making and ensures policy appraisals by taking into account the costs and benefits of the natural environment.

1. Community Ecology

Learning Objectives

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

- distinguish between major and minor community.
- explain some characteristics of a community

A community is the assemblage of organisms of different species that live in the same area at the same time. The organisms in a community are bound together by a shared environment, and the network of influence each species has on the other and the community. Community ecology is the study of interactions between the populations in the community in relation to the environment.

A. Types of communities

There are two types of communities. They are minor community and major community.

A minor community is a smaller community with a lesser variety of organisms which are not self-sustaining and is more or less dependent on adjacent communities for its sustenance. A colony of ants is an example of a minor community.

A major community is a large community with a wide-range of organisms which makes it a self-regulating and self-sustaining system. It is relatively independent from the adjacent communities. The major community comprises of many minor communities. For example, pond community consists of many minor communities of aquatic plants, algae, earthworms, snails, protozoa, insects, crabs, fishes, etc. Other examples include forests, lakes, swamps, grasslands, etc.

B. Characteristics of a community

The characteristics of a community are as follows:

i. Structure

Community structure is the composition of a community, which includes the number of species, their population, and the patterns of interaction between the different species. Therefore, community structure can be studied by determining the density, frequency, and abundance of species population in a particular ecosystem. Community structure is influenced by factors such as climate pattern,

Reprint 2022

geographical features, species variations, and frequency of disturbances and interactions. Thus, at different times, the composition of the communities in an ecosystem may vary. The composition of land and water community structure is shown in Figure 1.1.

(a) Land community (b) Water community

Figure 1.1. Examples of community

ii. Dominance

A dominant species is a plant, animal or functional group of different species most commonly found in a particular ecosystem. It is generally the most populous species that comprises the greatest biomass in an ecosystem. They can exercise major control or influence because of their physical size, population numbers or activities that have an impact on another organism or the environment. Thus, many communities are named after them. For instance, a community with grasses as the dominant species is called a Grassland. Figure 1.2 shows ruminants grazing in a grassland community.

Figure 1.2. Grassland community

There are species with less population in a community and yet plays a unique and crucial role in the functioning of an ecosystem. These species are known as keystone species. For instance, prairie dogs are considered as keystone species of the grassland. Prairie dogs are burrowing rodents living in large colonies that feed on grasses. As they feed on one type of plant, other varieties of plants grow in its place. This enhances the diversity of plant species in the area they inhabit. Burrowing by prairie dogs improves the soil conditions. While making burrows, prairie dogs mix organic materials, droppings and different layers of soil which help in aeration and moisture retention in soil. The soil in prairie dog colonies contains higher concentration of nitrogen, phosphorus and organic matter that improves soil fertility. Such conditions favour the growth of diverse plant species. Hence, cattle, antelope and bison often prefer to forage within prairie dog colonies. Thus, without the prairie dogs the grassland ecosystem would cease to exist or would be dramatically different from the original state.

Figure 1.3. Prairie dogs

Similarly, in the plains of Serengeti, lions are keystone species because lions limit the population density of zebras and allow other herbivore species to sustain within the vegetative carrying capacity. Without the population regulation through predation, zebras compete with other herbivores within a community and reduces the food resources for many species within the trophic levels.

The removal of keystone species from the community can lead to unstable community. For example, in the west coast of North America, experimental removal of starfish (*Pisastero chraceous*), which was the keystone species, resulted in the rapid increase in the population of mussels (*Mytilus californianus*). The mussels crowded the community to the extent that other species were eliminated which reduced the species diversity and stability of local food webs. Similarly, when prairie dogs are removed from the grasslands, the population of many other animals such as burrowing owls, swift foxes, rattlesnake and black-footed ferrets declines.

Reprint 2022

iii. Diversity

The diversity of a community is the number of different species it contains. Diversity depends on species richness, abundance and the evenness of species in a community. When ecological communities are more diverse, the communities are more stable and resilient. Figure 1.4 shows the diversity in a forest community.

Figure 1.4. Diversity of life in African Savannah

iv. Periodicity

Periodicity refers to the activity patterns of various life processes, such as respiration, growth, reproduction, feeding, and shelter during different times of the year. Community periodicities are associated with the daily rhythms of either diurnal or nocturnal, seasonal or tidal or lunar variations. For example, in daily periodicity, bees and wasps are diurnal while mosquitoes and cockroaches are nocturnal. Similarly, lungfish aestivate by burying themselves in mud and cover their bodies in mucus to hold in moisture for periods up to three years without water. Lungfish breathe using lungs instead of gills and get oxygen through mucous tube. Bears hibernate in the beginning of September or October and emerge six or seven months later. Bears live on the fat built up during the summer and the fall months.

Figure 1.5. Californian grunion

Californian grunion (*Leuresthes tenuis*), a small silvery fish leaves the sea to spawn in the sand of several Californian beaches. The spawning lasts from late February until early September but takes place only on three or four nights after the full or new moon. The spawning commences from one to three hours after the peak of spring tide and lasts for about an hour. The female swims on to the beach with an ingoing wave. She digs her tail into the wet sand and releases the eggs about 2 inches beneath the sand. The eggs are buried by about 8 to 10 inches of wet sand when the tide falls. The eggs get washed out of the sand again at the next spring tide cycle and hatch under the stimulus of wave agitation.

v. Stratification

Stratification refers to the community in which the population are spaced or distributed into horizontal or vertical strata. For instance, natural forest communities can be divided into different vertical strata as an emergent layer, canopy, understory and forest floor as shown in Figure 1.6.

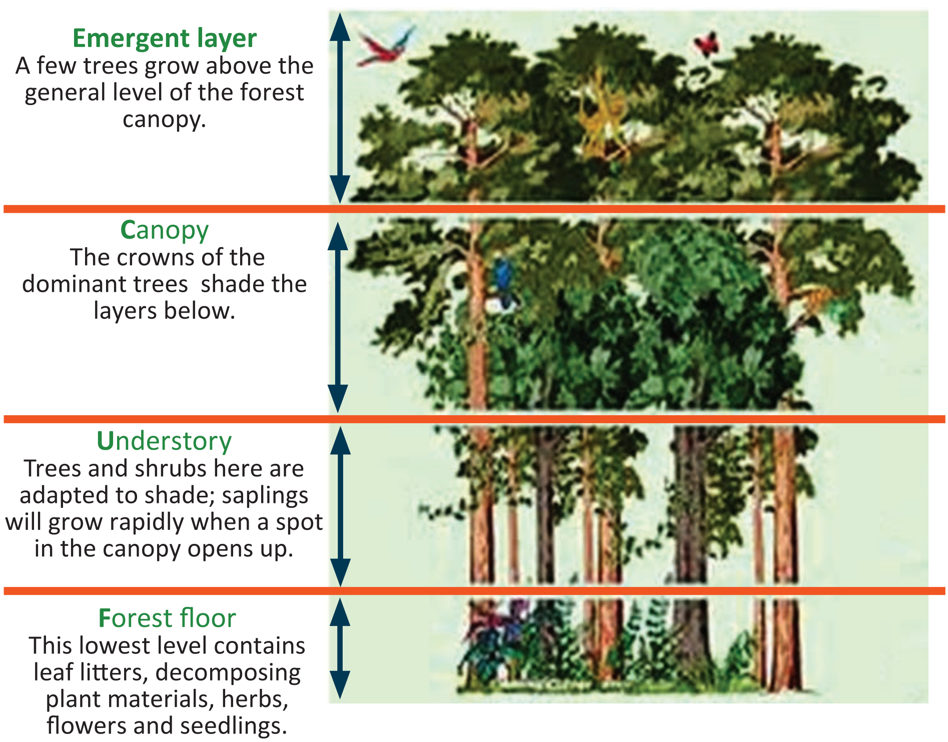


Figure 1.6. Vertical stratification in forest community

Similarly, horizontal stratification is the distribution of individuals on the floor which is categorised into three types: uniform, clumped (in groups) and random (irregular) distributions, as shown in Figure 1.7. Uniform dispersion occurs when resources like food, water and living spaces are limited. This also happens when there are competition and nesting. Clumped dispersion occurs when resources are clumped together. The flocks of birds, schools of fish and hives of bees are an

Reprint 2022

example of clumped dispersion. Random dispersion takes place in the case of seed dispersion by the wind or animals.

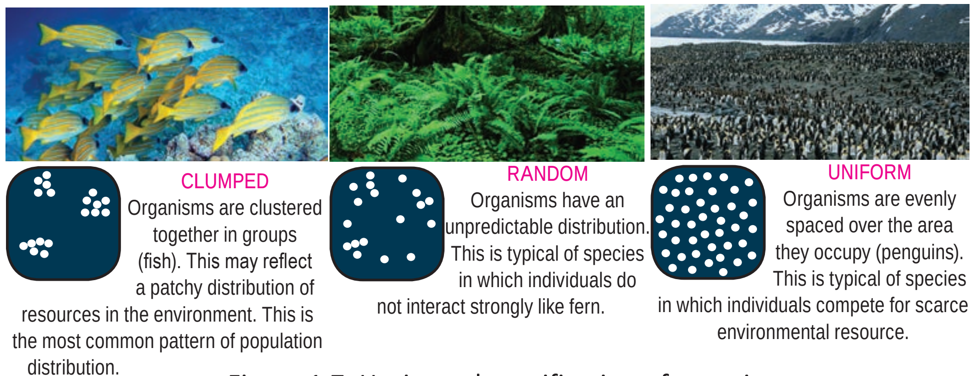


Figure 1.7. Horizontal stratification of organism

Animals also exhibit stratification as some live on the forest floor, some on shrubbery and low vegetation, and some on the treetops. Stratification of communities provides a variety of habitats which decreases the interspecific struggle. It also facilitates the effective utilisation of the Sun's energy by the organisms.

vi. Ecotone and edge effect

In between adjacent ecological communities, there lies a transitional zone having

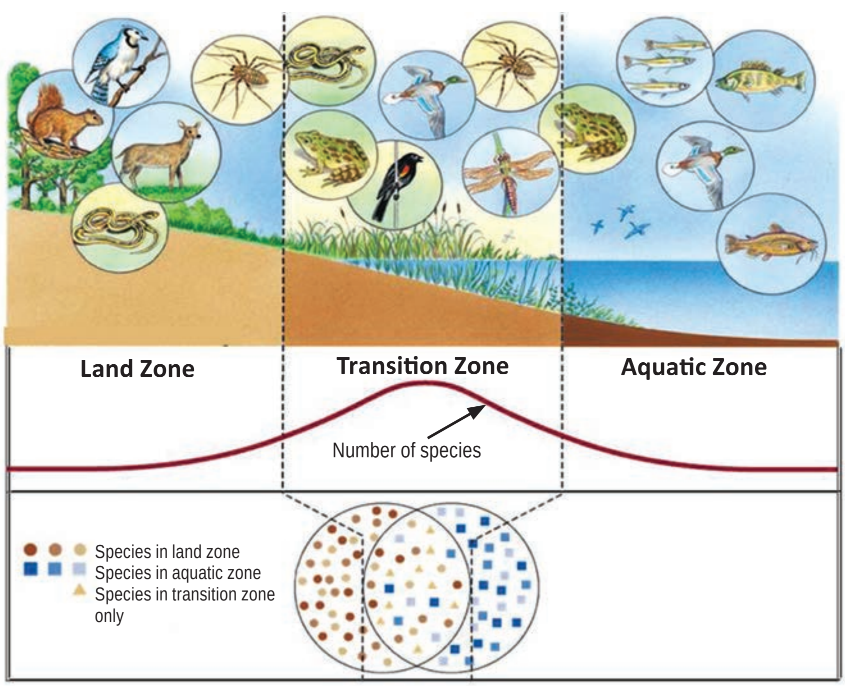


Figure 1.8. Ecotone and edge effect

a set of characteristics uniquely defined by space, time scales and strength of interactions. This zone is called ecotone. Ecotone can be very sharp like the boundary between the edge of a forest and a stream or diffuse like in the case of the transition between desert and savanna. An ecotone may be as narrow as one kilometre or as broad as hundred kilometres.

The ecotone offers an abundance of food and shelter. It contains organisms from both the communities. Thus, ecotones contain larger variety of species of plants and animals than either of the adjacent communities. This is due to the wider range of suitable environmental conditions. Such occurrence of increased variety and intensity of plants and animals at the ecotone is called edge-effect. Some species are completely restricted to the ecotone. They are called edge species.

vii. Ecological niche

An ecological niche is the collective set of roles and characteristics that organisms assume in the environment. A role can be as a competitor, predator, pathogen, etc. The ecological niche of a lion as a predator is depicted in Figure 1.9.

Figure 1.9. Ecological niche of a lion as predator

Ecological niche determines the survival and continuity of species in the community. Every population has an ecological niche, and this niche is the primary determinant of structural, physical and behavioural adaptations of the population in a community. Niches of distinct or even closely related species differ at least in some aspects, as interspecific competition minimises their overlap. Thus, no two species can occupy the same niche within a community, because when two species compete for the same habitat and resources, the stronger one will ultimately eliminate the weaker one.

The niche of organisms in a community is categorised into fundamental niche and realised niche. The fundamental niche refers to a wider range of environmental conditions, roles of species, and resources under which a species survives, grows, and reproduces under natural conditions, without much competition from others. The realised niche is the actual habitat where the organism finally lives and gets well adapted. The realised niche is generally smaller than the fundamental niche because of the interspecific interactions. For instance, raccoons live in forests and forests are their fundamental niche. However, today raccoons are well adapted to live in towns and cities and feed on garbage. Therefore, the urban environment is realised niche for raccoons.

viii. Interspecific association

In a community, no organism lives in absolute isolation. Organisms interact with the environment and other organisms in the community for its survival. The interaction of organisms between the species in a community is termed as an interspecific association. There are different interspecific associations such as competition, predation, parasitism, commensalism and mutualism. Figure 1.10 shows a mutualistic interspecific association between a bee and a flower, in which the bee transfers pollens while getting nectar from the flower.

Figure 1.10. Interspecific association between a bee and flower

ix. Community productivity

The net production of biomass and storage of energy by a community per unit time and area is known as community productivity. It is usually expressed in units of mass per unit surface per unit time (gram/metre^2/day). Figure 1.11 illustrates the productivity of biomass in the body of a rabbit in a community. The community productivity can be divided into two types: primary productivity, which includes the biomass of all the autotrophs (plants), and secondary productivity, which includes the biomass of all the heterotrophs (animals). In general, community productivity depends on certain factors like water, temperature, light, atmosphere, nutrients,

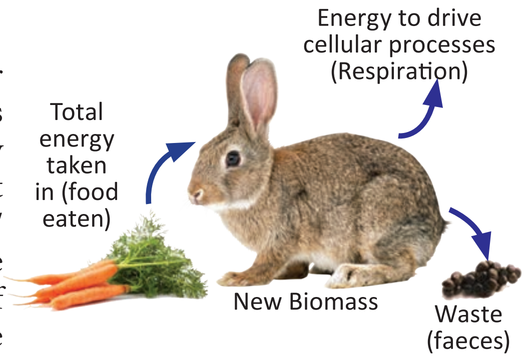


Figure 1.11. Biomass productivity in a rabbit

etc. Community productivity functions as an indicator of community's health, and measures the stability and sustainability of the community.

x. Biotic stability

The ability of a community to regain equilibrium and maintain homeostasis soon after a disturbance in the population of a species is known as biotic stability. Higher the diversity of species, more is the stability of the community, because it provides more alternative sources of food, prevents spreading of epidemics and promotes better adaptations with the same resources. The importance of biotic stability of a community ensures the continuity of biogeochemical cycles for the functioning of the ecosystem and prevent the extinction of species so that the biodiversity is conserved. Figure 1.12 illustrates the different phases that occur in a forest community to attain the biotic stability after it has been destroyed by fire.

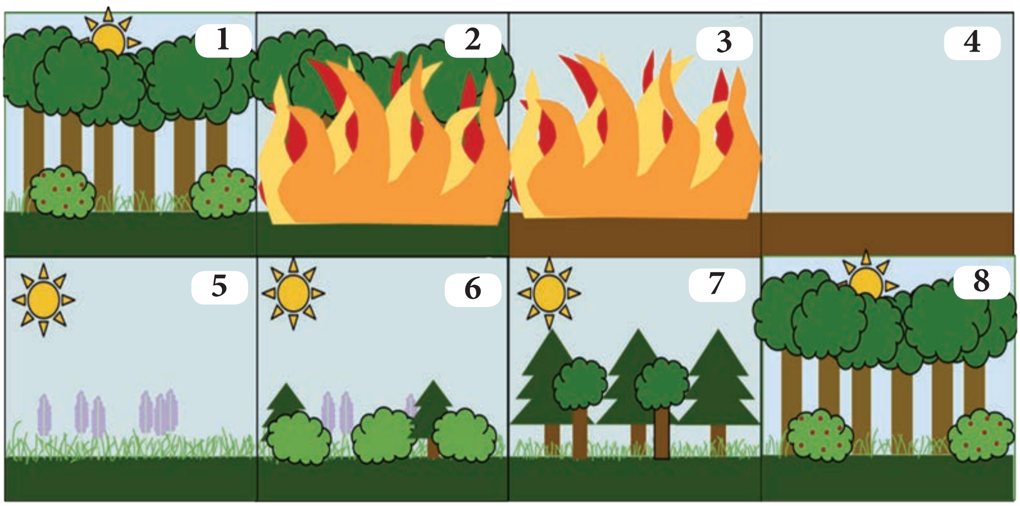


Figure 1.12. Phases undergone by a forest community to attain biotic community

Activity 1.1. *Exploring the characteristics of a community*

Instruction:

1. Watch videos on land and water community.
    - YouTube web link to land community video: https://www.youtube.com/watch?v=9bQNRVyI4I0
    - YouTube web link to water community video: https://www.youtube.com/watch?v=X3CmyWl8vc0

2. Observe the diversity in each video.

3. Use the idea from the videos to explore nearby land or aquatic community in groups.
4. Some groups may study land community while others study aquatic community.
5. Select an area in each community for your study. Your study may focus on structure, dominance, diversity, periodicity, niche, interspecific association and stratification.
6. Collect data and information from the area.
7. Compile the data and make a presentation describing the characteristics of the community that you have studied. Your presentation may be supported by photographs or pictures.

Questions

1. Differentiate the following terms:
   a) Habitat and niche.
   b) Community ecology and ecosystem ecology.
2. How important is an individual variation to population, community and ecosystem?
3. How does the ecological interaction between the species affect functioning of the ecosystem and its stability?
4. What can be the impacts of removing a dominant species from a community?

Explore:

https://www.youtube.com/watch?v=-VbR4S3ZuNQ

2. Ecosystem Services

Learning Objectives

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

- describe ecosystem services in relation to Bhutan's rich biodiversity.
- appreciate the importance of ecosystem services for the well-being of Bhutanese people.

Bhutan is a part of the Eastern Himalayan biodiversity hotspots due to her rich biodiversity. Bhutan contains twenty-three Important Bird Areas (IBA), eight eco-regions, a number of Important Plant Areas (IPA) and wetlands, including three Ramsar Sites. The rich biodiversity of Bhutan provides a number of natural services which are essential for people's health, prosperity and quality of life, as shown in Figure 1.13.

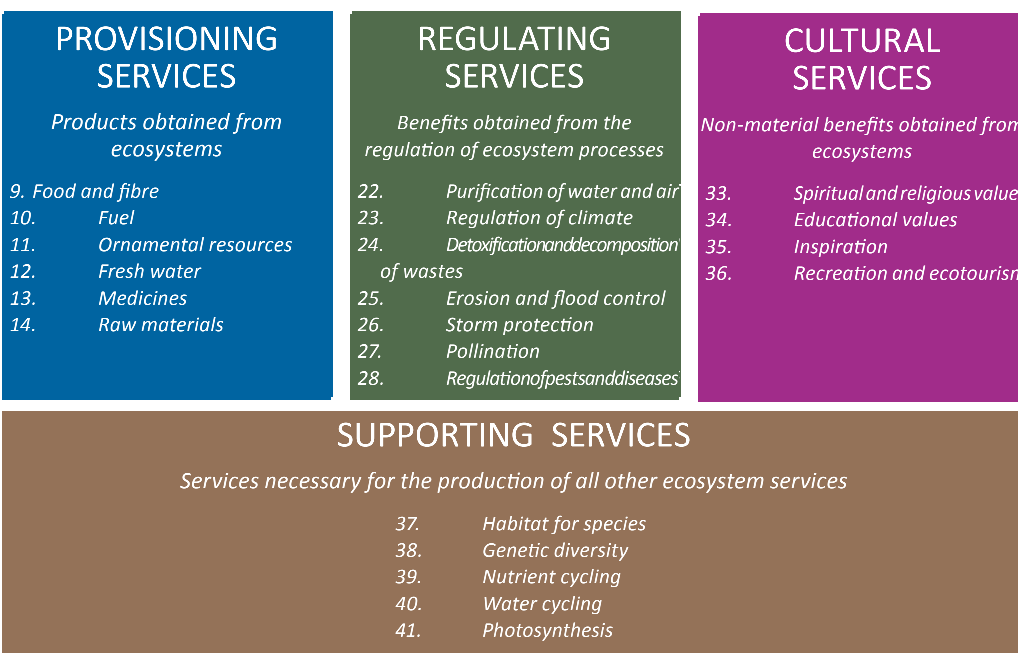


Figure 1.13. Ecosystem services

A. Provisioning services

Provisioning services are ecosystem services that describe the materials, products or energy outputs obtained from ecosystems. They include:

- ***Food and fibre:*** An ecosystem provides conditions for growing, collecting, hunting or harvesting food. Food comes from managed agro-ecosystems together with freshwater ecosystems or forests.
- ***Fuel:*** Wood, biofuels and plant oils are derived directly from wild and cultivated plant species.
- ***Ornamental resources:*** Animal products such as skins, shells and plumage of birds are used as ornaments. Aquarium fishes are kept as popular pets. Flowering plants are used for landscaping.
- ***Fresh water:*** Vegetation, particularly forests, promotes higher rates of evapotranspiration leading to increased atmospheric humidity and moisture leading to higher cloud formation and rainfall generation. Rivers are sources of hydro energy.
- ***Medicines:*** A wide variety of plants are used as raw materials for the pharmaceutical industries.
- ***Raw materials:*** A great variety of materials for construction and processing industries are derived from ecosystem.

B. Regulating services

Regulating services are the services that ecosystems provide by acting as regulators. They create and maintain healthy environmental conditions. Some of the examples are:

- ***Purification of water***: The process that regulates water quality includes plant and microbial nutrient uptake, pollutant sequestration in soil, breakdown of organic pollutants, acidity buffering and denitrification. For instance, wetlands filter both human and animal waste, decompose organic wastes through biological activity of microorganism and eliminate harmful pathogens. Wetlands also remove nitrogen and phosphorus from agricultural runoff preventing eutrophication of streams and rivers.
- ***Purification of air***: Ecosystem contributes to air quality by removing pollutants from the atmosphere. Oxygen released through photosynthesis enables the atmosphere to clean itself through oxidation of compounds such as carbon monoxide. Studies have found that, in urban areas, the presence of urban parks with good vegetation lowers the urban temperature and purifies air which significantly reduces the prevalence of early childhood asthma.
- ***Regulation of climate***: Ecosystem regulates the global climate by storing and sequestering greenhouse gases that keep the surface of the Earth at a temperature conducive for life. As trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it in their tissues. The dark

surfaces, especially those covered by evergreen forest absorbs more radiation than light surfaces covered by snow. Evapotranspiration from soil and plants, regulate the amount of water entering the atmosphere, cloud formation and influence the radiative properties of the atmosphere.

- ***Detoxification and waste decomposition***: The biological activities of organisms through bioremediation and phytoremediation detoxify the pollutants. Pollutants like ammonia and oxides of nitrogen are also assimilated by plants and microbial activities. The decomposition of organic wastes and debris by decomposers like bacteria, fungi and earthworm recycle the nutrients into the soil.
- ***Erosion and flood control***: In areas experiencing heavy rainfall, vegetation cover intercepts raindrops and allows rain to gradually descend into the soil, rather than hitting directly which may lead to soil erosion, landslides and flood. Similarly, wetlands act like sponges by absorbing rainfall and allowing it to percolate into the soil, thereby reducing the speed and volume of runoff entering streams and rivers, and preventing floods.
- ***Storm protection:*** Living organisms create natural barriers or buffers to mitigate the effects of some natural hazards. The presence of forest reduces the damage caused by windstorms. Trees also stabilise slopes and modify soil moisture protecting against soil erosion caused by wind.
- ***Pollination***: Birds, insects and wind help to pollinate plants which are essential for the development of fruits, vegetables and seeds.
- ***Regulation of pest and diseases***: The actions of predators and parasites as well as the defence mechanism of their prey regulate pests and diseases that attack plants, animals and people.

C. Cultural services

Cultural services are the non-material benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. Some of the cultural services are:

- ***Spiritual and religious values***: Natural features of the environment are often associated with the identity of an individual, a community or a society. Many religions attach spiritual and religious values to ecosystem and their components. Faith in religion and traditional knowledge creates a sense of necessity to conserve nature. Societies place a high value on the maintenance of historically and culturally important landscapes and significant species.
- ***Educational values***: Ecosystems and their components and processes that occur in the environment provide a basis for education. Natural setting is used for school excursions and scientific investigations.

- ***Inspiration***: Ecosystem provides a rich source of inspiration for art, folklore, national symbols, architecture and advertising.
- ***Recreation and ecotourism***: The peace and tranquillity of the beautiful landscapes and the amazing wildlife attract thousands of tourists. Recreational activities, such as walking, rafting, camping, safari and nature study provide opportunities for people living in an urban environment to experience the benefits of ecosystem services.

D. Supporting services

Supporting services are the life-supporting services provided by the ecosystems that help other processes in nature to work and maintain conditions. They include:

- ***Habitat for species:*** Ecosystem provides different habitats that are essential for individual plant or animal to survive, such as food, water and shelter. Migratory species like birds, fishes, mammals and insects all depend upon different ecosystem during their movements.
- ***Genetic diversity***: Ecosystem helps in maintenance of genetic diversity. A stable and healthy ecosystem consist of variety of habitats that support diverse flora and fauna. It provides suitable conditions for the survival and evolution of species that are less susceptible to pest and climate change.
- ***Nutrient cycling***: Ecosystem maintains the essential nutrients for life such as nitrogen and phosphorus at different concentrations. Nutrients are released into the environment through the life cycle of the organism as they die and decompose.
- ***Water cycling***: Water cycles through ecosystems and is essential for living organism.
- ***Photosynthesis***:Photosynthesis produces oxygen necessary for living organisms.

Activity 1.2. *Exploring ecosystem services*

Instruction:

1. Work in groups.
2. Visit a local community.
3. Prepare a questionnaire to interview the people in the community to find out: (Teacher may help students to prepare the questionnaire).
   a) various services availed by the community from the ecosystem.
   b) perceived threats to the ecosystem due to the services availed.

   c) some of the strategies followed to sustain the supply of services by the ecosystem.

4. Record, analyse and interpret the data collected from interview questionnaires and field observation.
5. Prepare a report of your findings and present to the class.

Questions

1. Which ecosystem service is utilised the most?
2. List all the cultural services provided by your local community.
3. Is there any over-utilisation of ecosystem services? Explain the threats posed due to the over-utilisation of the services.
4. List down some actions to prevent the threats listed above.

Questions

1. Explain the impact(s) on sustenance of livelihood due to lack of regulating services of ecosystem.
2. How does a rich biodiversity influence the provisioning services of ecosystem?
3. Evaluate the contribution of cultural services to the conservation of the biodiversity in the Bhutanese context.

3. Valuing Ecosystem Services

Learning Objectives

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

- explain the importance of ecosystem services valuation.
- interpret the values of ecosystem services from different perspectives.
- discuss various methods of ecosystem services valuation.
- relate the importance of ecosystem services valuation in the conservation of ecosystem.

Natural ecosystem provides services that are critical to the functioning of the Earth's life support system and contributes to human welfare. The well-being of the people depends largely on the ecosystem. As the demand for the ecosystem services is increasing rapidly with the population, the ecosystem services are becoming scarce. The ecosystem is being degraded in its capacity to provide services. Thus, understanding the role of ecosystem services in context of human wellbeing is necessary for conservation and sustainable use of ecosystem services. It has now become important to quantify the value of ecosystem through various approaches.

A. Ecosystem services valuation

Ecosystem services valuation (ESV) is a process of assessing an estimate of human impacts on the ecosystem due to continual use of resources. It determines the economic value (also known as total economic value) of ecosystem services in terms of sustainable use, fair distribution and efficient allocation of ecosystem services.

The valuation ranges from market price to replacement cost values. The market price value is the current economic value of ecosystem services such as water, wood and food resources while replacement cost value is the cost of replacing a functional ecosystem with a human-made system. A good example for this is the cost of replacing the natural process of waste treatment (i.e. by nutrient cycling) with waste treatment plant.

Total economic value (TEV) is the total gain in wellbeing from a policy measured by the net sum of the willingness to pay (WTP) or willingness to accept (WTA) for an ecosystem service. The TEV consists of a series of embedded values as shown in Figure 1.14.

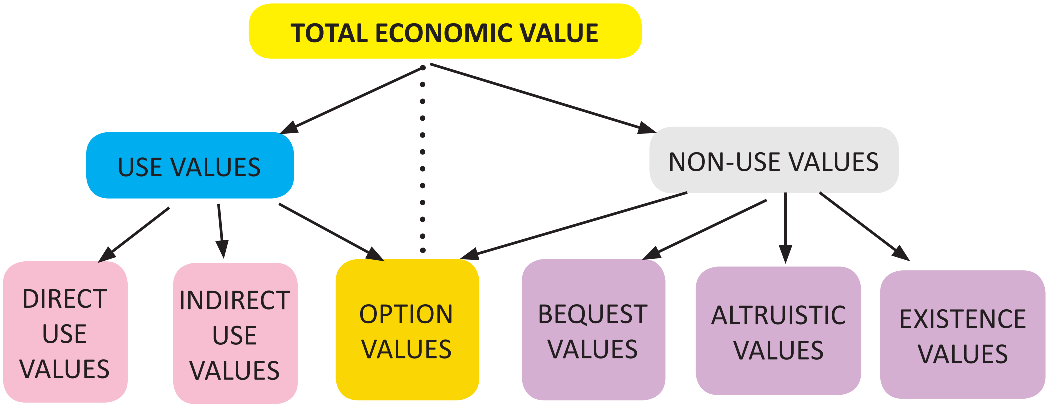


Figure 1.14. Components of total economic value of ecosystem services

The components of TEV are:

a. Use value

It involves interaction with the resources and is of three different types, i.e., direct use, indirect use and option value:

- ***Direct use value:*** It is a planned use of ecosystem services. It is either consumptive use where the resources are extracted from the ecosystem (e.g. food, timber) or non-consumptive use where the resources are used without extraction (e.g. recreation, site views). The services can also be marketable (e.g. timber) or non-marketable (e.g. aesthetic beauty that people enjoy by direct observation).
- ***Indirect use value:*** It refers to the value of some processes that support the ecosystem services and are not used directly. For example, processes like regulating fertility, air quality, climate and nutrient cycling are not used directly but they have some embedded value for the production of services we use.

b. Non-use value

It is derived from the knowledge that people have regarding the sustainable use of ecosystem services. It contains three main components:

- ***Bequest value:*** The value that arises from the fact that the ecosystem resource will be passed on to future generations. For example, protection of water sources so that the water resources are sustained for future generations.
- ***Altruistic value:*** The value that people place in making the ecosystem resources available to others in the current generation. For example, cleaning campaign by schools in public places.

- *Existence value:* The value people place for the existence of an ecosystem resource though they may not have the intention to use the service. For example, people willing to pay/donate for the protection of whales though they may not derive any benefit from it.

c. Option value

It incorporates the fact that we are uncertain of the future values of an ecosystem. These are not use value since they are not derived from current use nor non-use values because the service may have a future use. For example, people are willing to pay for the protection of a national park though they may not have the intention to visit it. They create an option for some possible uses in future. Such values act as insurance for conserving ecosystems for future.

B. Importance of ecosystem service valuation

The ecosystem service valuation creates a better understanding of the importance of nature and impacts of human activities on the environment. It has huge implications on planning and implementation of projects in regard to the environmental protection and conservation. Some of the major importance of ESV includes the following:

- It helps in making guided decisions on activities for ecosystem conservation, preservation and restoration.
- It ensures efficient use of public funds and helps maximise the environmental benefits for the sum paid by people for using ecosystem services.
- It encourages public participation in environmental initiatives for protection and conservation.
- It assesses the impact of human activities on the environment and helps to plan to minimise the exploitation of natural resources.
- It assesses and identifies sites where exploitation is extensive and accordingly makes place-based policies for utilisation of natural resources.
- It provides the knowledge on proper utilisation of ecosystem services to ensure a sustainable use.
- It helps in determining the restoration cost of ecosystem services in a particular area.

C. Payment for ecosystem services (PES)

A major role of ESV is to ensure a sustainable use of ecosystem services along with conservation of the ecosystem from where the service is derived. Schemes like Payment for Ecosystem Service (PES) are implemented for sustainability of ecosystem services.

Payment for ecosystem services is the system of monetary payments made to stakeholders, such as farmers and landowners for abstaining from environmentally harmful practices. Such scheme contributes to the maintenance and preservation of ecosystem services. It is a benefit-sharing mechanism between the suppliers and consumers. In Bhutan, Watershed Management Division (WMD), under Department of Forest and Park Services, has been planning and implementing PES. A case study on Yakpugang PES scheme in Mongar is a good example:

Activity 1.3. *Exploring on payment for ecosystem services*

Instruction:

Read the case study and answer the following questions.

Yakpugang Payment for Ecosystem Service Scheme

Of the three pilot sites recommended in the PES Feasibility Study, October-November 2009, a PES scheme has become operational in Yakpugang community forest in Mongar with support from the SNV. The scheme focuses on protection and enhancement of the Yakpugang community forest, which forms a catchment area and serves as the main source of water for Mongar township.

The PES scheme is based on a contractual agreement signed between the Yakpugang community forest management group (as service providers) and the municipal authority of Mongar town (as service recipients). The agreement lists six specific activities pertaining to grazing control, protection of community forest against illegal extraction, maintenance of buffer area (with no clearance of vegetation) along the streams and above the source, and removal of forest debris from the streams.

In fulfilment of the specified activities (verified by the verification and monitoring team), the community forest management group is to receive Nu. 52,000 annually from the municipal authority of Mongar town.

Source: Consolidated report on review, project proposal and programmatic framework, July 2012

Questions:

1. How does the scheme benefit the Yakpugang community and Mongar town?
2. What are the activities carried out by the community for making the scheme effective?

Reprint 2022

3. Why is Mongar municipality willing to pay Nu. 52000 to Yakpugang community?
4. Suggest some areas near your community where PES can be applied.

D. Methods of ecosystem service valuation

There can be several methods used for valuation of ecosystem services, depending on the relevance to the ecosystem, where the valuation is conducted. Some of the methods include the following:

a. Market price method

This method deals with valuation of those ecosystem products and services that are bought and sold in the commercial markets. Using the standard economic techniques, the economic benefits of goods and services are evaluated qualitatively and quantitatively. It also considers the demand and supply of particular goods or services in order to determine their price.

Activity 1.4. ***Determining ecosystem service valuation by market price method***

Instruction:

1. In groups, study the given situation in Box 1.1.
2. Follow the steps to determine the total economic loss using the given data.
3. After completion of your activity answer the questions that follow:

Box 1.1. A situation of commercial fishing area in Samdrup Jongkhar

A commercial fishing area in Samdrup Jongkhar has been closed due to the decline in fish production which resulted from water pollution. The management wants to evaluate the loss.

Before pollution, the market price of fish was Nu 50 per kg and maximum Willingness to Pay (WTP) by consumers was Nu 100 per kg. The total fish production was 10,000 kg and consumers spent a total of Nu. 500,000 in that year. The fishermen were paid Nu.10 per Kg and the variable cost of production was Nu 5.00 per kg.

However, after pollution the variable cost of production increased to Nu 6 per kg and market price rose to Nu. 70.00 per Kg though the fishermen were paid Nu 10 per kg. The total production decreased to 6000 kg and consumers spent Nu.420,000 that year.

Step 1. Calculate the consumer surplus before pollution.

$$\text{Consumer Surplus} = \frac{\text{(WTP - Market price of fish) x Total spending before pollution}}{2}$$

Step 2. Calculate the consumer surplus of fish after pollution.

$$\text{Consumer Surplus} = \frac{\text{(WTP - Market price of fish) x Total spending after pollution}}{2}$$

Step 3. Calculate the loss in economic benefit to consumer.

Loss in economic benefit = consumer surplus before pollution – consumer surplus after pollution

Step 4. Calculate the producer surplus before pollution.

Total variable cost = variable cost (before pollution) X total production (before pollution) producer surplus
= total spending (before pollution) - total variation cost

Step 5. Calculate the producer surplus after pollution.

Total variable cost = variable cost (after pollution) X total production (after pollution) producer surplus
= total spending (before pollution) - total variation cost

Step 6. Calculate the loss in producer surplus.

Loss in producer surplus= producer surplus before pollution – consumer surplus after pollution

Step 7. Calculate the Total economic loss.

Total economic loss = loss in consumer surplus + loss in producer surplus

Questions

1. How does consumer surplus differ before and after pollution?
2. How will the result differ if the pollutants are removed? Why?
3. What is the purpose of determining total economic loss for the above situation?
4. Relate the economic loss to the status of the ecosystem services.

b. Productivity method

Productivity method is used to determine the economic value of ecosystem goods and services that influence the production of commercially marketed goods. This approach selects those goods and services that are used along with other inputs for the production of commercial goods. It is more applicable to cases where only producers are affected by the change of the resources while consumers remain unaffected.

For instance, if an agency that supplies water to a town has a concern over pollution of water reservoir due to surface runoff, the cost of purification of water will escalate after contamination, as more chemicals and filters are required for purification. The agency has two options: first, invest more on purification of water or second, take measures for minimising surface runoff to reduce the cost of purification. For valuation, the agency measures the benefits concerning the cost of purification before and after minimising surface runoff. Finally, they compare the benefits and come up with a decision. For example, the cost of purification before minimising surface runoff is Nu. 10,00,000 per year, while the cost of purification after minimising surface runoff is Nu. 500,000. The agency opts for the second since there is a benefit of Nu. 500,000 per year. At the same time, to minimise surface runoff, the agency plants trees around the reservoir, which is ecologically beneficial for the sustenance of ecosystem service.

c. Hedonic pricing method

This method is used to determine the economic values for ecosystem services that have a direct influence on the market price of other commodities. Such services might not have an immediate economic use to the consumers. However, they have a direct effect on how economic goods and services are priced.

Hedonic pricing method is used to value the environmental attributes, such as noise, air and water quality, and ecological amenities like beautiful views that directly affect the price of residential properties. For example, people will be willing to pay more for houses with good water quality and supply, though they may not need to pay for water. In this case, water is being an influential factor in determining the house rent, thus, showing that water has a certain intrinsic value that influences the market price.

d. Benefit transfer method

It is used to estimate the economic values for ecosystem services of a site, using the information from assessments that had been carried out for some other similar sites. For example, values for wetland protection in a particular district may be estimated by applying values of wetland protection from a study conducted in another district.

Benefit transfer method is used when time, fund, data availability or other factors hamper the conduct of original valuation study of ecosystem service at a particular site, where some measure of benefits are needed regardless. This method is more reliable for making estimates of recreational values.

Questions

1. Why is the knowledge of ecosystem service valuation important for policy makers?
2. A park is being upgraded to provide additional recreational opportunities. One proposal is to add a swimming pool. Park staff want to know the benefits of the swimming pool but do not want to spend an enormous amount of money on valuation study. Which type of ecosystem service method will you use for the valuation study? Support with reasons.

Reprint 2022

Exercise

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

   i. Identify the supporting services from the following:

   A. Roots of the trees hold soil and water.

   B. Plants produce oxygen necessary for living organisms.

   C. Transpiration from leaves maintains the temperature of the plant.

   D. Flowers serve to beautify the area.

   ii. The realised niche of an organism is the

   A. area a species can occupy in the face of exploitive competition.

   B. habitat of a species within a community resulting from clumping.

   C. habitat that exists in nature as opposed to the ideal.

   D. life pattern that the organism assumes.

   iii. Keystone predators can maintain species diversity in a community if they

   A. prey on the community's dominant species.

   B. competitively exclude other predators.

   C. allow immigration of other predators.

   D. prey only on the least abundant species in the community.

   iv. Which of the following items are included within the definition of Total Economic Value?

   I. *Existence value*

   II. *Nuisance value*

   III. *Use value*

   IV. Correction value

   A. I and IV

   B. II and III

   C. I and III

   D. I, II, and IV

v. Which of the following is referred to as the hedonic price method for valuing environmental assets?

A. Using linkages between variations in house prices and geographical proximity to an environmental asset.

B. Using option value to estimate the value of an environmental asset.

C. Using existence value to estimate the value of an environmental asset.

D. Using willingness to pay to value an environmental asset.

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

i. People visiting Aja Ney in Mongar is an example of ……………..ecosystem service.

ii. Deer living in forests eating plants without resource limitation is ……………..niche.

iii. The diversity of organisms is larger in the .... zone than in the adjacent communities.

iv. The community forest is an example of ……………..value.

v. The …………….. method is used for valuation of those services that influence the price of other services.

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

i. A natural forest community can be divided into different horizontal strata.

ii. Dominant species is one that has the greatest effect on all the other species in an ecosystem.

iii. Water cycle and nutrient cycle are examples of regulating services of the ecosystem.

iv. Plantation of tree sapling is an example of bequest use value.

v. PES is an approach for valuation of ecosystem services.

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

i. Explain how ecosystem helps in purifying the air.

ii. Discuss how the canopy of the trees affect the abiotic factors and other species present in the forest.

Reprint 2022

iii. Study Figure 1.15 and answer the following questions:

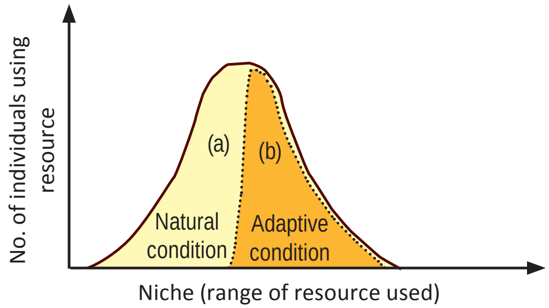


Figure 1.15.

a. Identify the niche of ‘a’ and ‘b’ in the graph.

b. What are the differences between the individuals in ‘a’ and ‘b’?

c. Why do different species in the ecosystem have different niche?

iv. Study Figure 1.16 and answer the questions that follow:

Figure 1.16.

a. Identify the possible ecosystem services that the figure represents.

b. Which ecosystem service valuation method is most appropriate for the valuation study of this place?

c. What environmental attributes should you use for the valuation study?

v. Which of the following ecosystems will be more productive in terms of primary productivity? Justify your answer.

[young forest, old natural forest, shallow polluted lake, alpine meadow].

vi. Explain the relationship between the ecosystem and society by studying

Figure 1.17.

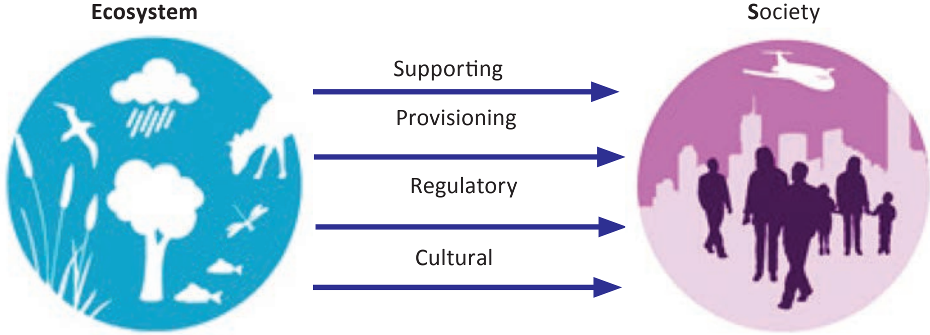


Figure 1.17.

vii. Study Figure 1.18 and answer the questions that follow:

a. What does the figure represent?

b. Why do warbler species occupy different parts of the tree?

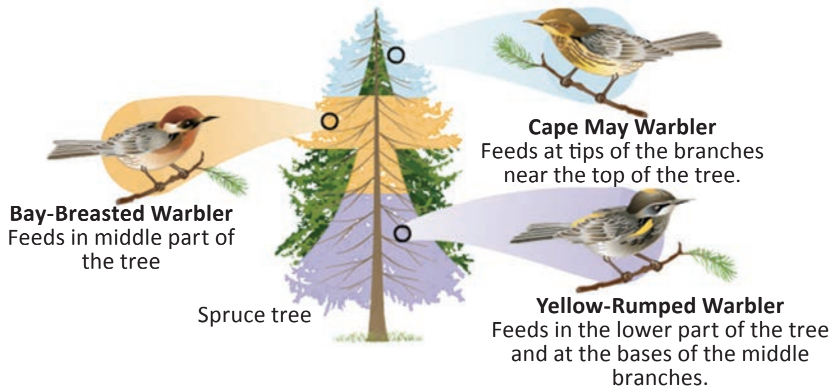
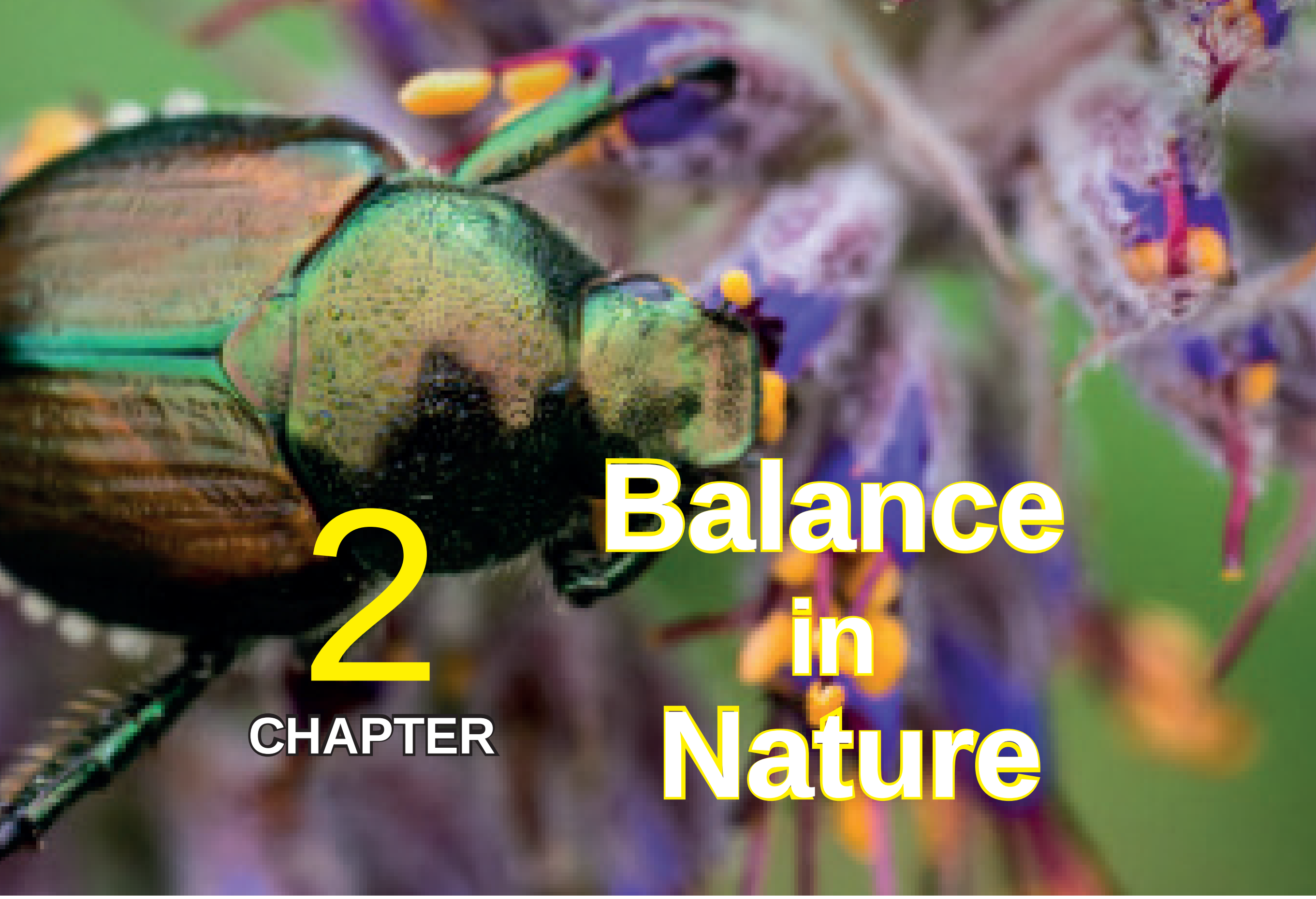


Figure 1.18.

c. What will happen if two warbler species attempt to occupy the same niche?



CHAPTER 2

Balance in Nature

Nature has an inherent ability to sustain various life forms and processes. A homeostatic mechanism called ecological succession maintains balance in nature and is regulated by a variety of environmental factors. It leads to the formation of a stable ecosystem that caters to the needs of the organisms living there. Succession exhibits the important perspectives of ecological resilience and brings proper balance between nature and the disturbing processes.

Reprint 2022

1. Ecological Succession

Learning Objectives

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

- distinguish between ecological time and geological time.
- describe succession caused by natural and anthropogenic disturbances.
- explain the causes of ecological succession.
- explain the evolution of a plant community.
- appreciate the importance of ecological succession for Bhutan.

The formation of stable ecosystem occurs through a slow process, influenced by a variety of natural and anthropogenic factors. These factors and organisms together change the environmental conditions, resulting in changes in the community and establishment of the most stable ecosystem.

A. Biological communities change over time

Biological communities are dynamic and undergo a gradual, progressive and predictive change which is termed as ecological succession. Ecological succession is defined as a gradual process by which an ecosystem develops over time with the replacement of a community by a relatively stable community leading to the establishment of the most stable and self-perpetuating community. Organisms living in a community keep changing, either by adaptation or replacement by

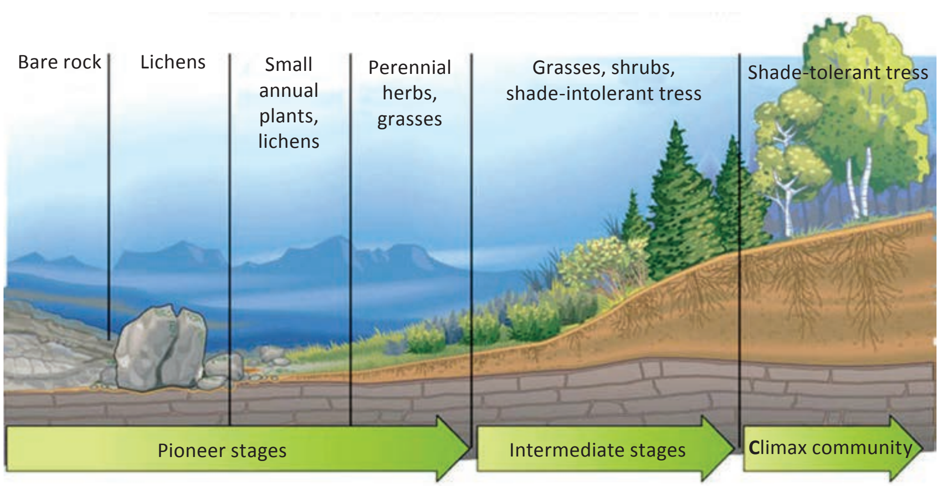


Figure 2.1. A forest succession

Reprint 2022

more stable ones. The change continues over time leading to the formation of the most stable community called climax community as shown in Figure 2.1. The climax community is highly stable, formed at the later stage and has more diversity and proper organisation of ecological niche. For example, a forest as a climax community has diverse forms of organisms and is self-perpetuating. The climax community continues to undergo minor developmental changes though the changes are not pronounced like in the earlier stages of succession.

The change in communities is driven by climate, edaphic conditions and association of organisms. Organisms inhabiting an ecosystem tend to change the environment. Some organisms adapt to the changing environment, but many cannot adapt and are therefore replaced by superior ones. This progressive change continues even after the most stable community is formed.

B. Causes of ecological succession

Ecological succession is regulated by a number of factors from its onset and even after the formation of a climax community. These factors are termed as 'Causes'. The causes are categorised as following:

(i) Initiating causes

The initiating causes are also referred to as disturbances. These are factors responsible for the destruction of the existing ecosystem after which ecological succession sets in on a particular site. The initial causes are either abiotic or biotic types. Abiotic events include landslides, soil erosion, fire, windstorms and volcanoes while biotic events include disease, grazing, pests, deforestation, etc.

(ii) Continuing causes

These are processes that bring constant changes in the structural composition of the community and the physical environmental conditions. Continuing causes include migration, aggregation and competition that cause changes in pH, humus content, soil mineral content, species composition, etc.

(iii) Stabilizing causes

These are the factors that stabilise the community composition. The factors are climatic conditions, soil fertility and water availability. For example, a climatic condition of an ecosystem influences the diversity, stratification, niche organisation and distribution of organisms in an ecosystem, which makes the ecosystem stable.

C. Disturbances in ecological succession

Disturbance refers to discrete events that bring changes in the structure, resources availability and the physical environmental conditions of an ecosystem. Events, such as fire, volcano, soil erosion and other anthropogenic activities bring huge changes within a short span of time leading to ecological disturbance. For example, volcanic lava destroys the entire ecosystem and changes the physical environmental conditions. Though the environmental conditions may become hostile for many species, some species can thrive and prepare the environment to regenerate the ecosystem. The magnitude of ecological disturbances are generally attributed to their types or nature, severity or intensity, and frequency of the events.

The ecological disturbances can be of natural or anthropogenic origin. Natural events such as volcanoes, cyclones, tornadoes, earthquakes, wildfires, tsunamis, avalanche and glacial retreat cause disturbance to ecosystem. The anthropogenic activities, such as agriculture, construction, mining, logging and scientific advancement are some of the prominent causes of ecological disturbances. These events exert a high degree of stress on the ecosystem and sometimes even wipe out the entire ecosystem.

Activity 2.1. *Exploring the causes of ecological disturbances*

Materials required:

Journals and internet sources

Instruction:

In pairs, carry out a literature research on the ecological disturbances caused by various natural and anthropogenic activities. Copy and complete Table 2.1.

Table 2.1. Events and their disturbances to nature.

Event	Category of disturbance (Natural /anthropogenic)	How does it cause an ecological disturbance?
1. Volcano		
2. Tsunami		
3. Storm		

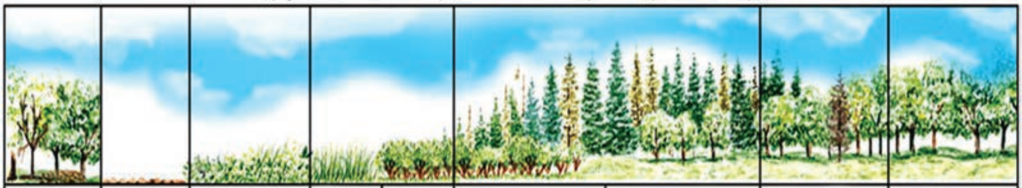
4. Construction		
5. Logging		
6. Agriculture		
7. Scientific advancement		

Questions

1. What are the differences in the severity of ecological disturbances caused by natural and anthropogenic events?
2. Identify the events of ecological disturbances that are common in Bhutan.
3. What are the common impacts of all the ecological disturbances?
4. Besides the negative impacts of ecological disturbances, they have positive impacts on the environment. Explain.

D. Ecological and geological time

The time frame in which an ecological succession occurs is termed as ecological time. The ecological time scale is the representation of ecological time, focusing on the events that occur in the order of tens to hundred years. It denotes the time taken for the progression of ecological succession through various stages in a particular area and gives an estimate of the time taken by each stage, as shown in Figure 2.2.



Mature oak/hickory forest destroyed	Farmland abandoned	Annual plants	Grasses and biennial herbs	Perennial herbs and shrubs replace grasses and herbs	Pines begin to replace shrubs	Young oak and hickory tress begin to grow	Pines die and replaced by mature oak and hickory tress	Mature oak/ hickory forest
		1-2 years	3-4 years	4-15 years	5-15 years	10-30 years	50-75 years	

Figure 2.2. Ecological time scale showing time frame for ecological succession

Geological time is the span of time since the formation of Earth till the present time. The geological time scale is the representation of geological time focusing on events in the order of thousands of years or more as shown in Figure 2.3.

Geological time scale depicts the course and pattern of evolution of living organisms. The entire time is divided into eons, eras, periods and epochs. It is constructed based on the fossil evidence that have been gathered for different organisms. The time scale specifies the evolutionary events in sequential order.

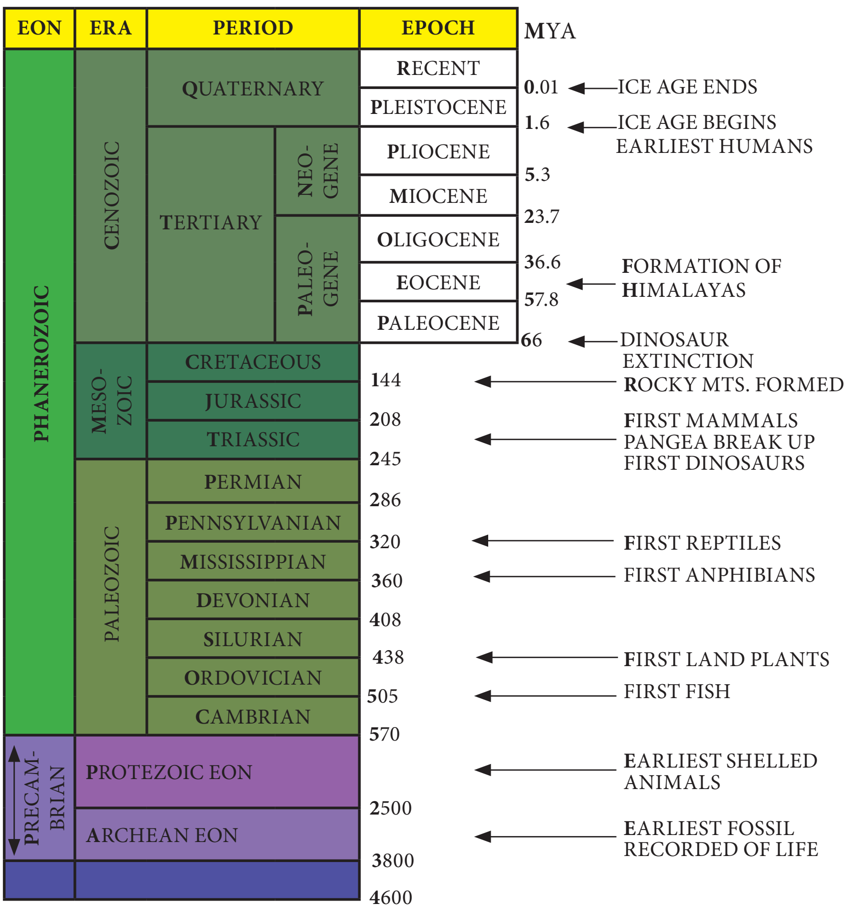


Figure 2.3. Geological time scale

E. Processes of succession

An ecosystem does not remain the same and keeps constantly changing due to the biotic or abiotic factors. The process continues and successive communities develop one after another in the same area until a highly stable community is formed. In an ecological succession, organisms can be classified into different groups or communities as discussed in the following sections:

(i) Pioneer community

Succession begins with colonisation of an area by some species that are tolerant to a hostile environment. These species are called pioneer species and it includes organisms like crustose lichens, bacteria, mosses, annual and perennial grasses and herbs. These organisms create a new microenvironment and form the first community in the area, which is called pioneer community. Gradually the pioneer species modify the environment by soil formation and the addition of organic food. This creates a suitable environment for new organisms and supports the continuity of succession.

Figure 2.4. Pioneer community

(ii) Seral community (or sere)

A seral community is an intermediate community that develops during ecological succession in an ecosystem advancing towards its climax community. In many cases, more than one seral community evolves until the climax conditions are attained. A sequence of seres is characterised by changes in the sets of populations present, increase in the diversity of species and increase in the total quantity of the living mass. The sequence of seres for a given region is often fully predictable with respect to the general types of the population expected at each sere and seral durations. For example, ecological succession in a terrestrial ecosystem includes seral stages such as annual grasses, perennial grasses, shrubs and a few trees. The stages are named based on the species that are physically dominant in the community.

Figure 2.5. Seral community

(iii) Climax community

A climax community is the final stage of ecological succession in which population of plants and animals remain stable and exist in balance with each other and their environment. The climax community contains different types of organisms, including those that were present in the earlier stages of succession. The presence of diverse forms of organisms helps in proper niche organisation and stabilisation of the ecosystem.

Activity 2.2. *Identifying organisms in ecological succession*

Materials required:

Spade, pencil and notebook.

Instruction:

1. Choose an area of approximately 1 m x 1 m, preferably the one which is not being disturbed or used much for other purposes.
2. Dig the area uniformly all around 15-20 cm deep and remove the layer of soil dug.
3. Fence the area to protect it from disturbances.
4. Observe the area at a regular interval and record in Table 2.2. (You may have to observe on a monthly basis for a year.)
5. You may also look for youtube videos on ecological succession to carry out this activity.
6. Answer the questions at the end of the activity.

Table 2.2. Living organisms appearing in different seral stages.

Date	Description of observation	Names of organisms (both plants and animals)	Name the seral stage

Questions

1. Explain the factors that supported the life of pioneer species in the area.
2. Predict how the pioneer species might change the existing conditions in the study area during the next two years.
3. Describe your observation in terms of ecological succession.

F. Steps of succession

In general, ecological succession describes the process of development of pioneer communities, seral communities and the stabilisation towards climax community. The basic steps identified in the process of succession are:

- *Nudation:* It is the destruction of an ecosystem leading to loss of entire ecosystem.
- *Migration:* Arrival of seeds, spores or other reproductive propagules to

Reprint 2022

inhabit the bare area. They are non-native to the area but are able to establish their community based on the environmental conditions.

- *Ecesis:* Initial establishment or colonisation of plant community in the new area through germination, growth and reproduction. This step helps to improve the conditions in the area for the growth of other species.
- *Aggregation:* Increase in population of the species which have established in the area come close to each other. They serve as a source of food for future inhabitants.
- *Competition:* Inter-specific and intra-specific competitions start for the resources as the organisms are aggregated. The species that are unable to compete with other species are normally discarded or replaced by superior ones.
- *Invasion:* Elimination of some species and change in the environment causes invasion of the ecosystem by some new species. The new invaders are usually superior to the native species and dominate the ecosystem.
- *Reaction:* Interactions of organisms within themselves and with the environment result in the changes in soil, water, light conditions, temperature, etc. The changed environment sometimes becomes unsuitable for the existing communities and they are completely replaced by another community.
- *Stabilisation or climax:* The community becomes more or less stabilised for a longer period and it maintains itself in equilibrium with the climate of that area. Thus, a climax community is mature, stable and self-sustaining.

When the successional environment becomes best suited to the current species in the community, the community becomes stable and reaches ecological equilibrium. At this stage, the community does not show profound changes in the environmental conditions and species composition.

Activity 2.3. *Enquiring merits and demerits of ecological succession*

Materials Required:

Questionnaires, pen and notebook.

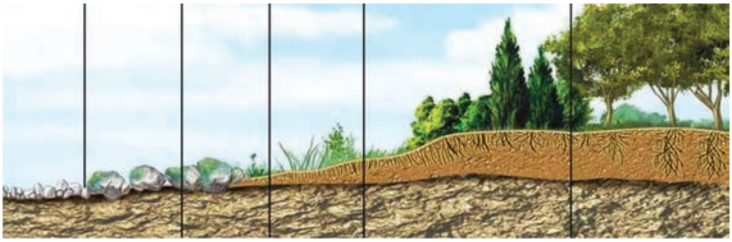
Instruction:

1. Use different sources of information to carry out this activity, including an interview with a few senior citizens.
2. Base your enquiry on the following:
   a. area(s) where ecological succession has/have been occurring over the last decade.

b. sequential ecological changes in terms of vegetation and animals supported by the factors that have influenced the changes.
c. factors that caused ecological succession in that area.
d. ecological succession on the livelihood in the community.
e. your opinions on the ecological succession

Questions

1. Most pioneer species are autotrophic in nature. Relate its significance to succession.
2. Study Figure 2.6 and answer the following questions:



(a) (b) (c) (d) (e) (f)

Figure 2.6

a) Assign the following plants to various stages of the ecological succession based on their order of appearance as shown in Figure 2.6.
   i. Perennial herbs and grasses
   ii. Shade-tolerant trees
   iii. Grasses, shrubs, shade-intolerant trees
   iv. Lichens
   v. Small annual plants and lichens

b) Explain the most significant difference between the stages ‘e’ and ‘f’.

c) Which stage in the picture can be considered as the ‘reaction’ step of succession? Why?

2. Kinds of Ecological Succession

Learning Objectives

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

- describe the kinds of ecological succession.
- explain that ecological succession leads to the stable ecological system.
- explain the significance of ecological succession in an ecosystem.

The influence of internal and external factors on ecological succession results in a variety of ecological successions. The variations in succession are observed in terms of pace of succession, pattern of succession, place of occurrence, etc. The variation in the pattern of ecological succession has led to the formation of a variety of ecosystems on the Earth.

A. Classification of succession

There are various types of succession based on different aspects like location, initiating factors and nutritional contents, which are discussed below.

On the basis of inhabitation of the place where ecological succession occurs, it is classified into primary and secondary succession as follows:

(i) Primary succession

The ecological succession occurring in a place that was previously uninhabited and lacks soil is called primary succession. Succession occurring on bare rock and Earth's surfaces exposed by glacial retreats, cooled volcanic lava and sand dune are some of the examples of primary succession. Primary succession is initiated by pioneer species, such as lichens, mosses and other lower plants which do not require deeper soil to survive as shown in Figure 2.7.

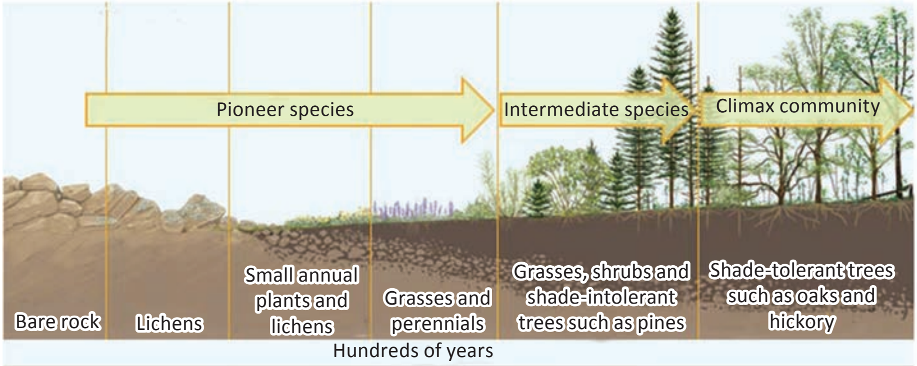


Figure 2.7. Primary succession

(ii) Secondary succession

The succession occurring in an area which was initially inhabited but destroyed by natural or anthropogenic disturbances is called secondary succession as shown in Figure 2.8. Succession occurring in abandoned crop field, deforested area or forest destroyed by fire, land devastated by flood or windstorm are some examples of secondary succession. Secondary succession can be referred to as a repairing process of a damaged ecosystem, and it occurs faster than the primary succession as soil sediments are already available that favour the growth of organisms.

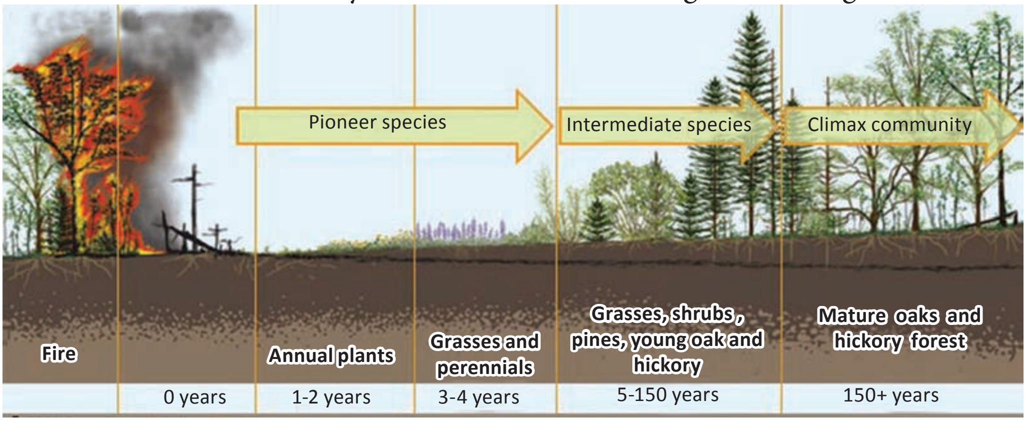


Figure 2.8. Secondary succession

On the basis of the factors that initiate or cause ecological succession, it is classified into autogenic and allogenic successions as follows:

(i) Autogenic succession

It is caused by interactions of organisms within the community which modify their environment leading to the replacement of the old community by a new community. For example, light requiring species growing under the tall trees die due to the shade, and gradually, a new community with shade tolerant species grow in the shade.

(ii) Allogenic succession

It is initiated by changes in the environmental conditions due to physical processes, such as soil erosion, leaching, volcanic eruption, deposition of silt, etc. These activities change the soil pattern and nutrient content of the soil, aiding the establishment of a new community. For example, volcanic eruption changes the ecosystem and soil fertility rendering it unfavourable for the native species, but making the area suitable for a new community. Animals also play an important role in allogenic succession because of natural activities like overgrazing, seed dispersal, pollination, etc.

On the basis of the organisms that dominate the earlier stages of the ecological succession, it is classified into autotrophic and heterotrophic successions as follows:

(i) Autotrophic succession

Ecological succession in which plants dominate the earlier stages of succession. Autotrophic succession begins in an inorganic environment. Gradually, the autotrophs change the environment making it suitable for other organisms to flourish.

(ii) Heterotrophic succession

In this type of succession, the heterotrophs are dominant, and it occurs in an organic environment. The pioneer species usually consists of bacteria, fungi and smaller animal species. It is relatively faster than the autotrophic succession due to the pre-existing food sources available for the organisms.

On the basis of nature of the habitat in which the succession occurs, ecological succession is classified as follows:

(i) Hydrosere

It is the succession occurring in aquatic habitats like ponds, pools and lakes. For example, a wetland is an intermediate stage of hydrosere, since it is the phase between fresh water and dry land. The pioneer species include phytoplanktons, diatoms and aquatic algae.

(ii) Xerosere

It is the succession that begins in a dry, bare land and is limited by water scarcity. Xerosere may include lithosere and psammosere. Lithosere occurs on dry surfaces of rocks and includes pioneer species, such as crustose lichens and some smaller bacteria. Psammosere occurs on sandy habitats and the pioneer species include salt tolerant species, such as littoral algae, glasswort, etc.

(iii) Halosere

It starts in saline soil or water and the pioneer plants are halophytes, such as *Salicornia* sp. and *Spartina* sp.

Serule (Microsuccession): It is the succession of microorganisms like fungi, bacteria, etc., taking place within a microhabitat. This type of succession occurs in dead trees, animal droppings, etc.

Activity 2.4. *Analysing the story of Ecological Succession*

Instruction:

Read the extract given below carefully and answer the questions that follow.

Mount St. Helens–A Story of Succession

On May 18, 1980, the Mount St. Helens volcano in Washington State exploded violently after two months of intense earthquake activity and intermittent weak eruptions, causing the worst volcanic disaster in the recorded history of the United States. During the eruption, a 300-mile-an-hour lateral blast of hot air and debris flattened the surrounding old growth forest. A cloud of ash climbed to 80,000 feet in 15 minutes and circled the globe in 15 days. All told, the eruption blasted more than 230 square miles of forests, lakes, meadows, and streams. Virginia Dale was in the first helicopter-load of ecologists to land at Mount St. Helens after it erupted. "I just remember how bizarre it was going out into that landscape," she says of the suddenly gray, ash-covered terrain. "It gave the impression of total lifelessness." Dale studies ecological succession, or how an environment recovers after a major disturbance.

Although areas in the blast zone around Mount St. Helens appeared barren and lifeless after the 1980 eruption, some plants and animals did survive. Pocket gophers in underground burrows, fish in ice covered lakes, and salamanders hibernating in mud were protected from the hot, stone-filled wind of the blast. Plants such as willow, vine maple, and black cottonwood were able to re-sprout from roots protected in moist soil. Those plants are called survivors, and they were very important to the re-initiation of plants on the barren landscape. Some snow-protected Pacific silver fir and mountain hemlock trees also survived. They served as important sources of seed for establishing the future forest inside the blast zone at Mount St. Helens.

Despite surviving the eruption, many of those plants and animals were unable to live in the harsh new environment. But some were able to tolerate the extreme conditions and helped to pave the way for new colonisers. Winds brought light seeds and insects to the area, enabling them to enter the area and become established. Plants and insects attracted birds, deer, and elk from nearby areas. Heavier seeds "hitchhiked" on the feathers of birds and in elk droppings. Ponds and springs created by the eruption became the centers of life for survivors and colonisers.

Today, many areas around the volcano still have a desert-like appearance, but the vast majority of plant and animal species that were found at Mount St. Helens before the 1980 eruption have returned.

In the blast zone, the establishment of plants was slow for the first few years following the eruption. Three years after the eruption, the average plant coverage on research plots was only 1 percent. Fourteen years after the eruption, plant is a dominant tree.

Mount St. Helens, May 17, 1980, one day before the devastating eruption. The Photo taken May 17, 1980, by Harry Glicken, USGS.

Mount St. Helens, soon after the May 18, 1980 eruption. Photo taken September 10 1980, by Harry Glicken, USGS.

coverage on those plots was up to 38 percent. Twenty years after the eruption, plant coverage was approximately 66 percent.

As red alder trees and lupines became established, they influenced succession. Because alder can also fix nitrogen, they improve the fertility of the soil like the lupine plant. Also, the rapidly growing alder trees created shade and added organic material to the ground surface. This contribution allowed shade-tolerant plant species to become established. Thirty years after the eruption, red alder

Despite the establishment of vegetation over the past 30 years, scientists predict that it will likely take several hundred years for the blast area to look the way it did before the eruption. Before the eruption, the forest canopy was dominated by old-growth Douglas fir, western and mountain hemlock, and Pacific silver fir, with many species of moss, lichens, herbs, and shrubs in the understory. Scientists will continue to study the blast area and to document the return of plant and animal communities for many years to come

Adapted: http://www.fs.fed.us/pnw/pubs/journals/pnw_2005_dale003.pdf.

Questions

1. Did any plant survive the eruption? If so, how did they survive?
2. How has the red alder tree influenced the succession?
3. What are the roles of survivors in regenerating the disturbed area?
4. What roles did factors such as wind, moisture, landforms, plants and animals play in succession after the eruption?
5. Based on the narrative, explain the ecological succession that has occurred.

B. Ecological succession and energy balance

Ecological succession represents a gradual process of stabilisation and accumulation of biomass over time. The increased biomass is understood in terms of species richness, niche organisation and establishment of balanced community structure.

In the earlier stages, there is a less number of species with lower population density due to which energy requirement is less. However, as the succession proceeds, there is an increase in the energy flow because more energy is required for the overall increase in biomass. The variety of interactions also increases which further escalates the need for energy. The energy flow continues to increase till the climax stage is reached and during the formation of the climax community, the energy flow is the highest.

Once the climax stage has been stabilised, rapidity of energy flow decreases as energy is required for maintenance, and the overall growth rate in terms of biomass becomes zero. At this stage, the community is in the state of equilibrium with the environment and the energy input equates energy output showing a balance of energy flow.

C. Ecosystem restoration and management of ecological succession

The knowledge of ecological succession is globally used for the management and restoration of ecosystem. Ecological succession can be managed through strategies such as restoration, rehabilitation, reclamation, remediation, replacement and stabilisation. The management of succession is carried out focussing on the structure, functions, diversity and dynamics of an ecosystem. It involves intentional modification of a site to attain a defined set of objectives.

The field of science that deals with restoration of the ecosystem is called restoration ecology. Ecosystem restoration is a process which involves activities or initiatives to assess and manage the recovery of an ecosystem considering its health and sustainability. Ecologists study processes like migration, nutrient cycling, life cycles, energy relations and interactions between organisms and ecosystem in order to regulate succession during restoration.

Reprint 2022

Generally, ecological restoration involves the following steps:

Step 1
Understanding the previous ecosystem structure and functions. It involves study of diversity, relationships, process, roles of organisms, climatic conditions, edaphic factors, energy relations, etc., of the ecosystem that existed before.

↓

Step 2
Setting achievable goals and objectives for the restoration process. It involves visualisation of presumed outcomes and setting targets for what is to be restored. Generally, the presumed outcomes are the genetic composition of selected population, population abundance of species, community structure and ecosystem functions.

↓

Step 3
Identification of activities for restoration. It includes changing landscapes, minimising degradation of soil, planting of trees, removal of some harmful species, etc.

↓

Step 4
Assessment of impacts of the identified activities. It involves the study of possible impacts of the identified activities and plans for development of alternatives, if required.

↓

Step 5
Preparation of an action plan, arranging the activities in sequence.

↓

Step 6
Implementation of the plan. It involves continual monitoring, regulation and assessment of changes caused by the activities.

Figure 2.9. Flowchart showing the process of ecosystem restoration

Questions

1. Identify some possible causes of primary succession.
2. How is autogenic succession different from autotrophic succession?
3. How does ecological succession maintain balance in nature?
4. Describe the process of ecological succession that will take place in an area affected by forest fire.

Exercise

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

   i. A landslide at the roadside has led to the removal of existing ecosystem and exposure of fresh surfaces to various climatic factors. It is best described by

      A. aggregation.
      B. reaction.
      C. nudation.
      D. competition.

   ii. When a garden is left uncultivated, the type of succession that can occur in that area of land is

      A. autogenic.
      B. allogenic.
      C. primary.
      D. secondary.

   iii. Which statement is CORRECT about ecological succession?

      A. Succession always results in the same climax community everywhere.
      B. Succession always starts with bare rock.
      C. Succession always ends with a pioneer species.
      D. The composition of climax community will depend on the area where succession occurs.

   iv. On a rock outcrop that has never been home to living organisms, which organism is likely to grow first on it?

      A. Grass
      B. Wildflowers
      C. Algae
      D. Lichen

   v. A certain area is polluted due to the addition of chemical effluents from the nearby factory. Which of the following can possibly occur in that area?

      A. Hydrosere
      B. Psammosere
      C. Halosere
      D. Serule.

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

   i. The initiating causes for ecological succession are also referred to as …………………

   ii. The flow of energy into an ecosystem increases as succession proceeds towards ………………… …………………

   iii. After a forest fire in a place, the ecosystem rejuvenates to its original state. This ability of the ecosystem to recover from the change is called …………………

   iv. The dispersal of seeds by birds to a new environment is an example of …………………step in an ecological succession.

   v. When similar types of organisms come together in an ecosystem, it is called …………………

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

   i. The final stage of ecological succession is a highly stable entity that is resistant to change.

   ii. Climate has a direct relation to the diversity of an ecosystem.

   iii. Ecosystem restoration leads to the production of an identical type of ecosystem that was there before.

   iv. The pioneer species in all types of succession are always the plants.

   v. The decomposed leaves of pines make the soil acidic which affect the growth of certain species and favour the growth of others. This type of succession is called allogenic succession.

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

   i. Study Figure 2.10 and answer the questions that follow:

      a. What does the figure represent?

      b. How are the changes achieved?

      c. How does the process shown in the figure help the environment?

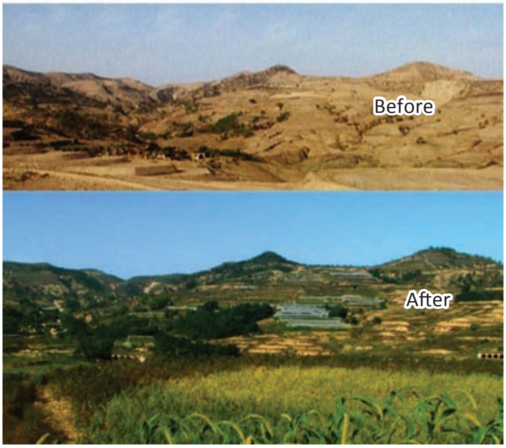


Figure 2.10.

ii. How do the disturbances of high frequency affect ecological succession?

iii. How does ecological time overlap with geological time?

iv. How does gene pollution act as a disturbance to the ecosystem?

v. Heterotrophic succession is sometimes referred to as degradative succession.' Explain this statement.

vi. Evaluate the pros and cons of ecological succession.

vii. Differentiate hydrosere from xerosere.

viii. Study the graph in Figure 2.11 and answer the questions that follow:

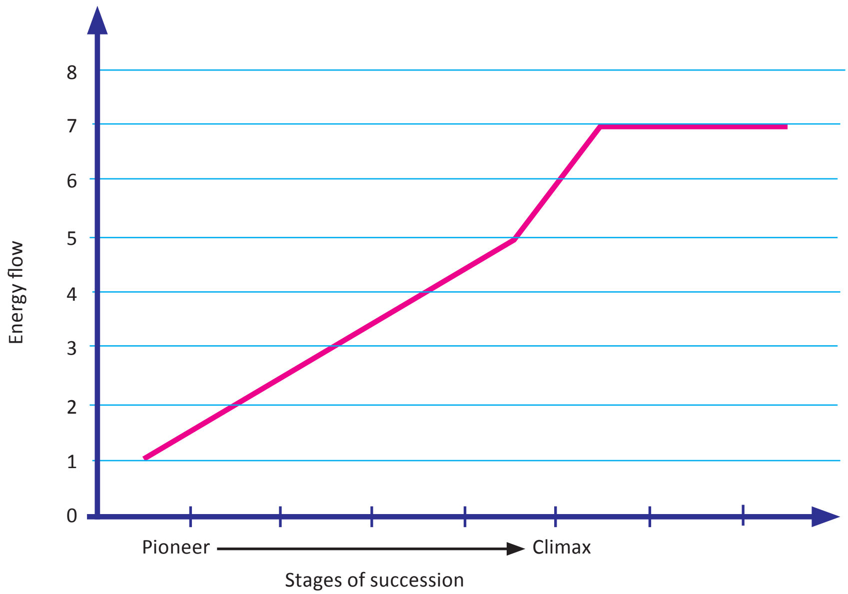


Figure 2.11.

a. Explain the relationship between energy flow and ecological succession.

b. Why does the energy flow after the climax stage, remain constant?

c. Why is there steep rise in energy flow at the onset of the climax stage?

3 CHAPTER

People and Environment

The environment provides all the resources essential for the survival of humans and other organisms on the Earth. However, with the human population explosion and changing lifestyles, the demand for the natural resources has exceeded the Earth's supply capacity. The relationship between humans and their environment is complex. To analyse the relationship and interaction of humans with the environment, it is important to be aware of the characteristics of human attitudes, behaviour and their impact on the environment.

1. Ecological Footprint

Learning Objectives

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

- measure Ecological Footprint.
- compare the Ecological Footprints of different countries with Bhutan.
- relate Ecological Footprint with sustainable development.

The resources that nature provides are limited. Humans consume resources at a rate faster than the environment can restore. The deciding factor for the restoration of natural resources depends on the type and the quantity of the resources used and also on the rate at which the natural resources are exploited. Therefore, natural resources need to be monitored and regulated to avoid degradation of environment due to excessive demand of resources for human consumption.

A. Measurement of Ecological Footprint

Human activities mostly depend on natural resources extracted from land and water. The biologically productive area or biocapacity like cropland, grazing land, built-up land, fishing ground and forest land provide resources and also absorb the wastes produced. The measurement of impacts of people on these biologically productive areas needed to support the lifestyle is defined as Ecological Footprint. The Ecological Footprint helps to understand the resources required to produce goods and the sustainability of resources on the Earth. The measuring unit for Ecological Footprint and biocapacity is global hectare (gha). A global hectare is the average productivity of all the biologically productive areas on the Earth in a given year. One global hectare is equal to the biocapacity of an area of one hectare or 2.47 acres. The understanding of global Ecological Footprint is used as a basis for calculating Ecological Footprint at individual, regional and national scale.

The Ecological Footprint varies across the globe since people in different parts of the world consume resources and generate waste in varying amounts. While carrying capacity estimates the productivity of the biosphere and the ability of bioproductive area to support living organisms, Ecological Footprint calculates the size of bioproductive area that was necessary to support all people living at any given time with a certain standard of living. Resource consumption and waste generation increase the Ecological Footprint and decrease the carrying capacity through depletion of resources. Thus, Ecological Footprint has inverse

Reprint 2022

effect on the carrying capacity of an area.

Ecological Footprint helps individual, country and world to assess and analyse the ecological impact a nature's carrying capacity. The analysis gives a benchmark for today's ecological performance, identify the challenges to decrease impact and give directions while developing effective strategies for a sustainable future. Therefore, the measurement of Ecological Footprint and carrying capacity is essential for evaluating and monitoring the pressure of humans on natural resources.

Activity 3.1. *Calculating individual Ecological Footprint*

Materials required:

Computer with internet access.

Instruction:

Work in groups.

1. Visit any of the web links given below:
   - http://footprint.wwf.org.uk
   - https://islandwood.org/footprint-calculator/
   - http://ecocamp.us/eco-footprint-calculator
2. Take the quiz and find out your Ecological Footprint.
3. Write down the description of your Ecological Footprint.
4. After completing the online quiz, answer the following questions.

Questions

1. List the four areas used to calculate the Ecological Footprint of an individual.
2. Which aspect of your life increases your Ecological Footprint?
3. What are some ways to minimise individual consumption?

The Ecological Footprint of a nation in global hectare is calculated by:

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

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. For example, if the total community forest area of Guma gewog in Punakha produces 13,000 m^3 of firewood with yield factor of for the production of firewood at 1.31. With equivalence factor 1.33 and annual consumption is 63,988 m3, the forest footprint of Guma gewog would be:

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

$$= \frac{63988}{13000} \times 1.31 \times 133$$

$$= 8.57 \text{ gha}$$

This means that Guma gewog consumed 8.57 global hectares of forest produce in a year. If 56 people lives in Guma gewog, the forest footprint per capita would be:

$$\text{Forest Footprint (per capita)} = \frac{\text{Footprint of an area}}{\text{Total number of popultion living in that aera}}$$

$$= \frac{8.57}{56}$$

$$= 0.15 \text{ gha/capita}$$

This means that individual consumed 0.15 gha of forest annually.

If the global forest footprint (per capita) is 0.277 gha, then an individual from Guma gewog consumes almost half of the global forest footprint per capita. Simalarly, Ecological Footprint of a nation is determined by finding the footprint of each of its six components as given in Table 3.1.

Table 3.1. Components of Ecological Footprint (Global Footprint Network, 2013)

Component	Description	Values (gha)	
Grazing Land Footprint	It can be calculated from the area used to raise livestock for meat, dairy, hide and wool products.	World Bhutan India S. Africa	1136832097.23 327516.5 10319619.25 6003534.17
Fishing Ground Footprint	It can be calculated from the area of marine and inland water ecosystem necessary to generate primary production of fish and other seafood.	World Bhutan India S. Africa	652067850.62 20446.75 20618321.96 4032577.68
Cropland Footprint	It can be calculated from the area used to produce food and fibre for human consumption, feed for livestock, oil crops and rubber.	World Bhutan India S. Africa	3977975174.71 292507.92 409868399.29 18381778.5

Built-up Land Footprint	It can be calculated from the area of land covered by human infrastructure, including transportation, housing and industrial structures.	World Bhutan India S. Africa	460211461.43 168273.18 60258779.19 1999437.88
Forest Footprint	It is calculated from the amount of timber, pulp, and fuel wood consumed by a nation each year.	World Bhutan India S. Africa	1996036271.86 2062074.4 167058423.37 13447997.86
Carbon Footprint	It can be calculated as the amount of forest, land required to absorb carbon emission from the burning of fossil fuels, land use change and chemical processes, other than the portion absorbed by water bodies.	World Bhutan India S. Africa	12379662309.83 608729.5 692411718.82 136277450.19

Total Ecological Footprint (gha)	**Bhutan**	**India**	**S. Africa**	**World**
	3479548.26	1360535261.8	180142776.28	20602785165.69

(Adapted: http://data.footprintnetwork.org/countryTrends.html (2013))

B. Ecological Footprint and development

Development refers to the gradual and dynamic process of economic growth concerning a particular society or a nation. It leads to improved standard of living and transforms the society. A developed economy makes optimum use of resources available and creates wealth and infrastructure, and provides solutions to the core issues of an economy like poverty, affluence, education, equity, unemployment, health hazards and other social parameters.

In most cases, development is accompanied by a noticeable increase in the use of natural resources which causes resource depletion leading to increased Ecological Footprint. To live sustainably, the Ecological Footprint must be less than the nation's biocapacity. If the Ecological Footprint exceeds the biocapacity, then the developmental activities are considered unsustainable. Development should cater to the present needs without compromising the needs of the future generations for it to be sustainable. For sustainable development, all nations must significantly reduce their overall footprints from over-consumption of resources. They must also reduce pollution and greenhouse gas emissions which contribute to a high Ecological Footprint. Countries with low to medium Ecological Footprints cannot aspire or afford to attain prosperity that may lead to high Ecological Footprint.

Activity 3.2. *Comparing Bhutan's Ecological Footprint with other countries*

Instruction:

1. Table 3.2 represents data of Ecological Footprint of different countries.
2. Use the information in Table 3.2 and draw a bar graph highlighting all six components of Ecological Footprint of different countries.
3. After completing the bar graph, answer the questions that follow:

Table 3.2.

Components (gha/capita)	Countries					
	World	**Bhutan**	**Australia**	**Singapore**	**Canada**	**Luxembourg**
Build-up Land Footprint	0.06	0.22	0.13	0.04	0.08	0.14
Carbon Footprint	1.72	0.81	5.01	5.22	5.28	10.37
Cropland Footprint	0.55	0.39	2.21	0.55	1.84	1.07
Fishing Ground Footprint	0.09	0.03	0.12	0.22	0.12	0.13
Forest Footprint	0.28	2.73	0.82	0.54	1.11	0.65
Grazing Land Footprint	0.16	0.43	0.51	0.24	0.33	0.73
Total Ecological Footprint	2.86	4.61	8.8	6.81	8.76	13.09

(Adapted: http://data.footprintnetwork.org/countryTrends.html (2013))

Questions

1. The Ecological Footprint of the world is lesser compared to Bhutan. What do you infer from this statement?
2. Calculate the difference between the Ecological Footprint of Bhutan with the Ecological Footprint of Luxembourg. Identify the component which shows the minimum and maximum difference.
3. Suggest some initiatives the government could adopt to reduce the total Ecological Footprint of Bhutan?
4. Looking at the given data, which component has maximum impact on a country's Ecological Footprint? Justify your answer.

C. Carbon Footprint

The developmental activities significantly contribute to emission of greenhouse gases (GHGs), which result in global warming.

Carbon Footprint is the measure of amount of greenhouse emissions which mainly consists of carbon dioxide by an organisation, event, production of goods and services or individual directly or indirectly. The primary source of carbon is burning of fossil fuels associated with human production or consumption activities. Figure 3.1 shows the relative contributions from man-made emissions of various greenhouse gases to climate change.

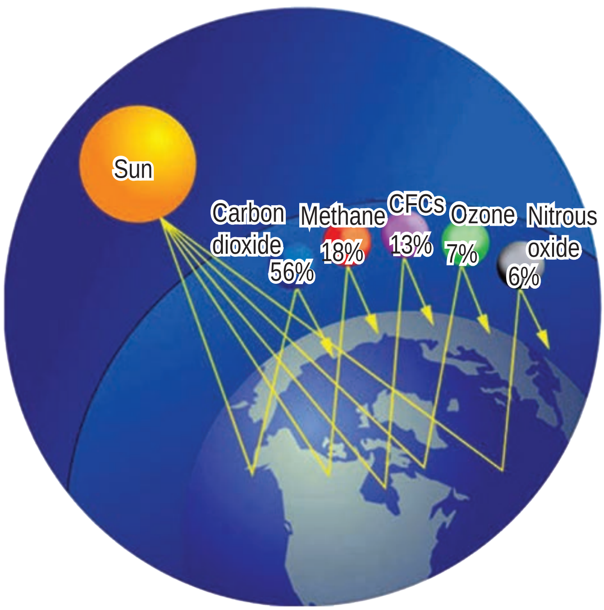


Figure 3.1. The relative amount of GHG produced by human activities
Source: http://www.koshland-science-museum.org.
Source: http://www.koshland-science-museum.org.

The carbon footprint is assessed by classifying the components into five major categories: housing, travel, food, products and services (Figure 3.2).

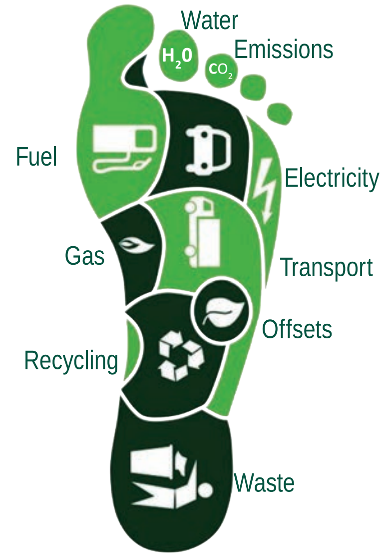


Figure 3.2. The carbon footprint

With climate change, many approaches have been proposed to provide estimates, determine carbon emission and implement mitigation strategies, such as carbon footprint calculators, life cycle analysis, input-output-based methods and tools, etc.

Carbon footprints have drastically increased over the past decades as nations have become industrialised. Reducing carbon footprint is the foremost step in reducing the over-consumption of the depleting resources. Individuals can calculate carbon footprint using the calculator available in the internet and become aware of lifestyles. Knowing carbon footprint helps an individual to make changes to go green and create a sustainable environment for the entire world.

Activity 3.3. *Calculating carbon footprint*

Materials required:

Computer with internet access.

Instruction:

1. Calculate your carbon footprint online using any one of the weblinks:
   - http://www.ei.lehigh.edu/learners/cc/carboncalc.html
   - http://www.carbonindependent.org/
2. Take the quiz and find out your carbon footprint.
3. After calculating your carbon footprint, share your carbon footprint with your friends and answer the following questions:

OR

1. Visit any one of the weblinks given below:
   - https://rvccc.org/calculate-your-carbon-footprint/
   - http://www.cef.ie/Downloads/CEF%20Basic%20Carbon%20Calculator.xls
   - http://www.carbonconversations.co.uk/p/materials.html

2. Download the file (MS Excel format) and calculate your carbon footprint.
3. Compare your footprint with your friends.

Questions

1. Compare your highest and the lowest carbon footprint with that of your friend with and analyse what caused the differences.
2. How can we minimise our carbon footprint and maintain our standard of living at the same time?
3. Based on the lifestyle of the people, compare the carbon footprint of urban residents with that of the rural community and justify your findings.

Questions

1. Is the Ecological Footprint a measure of carrying capacity? Explain.
2. In what ways can the recycling of waste lower the Ecological Footprint?
3. In what way is the knowledge of Ecological Footprint and carbon footprint important to the policy makers?

2. Urbanisation, Industrialisation and Environmental change

Learning Objectives

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

- discuss the environmental impacts of urbanisation.
- evaluate the impact of industrialisation.
- map the locations of the industrial plants in Bhutan and evaluate their suitability.

Urbanisation is a social process whereby the cities grow and an increasing proportion of the population lives in cities and the suburbs of cities. As rural people move to the urbanised areas for better opportunities, pressure on the environment increases. This pressure indirectly influences the process of industrialisation. Urbanisation and industrialisation, therefore, share a positive correlation with growth and development. Both the processes are important for the human welfare, yet their impacts have brought huge and often undesirable changes in the social, economic and environmental domains.

A. Urbanisation and environment

Urbanisation of small villages or towns into large towns and cities happens mainly as a result of migration, industrialisation, modernisation and economic development. As the town grows into a city, it spreads outwards into the surrounding agricultural lands or natural areas, such as forests, grasslands and wetlands.

Figure. 3.3. Thimphu before and after urbanisation

(Figure 3.3). The town often loses its open spaces and green cover unless consciously preserved leading to the destruction of the quality of life in urban areas.

Urbanisation in Bhutan has been accompanied by administrative reforms, creation of service centres, economic development, migration and modernisation. People migrate from rural to urban areas in search of better income opportunities, jobs, education and much more. The trend of migration is still prevalent in Bhutan resulting in rapid urbanisation. Bhutan has lost its precious farmlands and other natural resources damaging the pristine environment in the process of urbanisation. Urbanisation has led to several positive and negative impacts on social, economic and environmental spheres.

The main driving forces for urbanisation are:

(i) Biophysical environment

The biotic and abiotic components of an environment in which an organism lives is called biophysical environment. The biophysical environment determines the form of organism, its survival and adaptation to specific environmental conditions such as temperature, light, humidity and nutrients. For example, Thimphu is an urban settlement, located at 2230 metres above the sea level. The altitude and climate determine the habitable zones for Thimphu valley. The fertile land, moderate climatic conditions, suitable rainfall, administrative reforms, the creation of service centres, feeder streams, continuous water supply, hillside forests and green pristine environment are some key elements which attract rural population and leading to rapid urbanisation.

(ii) Natural increase in population

It occurs when the number of births exceeds the number of deaths. The natural increase in population is estimated in percentage. For example, if the birth rate is 20 per 1000 population, and the death rate is 8 per 1000 population, then the natural increase = 20 - 8 = 12. That is 12/1000 x 100 which is equal to 1.2 %. The population will decline if the death rate exceeds the birth rate. When the population increases in a particular place, more service facilities are built or expanded, resulting in expansion of smaller towns into cities.

B. Impacts of urbanisation

Urbanisation has impacts on social, economic and environmental domains. It has positive impacts along with several irreversible negative impacts on the global biosphere, such as loss of productive farmlands, a rise in energy demand, alteration of climate, modification of hydrological and biogeochemical cycles, fragmentation of habitats, and reduction of biodiversity.

Activity 3.4. *Identifying the causes and impacts of urbanisation*

Instruction:

Study Figure 3.4 in groups and sort out the 'causes' and 'impacts' of

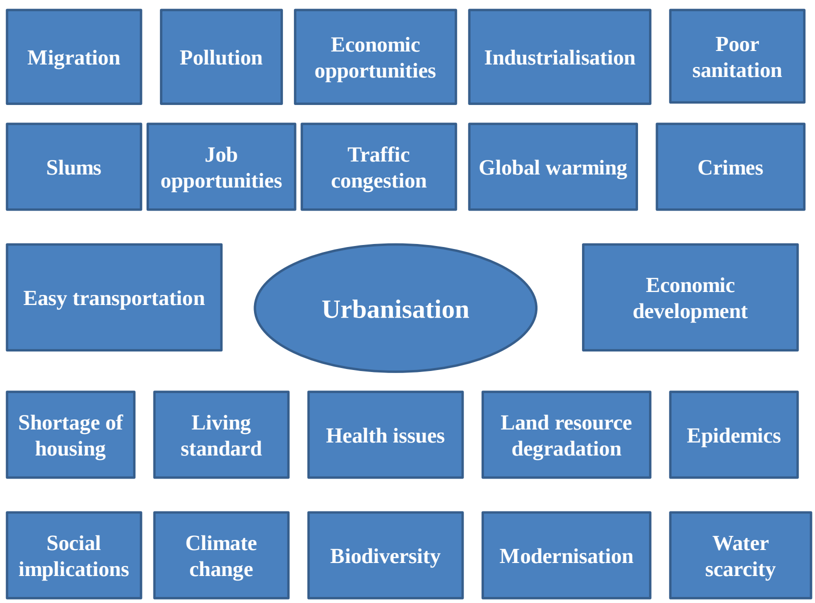


Figure 3.4.

urbanisation. Based on your study, answer the questions that follow:

Questions

1. List at least four factors that would pull you away from a village towards town.
2. Why is urbanisation both 'curse' and 'boon' for Bhutan?
3. Identify two factors that can be both causes and impacts of urbanisation? Justify your answer.

C. Industrialisation and environment

Prior to industrialisation, most economic activities were dependent on farming. However, the increasing population and demand for better lifestyles have encouraged many farmers to shift their traditional practices to development of industries.

General attributes of industrialisation include:

(i) Specialisation of production

It is a form of social division of labour that focuses on the production of limited products or services. Specialisation of production provides many advantages in terms of output, variety, quality of products, size of the market and cost reduction. Table 3.3 depicts different types of industries based on specialisation of production.

Table 3.3. Types of industries

Sl. No	Types	Description
1	Primary industry	Primary industries extract raw materials directly from the physical environment(land or sea). Example: agriculture, mining, fishing, oil extraction and forestry.
2	Secondary industry or Manufacturing industry	Secondary industries use the raw materials provided by the primary industry to manufacture products through manual labour or machines. Example: a car factory, textile industries and construction industries.
3	Tertiary industry or Service industry	Tertiary industries neither produce raw materials nor make products. Instead, they provide services to other people and industries. Tertiary industries can include hospitals, banks, hotels and communication services.
4	Quaternary industry	Quaternary industries involve the use of high tech services. People who work for these companies are often highly qualified within their field of work. Consultation firms, Research and development companies are the most common types of businesses in this sector.

Activity 3.5. *Understanding the impacts of industries in Bhutan*

Instruction:

1. Work in groups.
2. Complete Table 3.4 and answer the questions that follow:

Table 3.4. Types of industries

Type of industry	Location (s) in Bhutan	Brief description on the suitability of the industry in the respective location	Specific impacts on the environment and human health
Cement plants			
Calcium carbide plant			
Food processing plant			
Handicraft & Wood industry			
Distilling and beverage plant			
Mining industry			
Hydro power industry			
Hotels and tourism			

Questions

1. Which type of industry pose higher risk to environment and health of humans? Why?
2. Why are hotels and tourism considered as a type of industry?
3. Which industry or industries pose a serious threat to biodiversity in Bhutan?

(ii) Transport and communication

Transport facilities have encouraged industrialists to provide a faster and convenient method in conveying raw materials to the producers and manufactured goods to the consumers. In the olden times, the use of foot and animal power caused several implications in the establishment and expansion of industries. However, with the progress in technologies, the transport system has also improved. Today, the three main modes of transportation are air, water and land that enable development of industries.

Similarly, the communication system also serves as an important catalyst in facilitating industrialisation. We have come a long way from the use of telegraphs to the use of internet today. In recent times, there has been a huge advancement of ICT that has helped industrialists in acquiring information on the demand and availability of resources, exchanging ideas to improve business plans, and accelerating the growth of industries.

(iii) Industrial location

The selection of a suitable location for the establishment of an industry is influenced by many geographical and non-geographical factors. Maximisation of profit, which also implies cost minimisation, is the most important goal for setting up an industry. Figure 3.5 shows some of the factors which pull the industry to an ideal location.

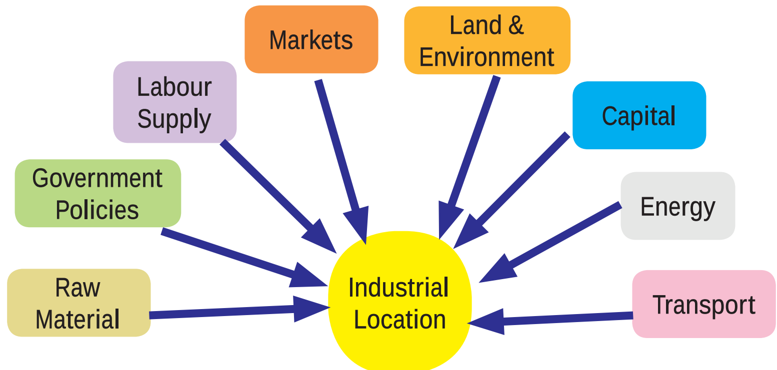


Figure 3.5. Factors influencing industrial location

(iv) Eco-friendly industries

The impact of industrialisation begins from the construction of industry and increases rapidly during its operation. The risks associated with industrial development include increased pollution and waste and overuse of natural resources. Therefore, for any type of industrial development, environmental impact assessment must be carried out as per the guidelines formulated by the concerned government to minimise potential environmental hazards.

Generally, industrial development should:

- minimise the impact on agriculture land and land management practices.
- have sealed access roads.

- dispose effluents properly.
- maintain visual qualities of the landscape.
- minimise the impact on the amenity of any nearby dwellings.

D. Impacts of industrialisation

Industrialisation has negative impacts on the environment such as depletion of natural resources, extinction of species, climate change and pollutions. These impact on the environment are major concerns in both developed and developing countries. Industrialisation also causes other social impacts which include:

(i) Time-space compression

Time-space compression is the process that brings places and people closer in terms of distance through the improvement of communication and transport technology. Improved transportation and communication speeds up the process of industrialisation which in turn accelerates population growth. Rapid industrialisation and population growth pose inevitable pressure on the natural resources. When nature is exploited for a longer period, the replenishing capabilities of the environment is greatly affected.

(ii) Social stratification

The process of industrialisation has greatly expanded the social inequalities within the society due to division of labour. It has created numerous occupational positions that have separated individuals based on their qualifications and earnings. Workers in the higher post are provided with high income and better incentives compared to the menial labourers. Similarly, inequalities based on age and sex is also a part of social stratification in the present era. In most industries, women and children are often paid less in comparison to men regardless of the similar nature of jobs. Many industrial societies also develop racial and ethnic stratifications which have caused some of the major concerns globally.

(iii) Global warming

Industries and their processes are the chief contributors to global warming. Carbon dioxide, nitrous oxide, fluorocarbons, perfluorocarbons, sulphur hexaflouride and methane are the major types of greenhouse gases. The products whose manufacturing causes the emission of these gases largely include cement, minerals, chemicals and metals. The increase in use of energy and land for industrial purposes has significantly caused enormous impact on the natural environment. Industrialisation entails activities that lead to the destruction of the environment through deforestation, waste generation and combustion of fossil fuels which are responsible for global warming.

(iv) Health and quality of life

Industrialisation has deteriorated the workers' quality of life due to long working hours in the industries. This means lesser family interaction, lack of communication, socialisation and other recreational activities. Many people move to the industrial areas in search of better employment opportunities. This causes rapid population growth within a short period of time, which in turn has serious implications like unemployment problem, increased crimes, pollutions and unavoidable waste.

Every individual living in the industrialised areas aspire for a better standard of living. The changing lifestyle and unhealthy food-habits result in poor health of the people making them susceptible to obesity and cancer. Other than pressure on the environment, due to industrialisation, some workers suffer from mental stress in their struggle to survive in the competitive world. This leads to various psychological disorders.

Questions

1. Give an example of technological innovation that reduces environmental deterioration caused by industrialisation.
2. Suggest some mitigation strategies to reduce the negative impacts of urbanisation on the environment.
3. How does industrialisation affect the environment in terms of the following?
    a. Population
    b. Technology

Exercise:

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

   i. Ecological Footprint is a methodology to

      A. calculate an individual's carbon footprint.

      B. calculate the size of population an area can support indefinitely.

      C. work out the total land required to maintain certain lifestyles.

      D. work out the size of your footprint.

   ii. Which of the following describes a sustainable society?

      I. Meets the need of the people without compromising the needs of future generations.

      II. Meets the economy and population size without exceeding the carrying capacity of the environment.

      III. Utilises non-renewable resources for the maximum benefit of the current generation.

      IV. Lives off income without depleting its natural capital.

      A. I, II and IV

      B. I, III and IV

      C. II, III and IV

      D. I, II, III and IV

   iii. Urbanisation is best defined as

      A. increase in the number of towns.

      B. increase in the proportion of urban population.

      C. people moving from rural to urban areas.

      D. changing lifestyles of people in urban areas.

iv. Non-geographical factor that influences industrial location is

A. raw materials.

B. transport facilities.

C. labour supply.

D. capital.

v. If a country's Ecological Footprint is larger than its biocapacity to replenish its renewable resources and absorb the resulting waste, it

A. is said to have an ecological deficit.

B. should be supported by other countries with smaller footprints.

C. is said to be a sustainable country.

D. is most likely a developing country.

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. sustainable development	a. Big Cola Pvt. Ltd.
2. urbanisation	b. gha
3. tertiary industry	c. population explosion
4. carbon	d. Bhutan National Bank Ltd.
5. biocapacity	e. greenhouse gases
	f. socio-economic and ecological equity

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

i. Use of solar panels, energy-efficient bulbs, public transport and organic food are different ways to reduce the _________ ___________.

ii. The amount of greenhouse gases released during different activities is measured by _______________ footprint.

iii. A teacher teaching in the school falls under _____________ industry.

iv. When ecological footprint exceeds the ______________ then developmental activities are considered unsustainable.

v. The dominant component that contributes to the overall ecological footprint is __________________.

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

   i. Urbanisation affects the carrying capacity of an ecosystem.

   ii. Increasing carbon footprint is the foremost step in reducing the over-consumption of resources.

   iii. Sustainable development initiative helps to curb the ecological deterioration.

   iv. The area demanded by a country's Ecological Footprint can exceed the area available to that country.

   v. Positive impacts of industrialisation and urbanisation outweigh the negative impacts.

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

   i. Study the bar graph in Figure 3.6 and answer the questions that follow:

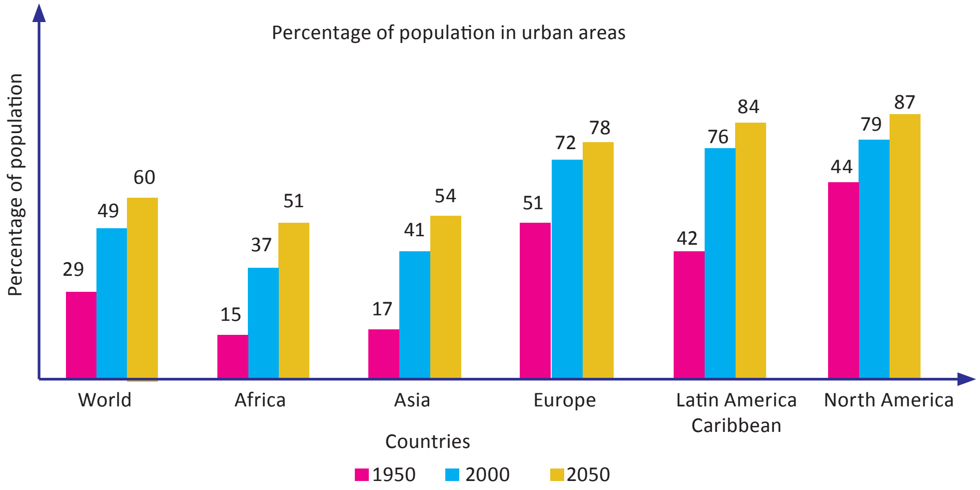


Figure. 3.6.

a. What is the trend of urbanisation over the years in different continents?

b. Which continent shows the highest urbanisation rate from 1950 to 2000?

c. Suggest a few strategies which the government of the above continents could adopt to decrease the predicted urban population growth the world will achieve by the year 2050.

d. Calculate the average rate of urbanisation of world and predict the percentage of urbanisation by year 3000.

ii. Human impacts on the environment can be measured using both ecological footprint and carbon footprint, yet the two differ in their characteristics. Identify and explain the differences.

iii. Figure 3.7 represents the area inhabited by population A and Population B and their respective Ecological Footprint.. One population is from a developed country and the other from a developing country. Study the figure and answer the following questions:

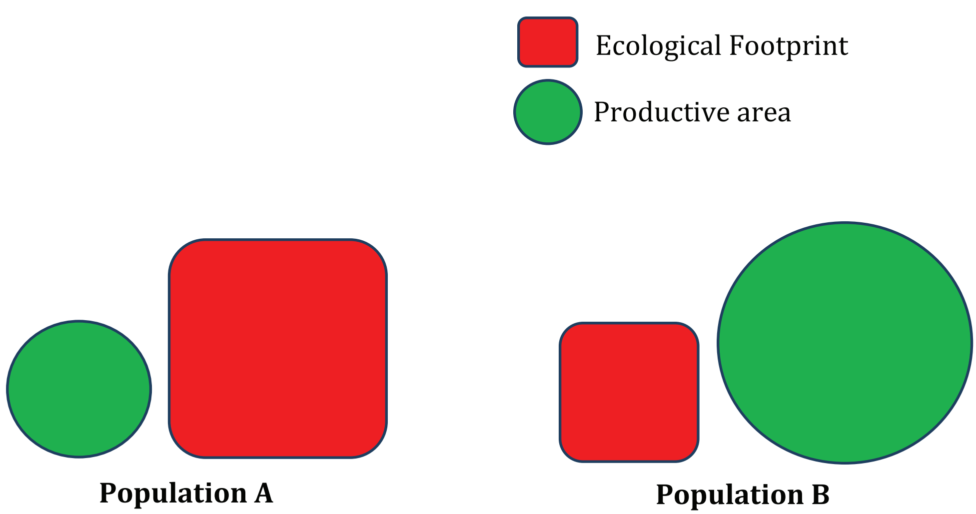


Figure 3.7.

a. Which population is most likely to be a living in a developing country? Why?

b. Identify which population, A or B, is exceeding the carrying capacity. List some probable outcomes that can arise in the area identified.

c. Why do you think country B has more productive area than country A?

Reprint 2022

Natural Resources Degradation

Population growth and distribution have significant roles to play in the sustainability of natural resources. Land and water are the main natural resources. Growth of population, changing lifestyles and differing consumption pattern have caused extensive degradation of land and water resources. Natural resource degradation threatens the ability of the environment to provide adequate resources to sustain life on Earth. It also has immense impact on environment, economy and social well-being of the people. Therefore, understanding the cause and effect of resource degradation has become important to provide timely mitigation measures and sustain life-supporting elements.

1. Land Degradation

Learning Objectives

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

- describe the phenomenon of land degradation.
- explain the processes that lead to degradation of land.
- explain the major causes of land degradation.
- analyse the social, economic and environmental impacts of land degradation

Land is an important substrate on which living organisms thrive and the biogeochemical cycles take place. The productivity of many sections of land is decreasing due to desertification, alkalinisation, acidification, salinisation and soil erosion. Land degradation has an adverse impact on the environment, the economy of the nation and the society as a whole. Such activities will not only affect the lives of humans but also of other organisms and the environment in general. Understanding its causes and impacts is important to prevent land degradation.

A. Land degradation and its causes

Activity 4.1. ***Predicting the causes and consequences of human activity in an area***

Materials Required:

Computer with pre-installed Google Earth Pro connected to the internet.

Instruction:

1. Go to desktop and open the Google Earth Pro app.
2. On the search field in the left corner, enter the coordinates (26°50'14.38"N 89°14'45.82"E) and press enter and wait till a yellow pin appears in the area.
3. Rename the pin as place A. (To rename, place your cursor on the yellow pin and click right button of your mouse and select properties. In the dialogue box, go to the field name and type A and press OK).
4. Scroll around area A and observe and measure the area of disturbance (To measure the area, on the toolbar above click on "Show ruler" and a

dialogue box appears. On the dialogue box, select POLYGON and set the perimeter to KILOMETRES and area to ACRES. Drag the cursor and select the entire area that has been disturbed and check the dialogue box to get the parameters).

5. Record both perimeter and area on your book.
6. Go to the search field and insert the coordinates (27° 8’56.25”N 90°51’50.73”E) and press enter and rename the place as B.
7. Scroll around B and observe.

Questions

1. Write your observations about A and B in separate paragraphs.
2. Specify what is happening in A?
3. Identify merits and demerits of the activity in place A.
4. How will that change the environment?
5. List some differences between A and B and reason out why?
6. Predict the area coverage after five years if the same trend continues in A.

According to the United Nations Convention to Combat Desertification (UNCCD), land degradation is the reduction or loss of biological or economic productivity and complexity of cropland, pasture, forest and woodlands resulting from land uses. Degradation of land is caused by natural phenomena, anthropogenic activities or a combination of both.

Land degradation is characterised by:

- soil erosion caused by wind and/or water.
- deterioration of the physical, chemical, and biological or economic properties of soil.
- long-term loss of natural vegetation.

Land degradation is occurring in almost all terrestrial biomes and agro-ecologies, in both low and high income countries. The following processes lead to degradation of land.

(i) Desertification

Desertification refers to land degradation in arid, semi-arid and sub-humid areas resulting from various factors, including human activities and natural phenomena. Overgrazing, over-cultivation, deforestation, poorly planned irrigation systems, droughts and floods lead to desertification.

Vegetation cover is important to bind soil. When trees and plants are removed for cultivation, fuelwood, logging, development or grazing, the soil becomes loose and the topsoil is washed away leaving behind a mixture of dust and sand. Soil may also be depleted of nutrients by intensive farming. Natural factors like wind and water aggravate soil erosion. Prolonged and recurrent drought accelerates the process of desertification by reducing the retentivity of soil. After drought, rainwater runs off quickly from soil washing the denuded soil along with organic materials. The removal of topsoil exposes the compact layer of soil which reduces the entry of water into the soil and makes the survival of plants difficult.

(ii) Alkanisation

Alkanisation is the condition in which the pH of the soil increases above the optimal range (pH 5.5 to 7). Alkaline soil is mostly clay soil with a high pH (> 9) and has poor soil structure with low infiltration capacity. The use of fertilisers and excessive evaporation of water from the soil leaves behind carbonate and bicarbonate salts of sodium and magnesium which increases the alkalinity of soil.

In an alkaline soil, calcium ties up with phosphorous making it unavailable for the plants, while phosphorous and molybdenum become toxic in the soil. Thus, the productivity of the land decreases.

(iii) Acidification

Acidification is the condition in which the pH of soil is below 3.5. Acidification can occur naturally by leaching, acid rain, and build-up of organic matter.

Leaching of nitrate is one of the major causes of agricultural acidification particularly in places where the rainfall is high and soils are sandy. Nitrate in a field may originate from many sources, including manures, composts, decaying plants, septic tanks, or from fertiliser. Nitrogenous fertilisers, such as ammonium sulphate acidifies the soil as it is biologically transformed to nitrate. The excess nitrate, which is not utilised by the plants leaches into the soil. This leaching of nitrate below the surface soil layers leads to acidification of soil.

Acid rain also contributes in adding acidic materials to the soil. Acidic materials, such as sulphur dioxide, ammonia, nitrogen oxides undergo complex chemical reactions in the atmosphere and return to the land surface in the form of wet deposition (rain, snow, cloud, fog) or dry deposition (dry particles, gas).

Many plants produce organic acids. When plant litter build up in the soil, they produce acids making the soil acidic.

Reprint 2022

As soil becomes acidic, the chemical change in the soil makes the elements less available to plants. For example, iron, aluminium and phosphorus combine to form insoluble compound making it unavailable for plants. Iron, aluminium and manganese also become toxic to plants in a soil with low pH. The acidity also affects biological processes necessary for the growth of plants. Highly acidic condition inhibits the survival of useful organisms like rhizobium (bacteria) and earthworms. This makes the land unproductive or unsuitable for agriculture or vegetation.

(iv) Salinisation

Salinisation is the accumulation of soluble salts in soil to the extent that soil fertility is severely reduced. Saline soil is characterised by the presence of an excess of soluble salts that interfere with the growth of most crops and plants.

Salinisation, both natural and human-induced, may occur in two climatic settings: arid and semi-arid, and humid regions. In arid and semi-arid regions, scarcity of water due to low rainfall and high evaporation do not allow necessary leaching of salts. Moreover, there is a net capillary rise of water which brings salts to the surface soil. In humid areas, on the other hand, excess irrigation or poor drainage cause the groundwater table to rise to the root zone of plants and make the soil saline. The major cause of human-induced salinity is due to the poor management of irrigation.

Salinity affects the physical and chemical properties of soil which leads to surface soil compaction and erosion. In addition, the salt destroys the soil bacteria and fungi by dehydration, which is important for the formation of organic matter and for nutrient cycles. High concentration of salts can also lead to exosmosis resulting in the dehydration of plants.

(v) Soil erosion

Erosion is a natural process of detachment of soil particles and their transport and deposition at distant places by natural agents such as water, wind, glacier, and gravity. Human actions such as deforestation, overgrazing, over-tilling, and shifting cultivation accelerate the soil erosion.

Soil erosion by wind and water is the most common and extensive, but the soil erosion due to water is the most serious in many places. It causes degradation through loss of hug amount of fertile topsoil along with plant nutrients through runoff water. It reduces the depth of soil, depletes the ground water table, limits the moisture storage capacity and feeding zones of crops, deteriorates the soil organic matter and destroys soil structure.

B. Land degradation in Bhutan

The pressure on land in Bhutan is growing with economic development and population growth. While the population density of Bhutan at a gross level is quite low with about 16 persons per square kilometre in 2005 (Population and Housing Census of Bhutan, PHCB 2005), the population density taken over arable and settlement areas soars to about 85 persons per square kilometre (NEC 2011).

Some of the causes of land degradation in our country are: unsustainable agricultural practices, forest fires, excessive use of forest resources, overgrazing, unchecked mining, developmental activities and urbanisation.

Agriculture practices become unsustainable when there is prolonged and unregulated use of chemical fertilisers. The use of chemical fertilisers result in depletion of organic matter in soil and subsoil compaction.

Occurrence of land degradation due to water erosion is widely prevalent across Bhutan. This is because except in few river valleys in the West and South, most of the cultivation takes place on steep slopes. The process is further exacerbated due to lack of adequate soil and water conservation measures, short fallow cycle in **tseri** cultivation, and poor management of irrigation system. Erosion becomes severe, especially during monsoon.

Forest fire is one of the major factors that leads to destruction of a huge area of forest land which leaves the land barren and vulnerable to soil erosion.

Excessive extraction of wood and non-wood products from forest also affects the stability of the land. Extraction of wood products for cooking, heating, industrial raw materials, and timber for constructions are the main threats to forest land. The degradation of forest land is accelerated by increasing extraction of non-wood forest resources for medicine, food, handicraft products, paper-making, animal fodder and leaves for manure. The volume of extraction and the technology used for extraction of resources from the forest have a significant impact on the quality of land. In rural areas, farmers continue to maintain large livestock herds as an important economic activity. Most of the grazing occurs in forest lands and as a result, the land is denuded. The topsoil is easily eroded from the denuded land making land dry and barren.

Developmental activities such as the establishment of industries, institutions, offices, monasteries, roads, etc., require clearing of vegetation or forest land. Construction of roads involves cutting of huge portions of fragile mountainous areas using dynamites and heavy machines. This weakens the fragile mountain slopes and leads to landslides.

Mining is one of the fast-growing economic sectors in Bhutan which has significant adverse impacts on land, vegetation, water, air, agriculture production, and lives of human and other organisms. The loss of vegetation cover and denudation of extensive land lead to desertification.

Urbanisation increases municipal waste generation and land degradation. Expansion of urban centres has consumed agricultural lands (Figure 4.1), hill slopes and other forms of land. Infrastructures like drainage system and sewer disposal system when poorly built and managed, can have adverse impacts on land and water resources. Poor management of solid wastes at the source and in the landfills degrades the land by emitting pollutants and leaching of toxic wastes.

Figure 4.1. Expansion of urban centres

The extent of degraded land compared to other countries in the region might be relatively small, but in the Bhutanese context, it is a significant one, since there is already a shortage of total arable land. This is because, less than 8 percent of the total area is cultivable, out of which only 2.93 percent is actually cultivated (LCMP 2010).

C. Impact of land degradation

The demand for land for economic development and pressure from expanding population have led to irreversible change in land use. Unsustainable land use for various purposes has also sped up the process of land degradation. Land degradation is an increasing problem in many parts of the world. It has long lasting impacts on the environment, economy and the society. Table 4.1 shows some of the prominent impacts of land degradation on different spheres.

Table 4.1. Impact of land degradation

Domains	Impacts
Environmental 	• Loss of biodiversity • Loss of habitats • Desertification • Drying up of water sources • Extinction of species • Surface runoff and floods • Loss of nutrients due to soil erosion • Global warming • Loss of ecological services for ecosystem
Economic 	• Decline in land productivity • Defensive expenditure(cost of preventing land degradation) • Replacement cost (cost of fertiliser to replace nutrients) • Restoration or reclamation expenditure (cost of restoring the soil to its former productive state) • Loss of economic services(wood production, groundwater recharge, tourism, etc.) • Off-site costs (low supply of food increases food price, health impacts due to malnutrition, diseases, etc.)
Social 	• Food insecurity and adverse health issues • Poverty (loss of income from agriculture) • Increased rural-urban migration • Public unrest • Conflicts and competing claims over natural resources • Inequality in society • Loss of social, cultural and spiritual values.

Activity 4.3. Understanding the relation among impacts of land degradation

Materials Required:

Chart papers, marker pens and sellotape

Instruction:

1. In groups, refer Table 4.1 and answer the following questions:
2. Display your work in classroom.

Questions

1. Discuss and elaborate on each impact of land degradation.
2. Illustrate the relationship among different impacts in the form of impact chain or impact web in the chart paper.
3. List some impacts of land degradation you observe in your community.

It is critical to understand the causes, impacts, climatic conditions, soil, water, land cover and socioeconomic factors to prevent or mitigate land degradation. Land degradation assessment is one of the primary tools in any policy-making process for conservation as well as reversing land degradation. Different approaches to land degradation assessment are adopted worldwide, which include expert opinions, field measurements, field observations, land user's opinions, productivity changes, remote sensing and modelling methods. Accordingly, methods or techniques need to be critically selected by considering their suitability, applicability and adaptability to local conditions. Some of the common methods used to assess land degradation are shown in Table 4.2.

Table 4.2. Methods to assess land degradation

Methods	What to assess?
1. Expert opinion (e.g. indicators, questionnaires, interviews, etc.)	• Land/ soil degradation: (severity, degree, extent, impact, cause & risk) • Soil (erosion, fertility, productivity, etc.)
2. Remote sensing and GIS (e.g. mapping)	• Vegetation change • Biodiversity loss
3. Modelling (e.g. erosion models)	• Vegetation change
4. Field monitoring and measurements (measurements to verify models/ pilot areas)	• Climate (rainfall, temperature for modelling) • Health/ condition
5. Grid system monitoring	• Biodiversity loss • Landscape/ Ecosystem function
6. Land user opinion	• Soil condition (quality, salinity, fertility, etc.) • Crop yield and suitability
7. Estimates of productivity changes	• Annual crop production/ income • Land area productivity • Variation of crop variety

Questions

1. Loss of ecosystem services due to land degradation has an economic impact on the people. Justify the statement.
2. Bhutan has limited arable land. Agriculture cultivation generally occurs on steep slopes. Predict the scenario of land degradation in Bhutan after ten years and explain the reasons for your prediction.
3. Why do you think that assessment of land degradation plays an important role in the policy-making process of a country?
4. 'The Mining sector is considered one of the 5 economic jewels of the country. But it is also perceived as one major activity contributing to land degradation.' What measures do you think can be taken to ensure that mining contributes to minimum land degradation?

Reprint 2022

2. Water Resources

Learning Objectives

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

- discuss fresh water availability, accessibility and equitable distribution.
- investigate the status of fresh water resources in Bhutan.
- assess the issues of over-utilisation of ground water.
- explain the impacts of contaminated ground water on the ecosystem.

Water is an indispensable resource for all forms of life on the Earth. All the human activities are centred around use of water. Industrialisation and many other developmental activities have limited the organisms the access to safe drinking water. Expansion of agriculture, damming, diversion, overuse and pollution have threatened water resources in many parts of the world.

Providing safe drinking water has become one of the greatest challenges today. Water contamination is a concern even for the developed countries with all the advanced technology and resources at their disposal. Therefore, the study of how human activities affect the quality as well as the quantity of freshwater resources, and the ways to manage them has gained a new dimension.

A. Accessibility and distribution of freshwater

Water resource includes rivers, lakes, oceans, ice caps, glaciers and ground water. Although water covers over 70% of the Earth's surface, 97% of the total water available on the Earth is saline ocean water and only about 3% is fresh water found in the form of ice caps, glaciers, groundwater, lakes and rivers. A total of 70% of the fresh water is locked up in icecaps and glaciers, and around 29% of the fresh water forms underground water. Only 1% of the fresh water is surface water that flows in the form of streams and rivers. The distribution of world's water is represented diagrammatically in Figure 4.2.

Fresh water is not just essential to support life but it is also a necessary input for human activities. Industries, mining, hydropower generation, tourism, subsistence and commercial agriculture, fisheries and livestock production are some areas that need fresh water. Though these human activities contribute to economic development, they pollute runoff water thereby posing threats to the fresh water system.

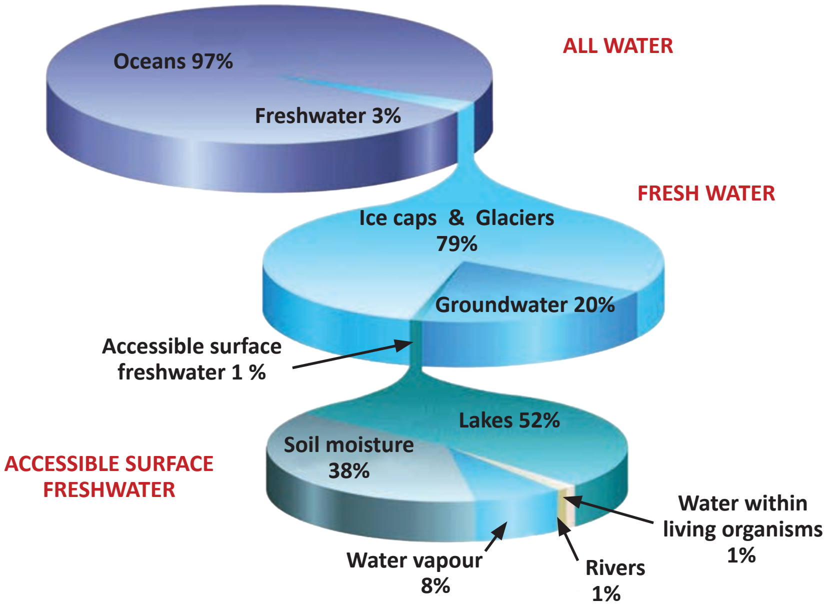


Figure 4.2. Distribution of world's water (www.aid-n.com)

Activity 4.4. *Analysing the status of fresh water resources*

Instruction:

In groups, read the case study and answer the questions that follow:

Securing the Natural Freshwater Systems of the Bhutan Himalayas

Bhutan's water resources are mainly in the form of glacier fed rivers and rain-fed streams. Bhutan has number of wetlands viz. glacial lakes, marshes, swamps, ponds etc. Bhutan has a very rich water resource with long term average annual flows of 73,000 million cubic meters per year which gives rise to perhaps one of the highest per capita mean annual flow availability of water at 109,000 cubic meters.

The major rivers provide water for hydropower and tourism/recreation. Tributaries and streams provide for all other uses with emphasis on water supply and irrigation. Sub-surface sources, in the form of springs and aquifers, provide water for domestic water supply and small scale irrigation.

The current scenario of abundant water resource might be challenged by the new, complex and pervasive dynamics caused by population growth and socio-economic development. Erratic rainfall patterns and the associated hydrological flows will have a huge impact on the overall water resource system in the country.

The proportion of population without access to safe drinking water declined from 55% in 1990 to less than 12% in 2008. The MDG target of reducing those without access to safe drinking water by half by 2015 has thus already been achieved (MDG progress report 2005). However, the sustainability of the urban water supply system and functionality of existing rural water supply schemes is one of the main challenges. 88% of the rural population and 98 % of urban population in the country now has access to piped drinking water supply (PHCB 2005). Analysis of the comprehensive rural water supply scheme (RWSS) inventory report in 2009 revealed that 31% of the rural schemes are non-functional due to various factors. Despite the availability of surface water sources in abundance at national level, there are localised water shortages. Further, while there is lack of information on the yield of spring sources, many springs are said to be drying up.

The water demand projection is focused on the consumptive use of surface sources. The result of the water balance assessment carried out by Norconsult indicates that at the national level, there is a large surplus of available and firm flow in the main north/south rivers. The Gross National Water Balance extracted from WRMP report is given in Table 4.3, which illustrates that Bhutan does not have an overall annual water balance problem on a national scale.

The National Environment Commission (NEC) is entrusted with the responsibility of coordinating water resources management in the Country as an apex body on water resources. For this, the Water Resources Coordination Division has been established under the NEC Secretariat, with the mandates of water quality monitoring, development of appropriate standards and coordination of the management of water resources. The holistic principles of Integrated Water Resource Management (IWRM) have been reflected as a cornerstone in the Water Act 2011.

Table 4.3 Gross National freshwater demand

Demand category	2002 (million m^3/ year)	2012 (million m^3/ year)	2022 (million m^3/ year)
Municipal Demand	*10*	*19*	*37*
Irrigation Demand	*393*	*472*	*472*
Rural Demand	*11*	*15*	*20*
Industrial Demand	*0.6*	*0.9*	*1.5*
Livestock Demand	*7.5*	*8.8*	*10.2*
Sum of maximum consumptive demand	*422*	*516*	*541*
Sum of water supply (exclusive irrigation) demand	*29.1*	*43.7*	*68.7*
Add-on irrigation demand	*15*	*-*	*26*
Non-consumptive hydropower demand	*6,700*	*16,600*	*26,900*

Source: Securing the Natural Freshwater Systems of the Bhutan Himalayas, 2011

Questions

1. Identify the various sources of freshwater in Bhutan.
2. All forms of life on earth require water. Discuss the status of fresh water in your community.
3. Explain the challenges that may affect the availability and accessibility of fresh water in future.
4. Through the analysis of the national freshwater availability and water demand projection data, predict the freshwater status in terms of availability and accessibility after the year 2022.
5. Suggest some strategies to conserve water resources for future generation.

B. Groundwater

The term groundwater usually refers to water that is collected underground. The layer of the earth below which the ground is saturated with water is called the water table. About 29% of the total fresh water resources are in the form of groundwater.

Groundwater flows through the aquifers, which is a layer of sediment or rock that is highly permeable and contains water. Layers of sand and gravel are good aquifers, while clay and crystalline rocks like granite are not, since they have low permeability.

a. Over-utilisation of groundwater

Groundwater is the largest source of usable fresh water in the world. In many parts of the world where surface water supplies are not available, the domestic, agricultural and industrial water needs are met by using groundwater. Pumping out groundwater faster than it can be replenished over long period causes depletion of ground water. Some of the impacts of groundwater depletion are:

(i) Lowering of water table

Groundwater withdrawals that exceed the recharge rate results in lowering of the water table. This poses difficulties in reaching the groundwater while boring wells for consumption. For instance, in the past 40 years, the water table has dropped by about 30 m and is still dropping at the rate of 2 m per year.

(ii) Increased cost for extraction

As the water table lowers, more energy is required to pump water above the surface of the Earth. The use of excessive energy to pump water from the great

Reprint 2022

depths of the Earth can be economically expensive.

(iii) Reduced surface water supplies

The supply of freshwater is dependent on the groundwater. The excessive use of groundwater causes the surface water like the lakes, streams and rivers to diminish their supply.

(iv) Land subsidence

Over the years, the groundwater has leached into the cavities of the earth. When the cavities of the Earth are filled with water, it supports the overlying rocks and soil. As the water table drops due to the excessive withdrawal of the groundwater, it causes gradual settling of the land resulting to a phenomenon known as land subsidence.

(v) Water quality concerns

As long as a high water table maintains a sufficient pressure in the aquifer, there is a flow of fresh water into the ocean. Thus, the wells that are located near the ocean yields fresh water. However, the lowering of the water table or a rapid rate of groundwater removal may reduce the pressure in the aquifer, permitting the salt water to flow back into the aquifer and the wells, resulting in contamination of groundwater with salt.

b. Groundwater contamination and its impact on ecosystem

Activity 4.5. *Examining the sources of groundwater contamination*

Instruction:

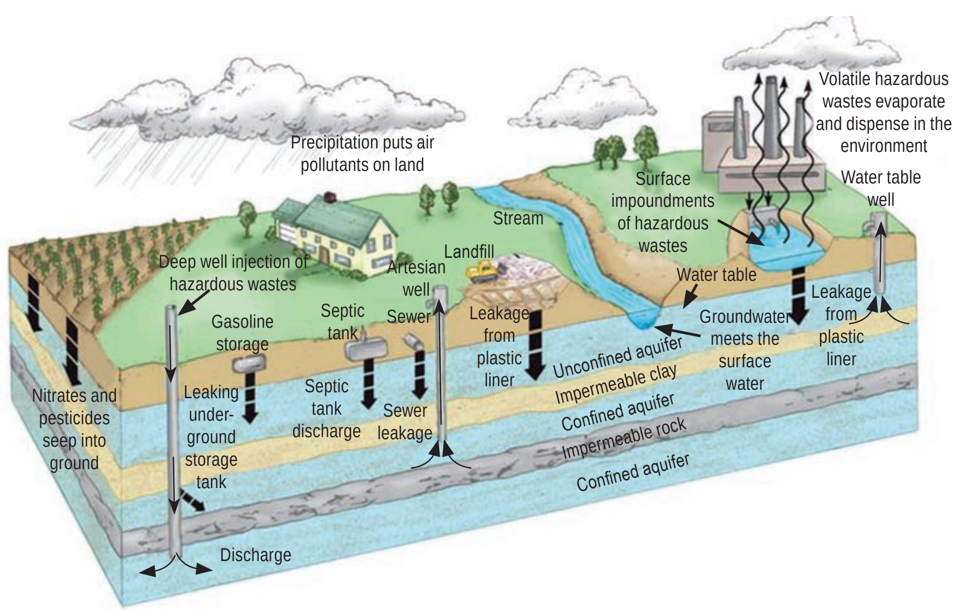


Figure 4.3. Sources of groundwater contamination (Wiley and sons, 2011)

Study Figure 4.3 and discuss in groups to answer the following questions:

Questions:

1. Identify the sources of groundwater contamination and their contaminants.
2. Explain physical process that causes groundwater contamination.
3. Suggest three ways to prevent groundwater pollution.
4. Analyse how humans contribute to contamination of groundwater.

Although groundwater is supposed to be safer since it has been naturally filtered during infiltration through the porous or semi-porous soil layer above the aquifer, in areas where population density and human activities are high, the groundwater is continuously being contaminated. The contaminants may be organic, inorganic or pathogenic. Some of the most common organic contaminants are dyes, rubbers, polishes, solvents, crude oil, insecticides, inks, paints, disinfectants, gasoline products, pharmaceuticals, preservatives, spot removers, paint removers, etc. Inorganic contaminants include pesticides, plasticisers, chlorinated solvents, aluminium, chloride, copper, dissolved solids, fluoride, iron, lead, mercury, nickel, silver, zinc, sodium, etc. Pathogens may include bacteria (coliform) and viruses. Groundwater contamination has adverse impacts on human health, the agricultural productivity and ecosystem.

Groundwater directly or indirectly supports ecosystems. The ecosystems that depend directly on groundwater are known as Groundwater Dependent Ecosystems (GDEs). GDEs include aquifer ecosystem, estuaries, wetlands and riparian ecosystems. Aquifer ecosystems host a wide variety of undiscovered species of microbes and bacteria that disintegrate contaminants into nutrient and energy for the ecosystem. Depletion and contamination of groundwater affect numerous species in GDEs, reducing the biodiversity. Similarly, wetlands and estuaries depend on groundwater to neutralise the salinity. Any change in the condition of the groundwater can result in the loss of these habitats.

Many springs, streams and lakes depend on groundwater. Contamination of groundwater can affect the organisms in these ecosystems, thereby disturbing the whole ecological balance.

Questions

1. Explain the roles of groundwater for the following:
   a. land subsidence
   b. surface water flow
   c. aquifer ecosystem
2. Explain the environmental issues that result due to over-utilisation of groundwater.
3. Explain the common causes of groundwater contamination and their impacts on human health.

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 is the most appropriate definition of land degradation?

      A. When the land changes due to human use resulting in the reduction in the overall quality of land.

      B. When the land changes due to natural causes resulting in the reduction in the overall quality of land.

      C. When land changes due to human use resulting in the reduction of land.

      D. When land changes resulting in a different landscape.

   ii. Grazing of a group of herbivores in a single area will lead to

      A. desertification.

      B. salinisation.

      C. alkalinisation.

      D. acidification.

   iii. What major threats can we expect on the environment as a result of the expansion of agricultural and constructional activities?

      I. *Landslides*
      II. *Soil erosion*
      III. *Desertification*

      A. II only

      B. I and II

      C. II and III

      D. I, II and III

   iv. In an agriculture land situated on the steep terrain, the major cause of land degradation is

      A. floods.

      B. landslides.

C. soil erosion.

D. wind erosion.

v. Which source of water is not suitable for drinking and cooking?

A. Glacier

B. Ocean

C. Stream

D. Lakes

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

Column A	Column B
1. Arable land	a. Result of mining activity
2. Groundwater	b. Result of land degradation
3. Land degradation	c. Water present in aquifer
4. Poverty	d. Leakage in septic tank
5. Land subsidence	e. Land suitable for agriculture
	f. Excessive withdrawal of the ground water

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

i. One of the major causes of acidification in agricultural soil is leaching of ________________ .

ii. Excessive withdrawals of groundwater result in depletion of _________ .

iii. The soil is ____________ in an area covered with plenty of pine leaves.

iv. Wetlands and estuaries depend on groundwater to _______________ the salinity.

v. Clay and crystalline rocks do not make good aquifers because they have low ________________ .

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

   i. Describe at least two factors that have contributed to the degradation of land in Bhutan.

   ii. Explain the relationship between land degradation and the economy of the community.

   iii. Explain the methods of assessing land degradation in a place.

   iv. Analyse the problems associated with over-use of surface water?

   v. The data on the estimates of vulnerability to desertification in some Asian countries are provided in Table 4.4. Analyse the data and answer the questions that follow:

Table 4.4.

Countries	Total land area (km^2)	Vulnerability to desertification							
		Low		Moderate		High		Very high	
		Area	%	Area	%	Area	%	Area	%
Bangladesh	133,910	85,163	63.60	0	0	0	0	0	0
Bhutan	47,000	1,407	2.99	0	0	0	0	0	0
China	9,326,410	262,410	2.81	239,107	2.56	65,638	0.70	72,214	0.77
India	2,973,190	1,277,328	42.96	744,148	25.03	206,317	6.94	165,912	5.58

Source: Eswaran. H et al. 2001. Land Degradation: An overview

   a. Which country has the largest area of land that is highly vulnerable to desertification?

   b. What relationship do you see between the total land area and the vulnerability to desertification?

   c. In Bhutan, 2.99% of the land is vulnerable to desertification. Which type of landforms could be more vulnerable? Why?

5 Pollution

CHAPTER

Over the years, increase in human population, change in economic production, change in life-styles, advancement in modern technology and numerous other factors have led to pollution of different spheres of the Earth. Major pollutants, such as carbon monoxide, arsenic, mercury, lead, spent plutonium and uranium threaten the very existence of life on the planet. All these pollutants affect the health of organisms and environment at a varying degree. Even the genetically modified organism (GMO) is considered as one of the potentially hazardous agents that may lead to contamination of the native environment. Therefore, the use of various monitoring tools to determine the quality of the environment has become imperative worldwide.

In order to minimise the risk posed by hazardous substances, risk assessment has to be carried out for appropriate risk management.

1. Air Quality Index

Learning Objectives

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

- assess the quality of air using air quality index.
- explain the methods to lower air pollution.

Different kinds of contaminants are discharged into the environment due to various human activities. Pollutants from industries, emissions from vehicles, nuclear wastes, pesticides, sewage, detergents and other chemicals enter different spheres of the Earth. These pollutants bring undesirable changes in the physical, chemical and biological components of the environment and is known to cause respiratory disorders and other health problems in organisms.

Figure 5.1. Air pollution

The change in the conditions of the environment is monitored by using various monitoring tools to quantify the amount of pollutants entering the environment. This helps us to monitor ambient levels of pollutants and trends of potential problems caused by pollutants. For air pollution, air quality index (AQI) is used to quantify the level of pollution in the air and determine its quality.

A. Determination of AQI

Air quality is measured by recording the concentrations of major air pollutants over a particular area at a given time. The AQI value changes hourly or daily and its value generally ranges from 0 to 500. The AQI value for a particular day is equal to the highest AQI value for the particular pollutant for that day. For example, in Figure 5.2, the AQI value of particulate matter (PM) 2.5 is 79, PM 10 is 40, O_3 is 4, NO_2 is 62, SO_2 is 1 and CO is 0. Therefore, the AQI value for that 48 hours is 79 (PM2.5). Although the number of parameters may vary from one country to another, the use of parameters such as ground-level ozone, particulate matters, carbon monoxide, sulphur dioxide, and nitrogen dioxide are very common. The amount of these pollutants released into the air are then converted into AQI values using a standard formula developed by the Environmental Protection Agency (EPA).

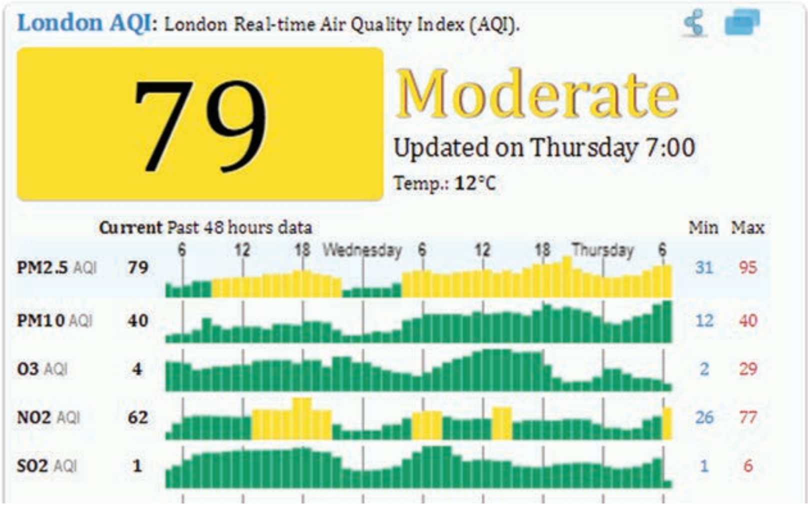


Figure 5.2. Air quality index

Table 5.1. Standard for AQI as per EPA

Pollutant	Averaging Time	Level (Standard Amount)
Ozone (O_3)	8 hours	0.08 ppm
PM 2.5	24 hours	40 μg/m^3
PM 10	24 hours	150 μg/m^3
Carbon monoxide (CO)	8 hours	9 ppm
Sulphur dioxide (SO_2)	24 hours	0.14 ppm

For instance, in Figure 5.2, PM2.5 released into air is 31.6 μg/m^3 at that particular time in London, then the AQI on PM2.5 can be calculated as:

$$\text{Air Quality Index (AQI)} = \frac{\text{Population amount}}{\text{Standard amount}} \times 100$$

$$\text{Air Quality Index (AQI)} = \frac{31.6}{40} \times 100 = 79$$

Similarly, if the level of PM 10 emitted in Pasakha industrial state is 60 μg/m^3 in a particular day, then AQI value of PM 10 is 40.

Many countries have adopted air quality control legislation, setting a standard on minimum level of emissions and air quality.

Figure 5.3. City under smog

In the UK, air quality standards are set by the Department for Environment, Food and Rural Affairs (DEFRA). Monitoring is widespread and air quality warnings are issued when pollution levels are expected to be dangerously high.

In the USA, since the 1960s, there has been a series of Clean Air Acts. Moreover, the Environmental Protection Agency (EPA) recognises the need to reduce the level of photochemical smog (Figure 5.3) in many of the country's large cities.

Likewise, in Bhutan, there are some existing policies and strategies that are geared towards promoting low emission transport sector. The key strategies include promotion of mass transport, non-motorised transport, and cleaner modes of transport (alternative fuels and electric cars). Some of the key policies are National Transport Policy (2006), Economic Development Policy (2010) and Transport 2040: Integrated Strategic Vision (2011).

B. Air pollution and health hazard

The deterioration of air quality causes a variety of acute health problems, especially to children and elderly people. They may cause irritation of eyes, nose and throat, cardiovascular disease, respiratory disease, lung cancer, allergic reactions, and some neurological disorders. Even healthy individuals are affected by prolonged exposure to poor air quality. Air pollution also affects the health of animals, plants, crops and the environment as a whole. Toxic air pollutant, acid rain and ground-level ozone can affect the health of trees, crops and wildlife.

To minimise the impacts of poor air quality, AQI is used as a tool to understand the level of air quality and accordingly take necessary actions at different levels. For instance, in some cities when AQI is very high, air pollution warning is issued and schools and offices and business are closed, and people are advised to stay indoors. Table 5.2 shows AQI range and levels of health concern against different air pollutants as categorised by EPA. If the AQI is higher than 500, it is called "Beyond the AQI." The health hazards related are the same with that of under Hazardous level.

Table 5.2. AQI level and related health concern

		Actions to protect your health from			
Air Quality Index (AQI)	Levels of Health Concern	Ozone	Particulate matter	Carbon Monoxide (CO)	Sulphur Dioxide (SO_2)
0 to 50 (Green)	*Good*	*None*	*None*	*None*	*None*
51 to 100 (Yellow)	*Moderate*	*Usually sensitive people should consider reducing prolonged or heavy exertion outdoors.*	*Usually sensitive people should consider reducing heavy exertion.*	*None*	*None*
101 to 150 (Orange)	*Unhealthy for sensitive groups*	*Active children and adults, and people with lung disease, such as asthma, should reduce prolonged or heavy exertion outdoors.*	*People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.*	*People with heart disease, such as angina, should reduce heavy exertion and avoid exposure to sources of CO, such as heavy traffic.*	*People with asthma should consider reducing exertion out-doors.*

151 to 200 (Red)	*Unhealthy*	*Active children and adults, and people with lung disease, such as asthma, should avoid prolonged or heavy exertion outdoors. Everyone else, especially children, should reduce prolonged or heavy exertion outdoors.*	*People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion.*	*People with heart disease, such as angina should reduce moderate exertion and avoid exposure to sources of CO, such as heavy traffic.*	*Children, asthmatics, and people with heart or lung disease should reduce exertion outdoors.*
201 to 300 (Purple)	*Very un-healthy*	*Active children and adults, and people with lung diseases, such as asthma, should avoid all outdoor exertion. Everyone else, especially children, should limit prolonged or heavy exertion outdoors.*	*People with heart or lung disease, older adults and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.*	*People with heart disease, such as angina, should avoid exertion and sources of CO, such as heavy traffic.*	*Children, asthmatics, and people with heart or lung disease should avoid outdoor exertion. Everyone else should reduce exertion outdoors.*
301 to 500 (Maroon)	*Hazardous*	*Everyone should avoid all physical activity outdoors.*	*People with heart or lung disease, older adults, and children should remain indoors and keep activity levels low. Everyone should avoid all physical activity outdoors.*	*People with heart disease, such as angina, should avoid exertion and sources of CO, such as heavy traffic. Everyone should reduce heavy exertion.*	*Children, asthmatics, and people with heart or lung disease should remain indoors. Everyone should avoid exertion outdoors.*

Note: Six levels of health concern follow the colour code for easy understanding

Activity 5.1. *Interpreting AQI*

Instruction:

1. Figure 5.4 shows the AQI at a particular time.
2. Study the parameters and the corresponding AQI values in situations (a) to (d) in Figure 5.4 and answer the questions that follow.
3. Refer Table 5.1 for AQI colour code.

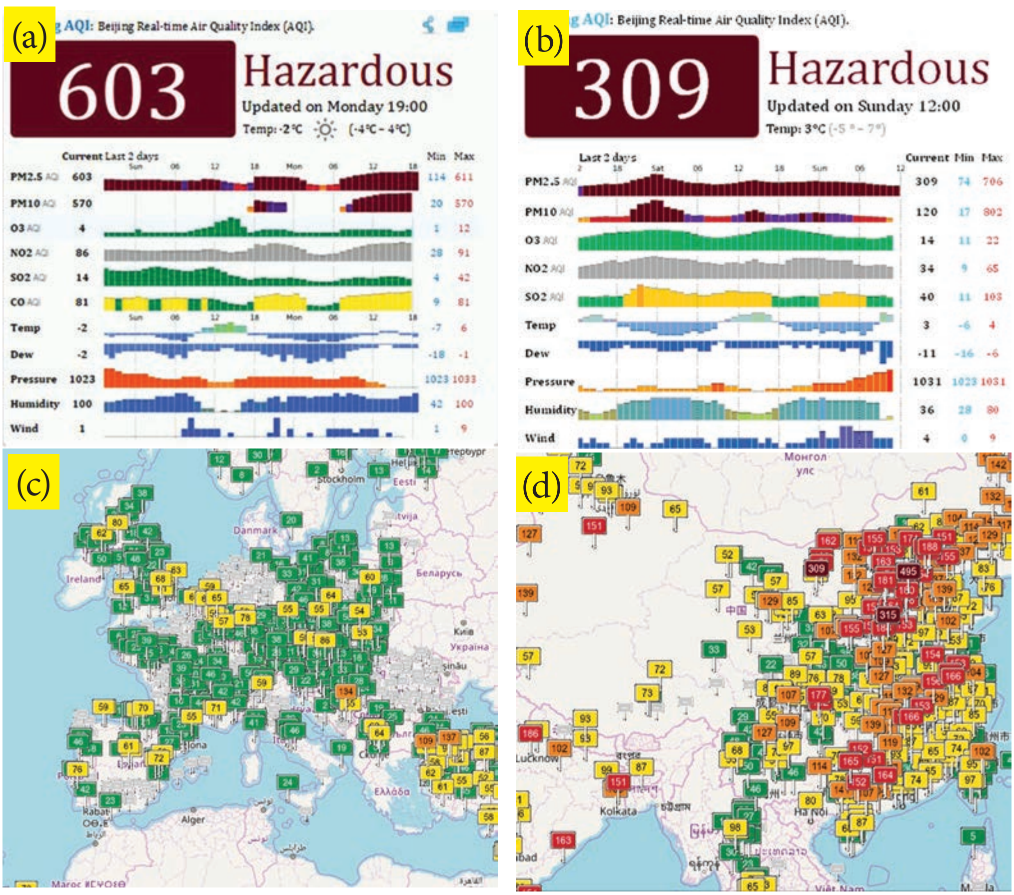


Figure 5.4. AQI case scenarios (www.waqi/info)

Questions

1. Identify the parameters that have reached unsafe levels at a particular point of time in figure (a) and (b).

2. What would be the AQI if there was a lack of particulate matters in figure (a)?
3. Which part of region (d) is at risk? Predict the consequences if necessary measures are not taken.
4. What is the amount of PM2.5 released in air as per figure (a)?

Questions

1. What is the purpose of AQI?
2. Why is PM 2.5 more harmful to humans than PM 10?
3. What can you do to avoid exposure to air pollution?
4. Complete Table 5.3.

Pollutant	Level	AQI
PM 10	70 µg/m^3	....
Ozone	....	35
Sulphur dioxide	105 ppm	....

Reprint 2022

2. Pollution Reduction

Learning Objectives

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

- discuss technologies used for reduction of greenhouse gas emission and pollution.
- explore the technologies for reusing and recycling wastes.

A. Technology for reduction of greenhouse gas emission and pollution

Innovation and investments in environment-friendly infrastructure and technologies can reduce greenhouse gas emissions. Some of the technologies used are:

(i) Carbon capture and storage (CCS) technologies

CCS is a technology that can capture carbon dioxide emitted during electricity generation using fossil fuels and industrial processes, preventing the carbon dioxide from entering the atmosphere. CCS involves capturing, transporting and storing carbon dioxide underground in depleted oil and gas fields as shown in Figure 5.5.

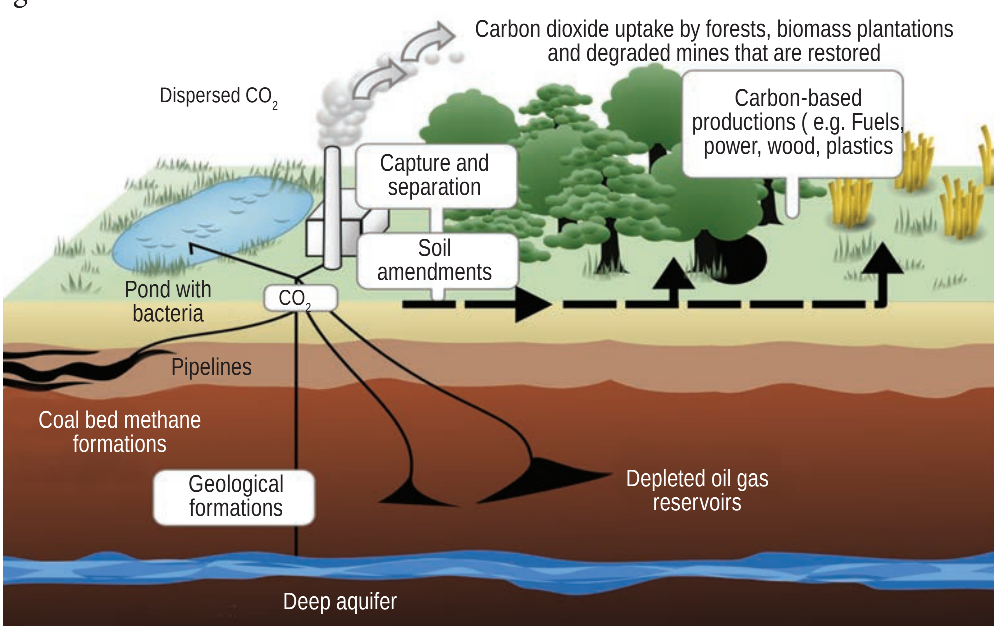


Figure 5.5. Sequestration of carbon dioxide emissions from a coal-fired plant

(ii) Carbon offsetting

A carbon offset is a mechanism adopted by individual or companies to compensate their carbon dioxide and GHGs emission by investing in environmental projects that reduces overall emissions. The project includes the use of wind energy, solar energy and hydro electricity, by investing in research and inventions of alternate energy resources and systems.(Figure 5.6).

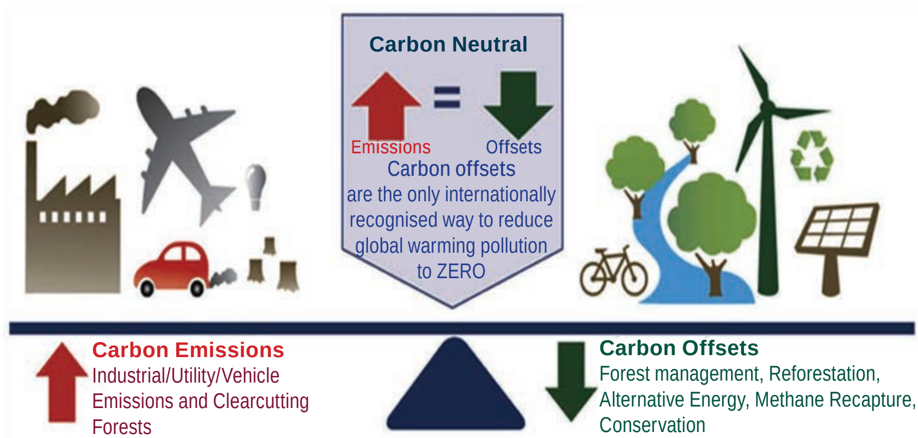


Figure 5.6. Carbon offsetting

(iii) Flue-gas desulphurisation (FGD)

Flue gas desulphurisation is a set of technologies used to remove sulphur dioxide (SO_2) from the exhaust of fossil-fuel power plants as shown in Figure 5.7. SO_2 is removed from the exhaust or chimneys by a variety of methods such as wet scrubbing using a slurry of alkaline sorbent, usually limestone or lime. FGD removes 90% of SO_2 from the exhaust thereby minimising environmental impact.

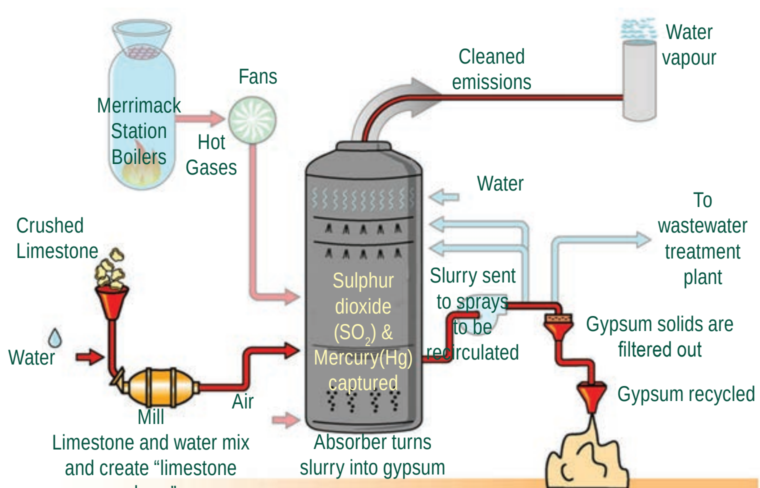


Figure 5.7. Working of flue gas desulphurisation technology

SNOX Flue gas desulphurisation is another process which removes sulphur dioxide, nitrogen oxides and particulates from flue gases.

(iv) Thermal oxidiser

A thermal oxidiser is a processing unit for air pollution control in many chemical plants that oxidise hazardous gases such as hydrocarbons to carbon dioxide and water at a high temperature. Water vapour is separated from CO_2 and CO_2 goes for sequestration. One of the most common thermal oxidisers used in the industries is the regenerative thermal oxidiser (Figure 5.8).

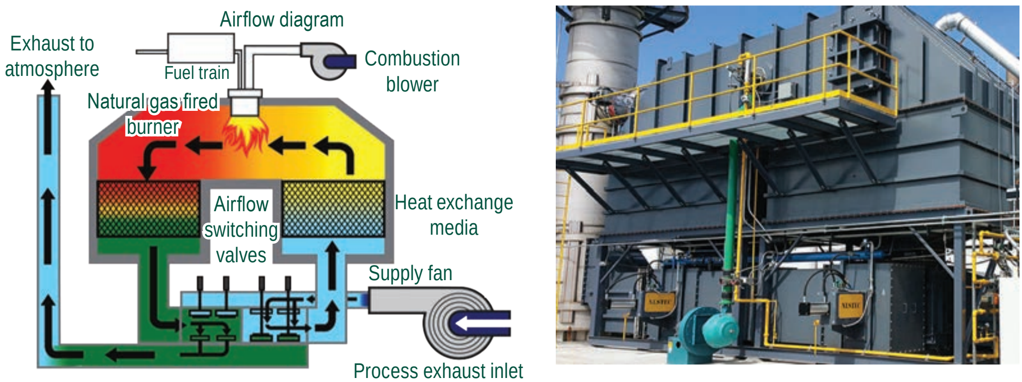


Figure 5.8. Regenerative thermal oxidiser

B. Technology for reusing and recycling wastes

Reusing and recycling are the most effective methods in minimising the wastes and pollution. It decreases the demand for fresh raw materials and energy consumption. Some of the technology and practices are:

(i) Recycling waste materials

Recycling is the process of converting waste materials into reusable materials. Recyclable materials include glass, paper and cardboard, metal, plastic, rubber, textiles and electronic appliances.

In Bhutan, The Green Road project started recycling plastics into road building materials in 2015. The technology involves mixing of plastic waste with bitumen to create an aggregate compound called polymerised bitumen that is then used to pave roads. By doing this, the project aims to reduce the amount of plastic going into landfills by up to 40% as well as significantly reduce the amount of bitumen, a viscous petroleum product, needed for laying roads.

(ii) Composting solid waste

Composting is a natural process of decomposition of organic solid waste that

Figure 5.9. Composting solid waste

yields manure or compost, which is very rich in nutrients (Figure 5.9). Composting of biodegradable waste, such as food, kitchen waste and garden waste, ensures that nutrients are recycled and returned to the soil. Composting process is aided by adding water and ensuring proper aeration by regularly turning the mixture of organic matter. Worms, fungi and bacteria further break down the material converting the inputs into heat, carbon dioxide and ammonia.

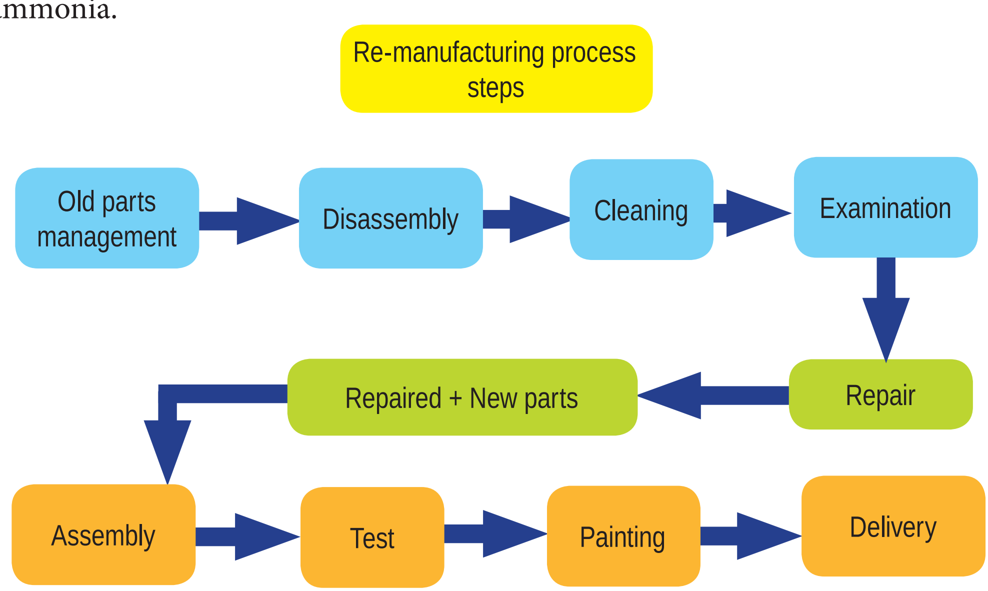


Figure 5.10. Steps of re-manufacturing process

(iii) Re-manufacturing

Re-manufacturing (Figure 5.10) is a process of rebuilding, repairing and restoring of an old instrument or equipment to make it usable again. For example, re-manufacturing of automobile parts, electric motor, tyres, etc, significantly reduces material and energy consumption in manufacturing.

(iv) Managing wastewater effluent

Wastewater can originate from households, industries, agriculture fields, commercial activities, surface runoff and sewage. Heavy metals like Hg, Pb, As, Cd and Cr are most common in industrial wastewater. One of the ways to treat wastewater is bioremediation. Bioremediation technology involves the use of living organisms to reduce or remove pollutant from the contaminated site. Phytoremediation is one such emerging green bioremediation technology that uses plants to remediate soils, sludges, sediments and water contaminated with organic and inorganic contaminants.

Activity 5.2. *Exploring technologies to reduce pollution*

Instruction:

1. Work in groups
2. Each group will select a pollutant depending on the source of pollution, such as industries, vehicles, homes, agriculture, etc.
3. Explore and discuss its impacts, and the ways and technologies that can reduce the pollutant.
4. Draw a poster showing the impacts of pollutant and the ways to reduce it.
5. Present your work in the class exhibition.

Questions

1. What are some of the benefits of the technology used in removable of each pollutant?
2. What are the common effects of all the pollutants?
3. Which technology or strategy do you think is the best option to reduce environmental pollution? Support your answer with valid reasons.

Questions

1. List any two examples of carbon offsetting.
2. How do recycling and re-manufacturing of waste materials reduce pollution?

3. Chemical Pollutants: Risk Assessment and Management

Learning Objectives

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

- describe the process of risk assessment.
- explain risk management based on the outcome of risk assessment.
- explain the importance of chemical risk management for the well-being of organisms.

Chemicals in the environment can be harmful, depending on many factors, such as toxicity and the dose to which organisms and environment are exposed. These chemical substances cause various health problems such as cancer, respiratory irritation, nervous system problems and congenital disabilities. Some health problems are immediate while others may have life threatening impact in the long run.

Risk assessment is a tool to determine if a particular chemical poses a significant risk to the health of organism or the environment. Based on the outcomes of risk assessment, appropriate actions are taken to reduce, control or eliminate the risk.

A. Risk assessment

Risk assessment is a technique for identifying potential hazard, evaluating and determining the level of risk to predict the likelihood of harm that can be caused by hazardous substances. Generally, risk assessment process involves four steps: hazard identification, dose-response assessment or hazard characterisation, exposure assessment and risk characterisation.

(i) Hazard identification

A hazard is a condition that has a potential to pose a threat to life, health, property, or environment. Hazard identification is the first and most easily recognised step in risk assessment and risk management. In hazard identification, the presence of potentially hazardous substances in the environment is identified.

(ii) Dose-response assessment

The dose-response assessment or hazard characterisation estimates how different levels of exposure to a toxic substance change the likelihood and severity of health effects. This assessment is done by evaluating the quantitative relationship between exposure to different levels of dose and response.

Figure 5.11 shows a typical dose-response curve used in the assessment of chemical hazard. The blue curve illustrates the chemical A with a threshold dose. This type of chemicals are non-toxic at low doses but becomes increasingly toxic and hazardous beyond the threshold dose.

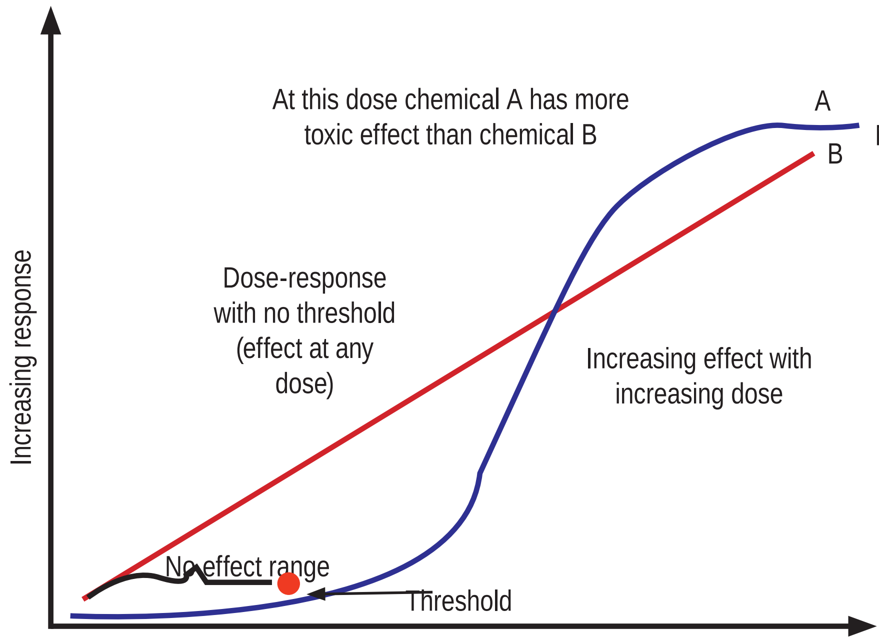


Figure 5.11 Dose-response relationship

The staight red line characterises non-threshold chemical B for which the effects are toxic at any dose and its effect increases as the dose increases. Increasing effect means an increasing adverse response, which can range from temporary irritation to permanent damage to the body or death of an organism. Many carcinogens are considered to be non-threshold chemicals.

(iii) Exposure assessment

Exposure assessment is a key phase in the risk assessment to estimate the intensity, frequency, and duration of exposures to the toxic substances. Individuals are often exposed to substances through more than one exposure pathway, for example, through contaminated water, air or food. In such situations, the total exposure is equal to the sum of the exposures through all pathways. The exposure assessment can be qualitative and(or) quantitative evaluation of the degree of exposure in terms of frequency and duration.

(iv) Risk characterisation

Risk characterisation is an estimation of health effects under various conditions of exposure to the potentially hazardous substances. The outcomes from hazard identification, dose-response assessment and exposure assessments are integrated to carry out risk characterisation. The exposure assessment is the most significant step in risk characterisation since the exposures can be controlled, whereas the hazard and dose-response are related to inherent features of the chemical agents and hence cannot be controlled. Therefore, the risk characterisation summarises and interprets the information of the level of risk and is a crucial step in the implementation of risk management.

After the risk assessment, if the chemical substance is found to be hazardous to the people and environment, the government and other regulatory agencies can set regulatory standards to reduce the threats.

B. Risk management

Risk management involves weighing policy options and selecting an appropriate course of action by integrating the results of the risk assessment. The strategies include avoiding the risk, reducing the probability of occurrence, or reducing the negative effect of the risk. However, the most common objective of risk management is to reduce risks to an acceptable level. Figure 5.12 shows the processes of risk assessment and reduction.

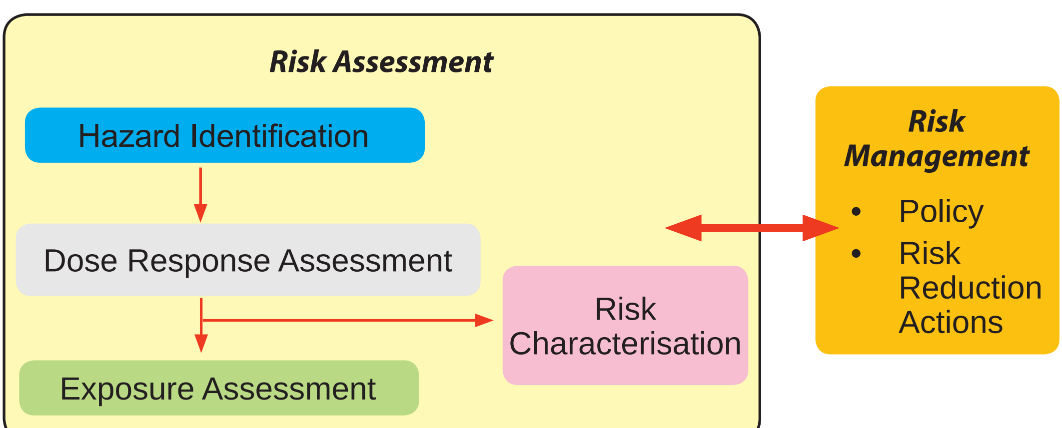


Figure 5.12. Process of risk assessment and reduction

Activity 5.3. *Analysing the effects of baby bottle chemicals*

Instruction:

In groups, read the case study and answer the questions that follow:

BPA in baby bottles

In 2010, Canada was the first country to take regulatory action leading to restriction and prohibition on the use of bisphenol A (BPA) in certain consumer goods.

BPA is an industrial chemical used in plastic-based products, ranging from refillable water bottles to the protective liners inside metal cans that make it possible to store food longer without spoiling.

Numerous studies have demonstrated that BPA is an Endocrine Disrupting Chemical (EDC) with an ability to affect the hormonal systems of animals and humans. BPA mimics the female sex hormone estrogen and, upon entering the body, can lead to reproductive impairment or cancer. Animal studies have shown EDCs are more likely to disrupt hormonal systems early in life compared to adulthood.

Humans are exposed to BPA when it leaches into foods and beverages from plastic packaging or storage containers. Heating or boiling substances in plastic containers (warming formula in baby bottles, for example) can facilitate the release of BPA. BPA can have disproportionately more severe effects on infants because their organs are rapidly developing and small size means that a small amount of BPA is at a higher concentration than in adult bodies.

Under the Chemicals Management Plan, a policy and program under the authority of the Canadian Environmental Protection Act (CEPA), chemicals are screened, prioritised and categorised for further risk assessment. BPA was identified as a high priority chemical because of its potential toxicity to the reproductive system and other endocrine functions.

Results of the risk assessment showed that BPA levels leaching out of plastics were below levels where the chemical is harmful to both the general population and most susceptible populations.

However, results for infants showed only a small difference between exposure level and effect level.

Weighing available and relevant scientific evidence, which showed the potential for increased exposure and developmental sensitivities of infants to BPA, and knowing that alternatives to BPA were readily available, led the Canadian government to ban BPA in plastics used to make baby bottles. This approach was consistent with the precautionary principle.

Other governments have followed suit. The European Union banned the manufacture and sale of BPA-containing baby bottles in 2011. In Denmark, BPA was banned in all food products for children aged three and under. In Australia, manufacturers voluntarily agreed to phase out BPA in baby bottles. As of 2011, the U.S has not taken federal-level action on BPA.

Table 5.4. The average Probable Daily Intakes (PDIs) of BPA for infants of different age groups

Age group	Average PDIs of BPA for infants taken along with formula intake measured in µg/kg-bw/day (microgram per kg per body weight per day)
0 to 1 month	*0.45*
2 to 3 months	*0.50*
4 to 7 months	*0.38*
8 to 12 months	*0.21*
13 to 18 months	*0.23*

(Adapted from: http://sciengpages.ca/wp-content/uploads/chemicalsandtoxicity.pdf https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety/packaging-materials/bisphenol/health-risk-assessment-bisphenol-food-packaging-applications.html)

Questions

1. Based on above case, identify and explain the areas of risk assessment.
   a. Hazard identification
   b. Dose-response relationship
   c. Exposure characterisation
   d. Risk characterisation
2. What was the outcome of the risk assessment?
3. Narrate a similar scenario in Bhutan that you are familiar with.

Questions

1. Examine the importance of risk assessment for health and safety of environment.
2. Which is the most crucial of all the four steps of risk assessment? Give reasons.
3. 'Risk management is guided by the outcome of risk assessment'. Justify the statement with suitable example.

4. Biological Pollutants

Learning Objectives

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

- explain biological pollutants and their effects.
- discuss environmental pollution caused by genetically modified organisms.

Biological pollutants include bacteria, moulds, mildew, viruses, animal dander (minute scales from hair, feathers, or skin) and cat saliva, mites, cockroaches, and pollens. They result in poor indoor air quality.

The effects of biological pollutants on our health depend on the type and intensity of pollution and the organism. Some organism do not experience health reactions from certain biological pollutants, while others may experience one or more of reactions, such as allergy, infection or toxicity.

A. GMOs and genetic pollution

GMOs contain genes which have been transferred from unrelated species. These may come from bacteria, viruses, plants or animals. These 'foreign' genes when transferred into other organisms cause genetic contamination or pollution of the natural gene pool of that organism.

According to Greenpeace, genetic contamination may arise in four situations if:

- wild, related flora growing nearby are pollinated by a genetically engineered(GE) crop.
- non-GE or organic crops in the neighbouring fields are pollinated by the GE crop.
- a semi-wild, weed or 'feral' population of GE plants develop if the GE crop survives in the agricultural or natural environment.
- microorganisms in the soil or the intestines of animals eating the GE crop acquire the foreign genes.

As plants and organism move, grow and reproduce, genetic pollution has a potential to multiply and spread beyond the initial habitat where it is introduced.

The most straightforward way to manage the risk of a GMO is to simply contain the organism, to somehow prevent it from spreading beyond its intended release site. Potential methods of containment include the use of barren zones around crops and plantings of trap plants into border rows.

Long-term, large-scale monitoring of transgenic plantings provides important research opportunity as well as valuable means of minimising risk.

To ensure prevention of genetic pollution, there must be:

- no commercial releases of GE crops until it is fully proven that they do not cause genetic pollution.
- independent assessment of the environmental impact to avoid planting GE crops as far as possible.
- field tests restricted to the assessment of the ecological impact on properly contained sites.
- coexistent rules that aim to ensure that there are no detectable contamination of neighbouring crops, and a strict liability on biotech companies for any harm arising from the release of their products (including economic harm).

Activity 5.4. *Investigating the impacts of genetic pollution*

Instruction:

1. Work in groups.
2. Search an article related to genetic pollution.
3. Read and discuss the threats posed by genetic pollution in the article.
4. After the discussion, interpret the article in the form of a poster.
5. Display the poster for evaluation.

Questions

1. How is genetic pollution a threat to human beings?
2. Is there any threat from genetic pollution in Bhutan? Explain.
3. Mention some ways to reduce genetic pollution.

Questions

1. List some of the biological pollutants you have encountered in your place and explain how they affect your health.
2. Genetic pollution is more dangerous than other types of pollution. Justify.

Exercise

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

   i. The process in which dose-response assessment and exposure assessments are integrated to predict risk to specific population is known as

      A. risk management.

      B. hazard identification.

      C. risk characterisation.

      D. probable exposure.

   ii. In Figure 5.13, factories and vehicles emit different gases which pollute the atmosphere. As a result, the man in the figure will be more prone to

Figure 5.13.

      A. skin cancer.

      B. rashes on the face.

      C. neck stiffness.

      D. respiratory disorders.

   iii. Which statement(s) is (are) true for genetic pollution?

      I. causes mutation in the organisms.

      II. may lead to the extinction of wild varieties.

      III. produces superior individuals.

A. I and II

B. II and III

C. I and III

D. I,II and III

iv. If the atmosphere is polluted with sulphur dioxide and oxides of nitrogen, which technology would you prefer to use for the reduction of these gases?

A. Flue gas desulphurisation.

B. SNOX flue gas desulphurisation.

C. Carbon offsetting.

D. Thermal oxidiser.

v. Which of the following pollutant is responsible for the yellowing of the Taj Mahal?

A. Carbon dioxide and nitrogen oxide

B. Ozone and sulphur dioxide

C. Sulphur dioxide and sulphur dioxide

D. Carbon monoxide and nitrogen dioxide

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

i. Genetic contamination is the transfer of transgenes from ____________ crops through pollen grains to the genome of related species.

ii. The level of mercury in the soil in a particular area was found to be very high after risk assessment. Hence this chemical requires ____________.

iii. Even when the concentration of some pollutants are ____________ the air quality index value can still be high due to other pollutants.

iv. Planting trees to reduce the effect of carbon emission in Thimphu town is an example of ____________.

v. The presence of harmful microorganisms in a house is ____________ pollution.

Reprint 2022

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

    i. You can recycle meat, bones and dairy products in school composting bin.

    ii. Carcinogens are considered to be threshold chemicals because they are toxic at any level of dose.

    iii. Higher the value of air quality index greater is the pollution in the air.

    iv. Genetic pollution in plants are caused mainly by self-pollination.

    v. Phytoremediation involves the use of plants for removing pollutants, whereas bioremediation involves the use of animals for the same purpose.

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. Sulphur dioxide	a. damages ozone layer
2. Carbon dioxide	b. reduces oxygen carrying capacity of blood
3. Carbon monoxide	c. forms ozone layer
4. Chlorofluorocarbons	d. causes greenhouse effect
5. Oxygen	e. damages monuments
	f. forms acid rain

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

    i. The level of air quality index is not always directly proportional to the industrialisation of the place or a country. Explain.

    ii. Why does hazard characterisation depend on the nature of the toxic substance?

    iii. Is banning of chemical import a good strategy for the chemical risk management? Justify your stand.

    iv. Reducing, reusing, recycling and remanufacturing things contribute towards reducing greenhouse gases in the atmosphere. Give an example of each process other than the ones given in the text.

    v. Compare and contrast GMO and Non- GMO crops.

vi. Figure 5.14 shows the annual average PM10 μg/m³ for Thimphu from 2004 till 2015. Study the figure carefully and answer the questions that follow:

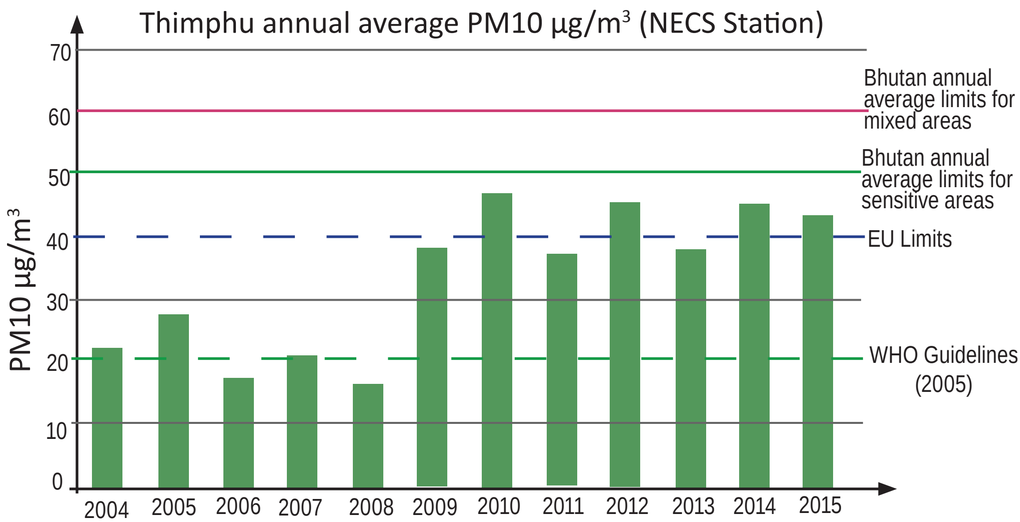


Figure 5.14

a) Calculate the AQI value of PM10 for 2004 and 2015. Compare the values and interpret your results.

b) In which year was the level of PM10 the least? Why?

c) What happens to the average level of PM10 over the years? Give reasons.

CHAPTER 6 CLIMATE CHANGE

Climate is one of the most important factors that affects the wellbeing of all life forms on the Earth. Slight disturbance in the components of the Earth (atmosphere, hydrosphere, cryosphere, lithosphere and biosphere) causes drastic changes in climate. Emission of greenhouse gases (GHGs) through various anthropogenic activities is one of the main causes of climate change. Climate change today has become a global concern.

The change in climate affects natural resources, disturbs fragile ecosystem and threatens the existence of living organisms. Numerous studies show that the climate change results in the change of phenological events of plants and animals. Therefore, in order to sustain life on the Earth, it has become crucial to adopt appropriate courses of action to mitigate the problems of climate change or adapt to it.

1. Mitigation and Adaptation to the Climate Change

Learning Objectives

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

- explain mitigation and adaptation based on IPCC and UNFCCC.
- describe some of the mitigation measures for climate change in Bhutan.
- analyse the vulnerability assessment of climate change.
- determine the impacts of climate change and suggest adaptive measures.

The two fundamental response options to the risks posed by climate change are mitigation and adaptation to climate change. In recent years, the world has made efforts to mitigate climate change through reducing and stabilising greenhouse gas concentration in the atmosphere. Since the progress in reducing the GHG is very slow, adaptation is now viewed as a possible option to reduce the vulnerability to the anticipated negative impacts of climate change. It is important that mitigation and adaptation measures complement each other to reduce the risk of climate change, as given in Figure 6.1.

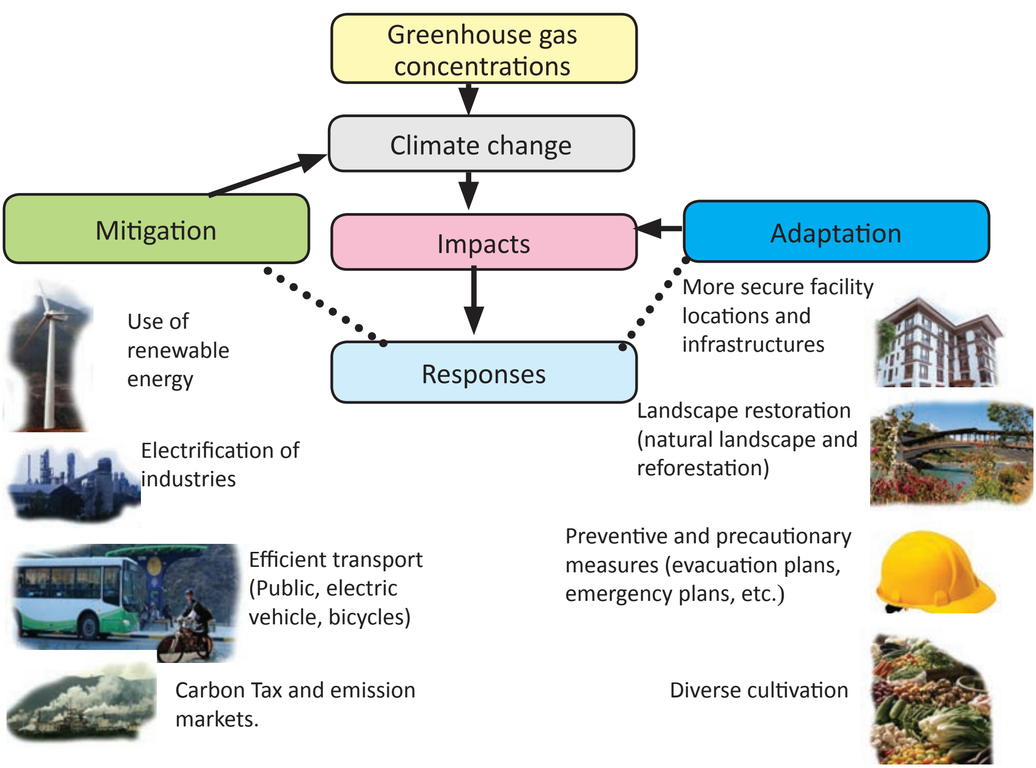


Figure 6.1. Mitigation and adaptation strategies for climate change

Reprint 2022

A. Mitigation of climate change

Mitigation is any action carried out to eliminate or reduce the risks and consequences of climate change. It is one of the main approaches to slow down the global climate change processes. According to the Intergovernmental Panel on Climate Change (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC), mitigation of climate change is an intervention to reduce the sources and enhance the sinks of GHG. Mitigation actions lower emissions of carbon dioxide, methane and particles like black carbon soot that have a warming effect.

Occurrence of extreme weather conditions, shrinking of ice caps, and extinctions of species are some of the visible evidences of climate change. Human activities result in higher global concentrations of greenhouse gases and warming of the planet. These effects are increased by a chain of natural phenomena in the Earth system. If GHG emission levels continue to rise, the future climate changes are likely to be even more extreme. The ultimate goal of mitigation is to prevent dangerous anthropogenic interference with the climate system. Table 6.1 shows some of the mitigation practices and technologies in different sectors.

Table 6.1. Mitigation measures

Sector	Key mitigation technologies and practices
Energy	• Improving supply and distribution efficiency. • Switching fuel from coal to renewable energy. • Using new and energy efficient technologies • Improving the insulation of buildings. • Installing led lighting, fluorescent lighting, and natural skylight windows. • Carrying out energy audit to reduce energy wastage.
Transport	• Using of more fuel-efficient vehicles. • Modal shifting from road transport to rail and other efficient public transport systems. • Using non-motorised transport (cycling, walking), • Proper land-use and transport planning.
Building	• Using of locally available raw materials for construction. • Installing of efficient lighting and daylighting. • Using of more efficient electrical appliances. • Improving insulation. • Designing solar heating and cooling.
Industry	• Using energy efficient equipment. • Installing heat and power recovery equipments. • Recycling of materials. • Controlling harmful gas emissions and other effluents. • Installing air and water pollutant filters.

Agriculture	• Improving crop and grazing land to increase soil carbon storage. • Restoration of cultivated peaty soils and degraded lands. • Improving livestock and manure management to reduce methane gas emission. • Improving nitrogen fertilizer application techniques to reduce N_2O emissions. • Using high yielding seeds.
Forestry/ forests	• Managing forest through afforestation and reforestation. • Using of forestry products for bioenergy to replace fossil fuel use. • Tree species improvement to increase biomass productivity and carbon sequestration. • Mapping land-use change.
Waste	• Installing equipment to recover methane gas from landfill. • Waste incineration with energy recovery. • Composting of organic waste. • Controlled wastewater treatment. • Recycling and waste minimisation.

Source: https://www.ipcc.ch/publications_and_data/ar4/syr/en/spms4.html

In Bhutan, the National Environment Commission Secretariat (NEC) coordinates the formulation of mitigation measure for climate change. Through the consultative process with relevant sectors, it facilitates the preparation of GHG inventory that describes sources of greenhouse gases and implementation of effective mitigation measure to reduce the emission.

In terms of GHG emission, Bhutan is distinguished as one of the few countries in the world with negative carbon emission. However, Bhutan's status as a negative carbon emitter does not make it immune to the impacts of climate change. Being a Himalayan country, it is more vulnerable to the impacts of climate change. Due to the impact of warming, the climate tends to become extreme even with a small change in altitude.

Some of the actions for mitigation of greenhouse gas emission in Bhutan include, enhancement of carbon sinks through conservation of forest and watershed management, fostering energy efficiency through use of renewable energy and technology transfer, and minimising negative impacts from developmental activities to environment through conduct of environmental impact assessment.

The following are some of the significant measures taken by Bhutan to mitigate the climate change:

(i) Constitutional mandate

The Article 5, Section 2 of the Constitution of the Kingdom of Bhutan 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."

(ii) Policies and plans

As a commitment to preserve its rich environment, many policies and action plans have already been developed, such as Vision 2020, National Forest Policy (2010), Forest and Nature Conservation Act of Bhutan (1995), Biodiversity Act of Bhutan (2003), Biodiversity Action Plan (2009), National Environment Strategy for Bhutan (1998), and the National Adaptation Programme of Action (NAPA 2006). Bhutan is also a party to the United Nations Convention on Biological Diversity (UNCBD), United Nations Framework Convention on Climate Change (UNFCCC), United Nations Convention to Combat Desertification (UNCCD), and United Nations Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES).

(iii) Carbon Neutrality

Bhutan has committed to remain carbon neutral during the United Nations Climate Change Conference, COP-15 at Copenhagen. Bhutan can remain carbon neutral by not exceeding greenhouse gas emission beyond carbon sequestration by forest, which is estimated at 6.3 million tonnes of carbon dioxide. At present, Bhutan's net greenhouse gas emission is negative, because Bhutan's rich vegetation acts as a carbon sink and absorbs million of tonnes of carbon emitted. Sustainable forest management and conservation of environmental services are some measures to achieve carbon neutrality.

(iv) Low Emission Capacity Building (LECB) Project

Bhutan is one of the member countries participating in the LECB programmes with the objective to promote low-emission and carbon resilient development. The LECB programmes are closely aligned with national development plans for enabling a sustainable green growth economy.

Other mitigation measures adopted by Bhutan include expansion of installed hydropower capacity in the country, use of electricity as the main source of energy, giving incentives for energy saving devices and low emission vehicles, and initiating various programs in agriculture like sustainable land management, improving livestock management and promotion of organic agriculture.

Activity 6.1. *Understanding REDD+ and its role in climate change.*

Instruction:

Read the passage and answer the questions that follow.

Bhutan and REDD+

Environmental conservation constitutes an important part of Bhutan's national spatial planning strategic framework and has always enjoyed a high priority on the country's development agenda. Bhutan`s protection and conservation of the environment and the safeguarding of forest and wildlife is ensured under the Constitution of the Kingdom of Bhutan. The Constitution directs every Bhutanese citizen to protect environments and natural resources. The Constitution of Bhutan under Article 5, section 2(d) mandates Bhutan to maintain 60% forests cover all the time. Over the years, set of strong laws and policies have evolved to ensure the protection, management and sustainable use of forests.

REDD+ stands for countries' efforts to reduce emissions from deforestation and forest degradation, and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks. Reducing emissions from deforestation and forest degradation (REDD+) is a mechanism developed by Parties to the United Nations Framework Convention on Climate Change (UNFCCC). It creates a financial value for the carbon stored in forests by offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. Developing countries would receive results-based payments for results-based actions. REDD+ goes beyond simply deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. Therefore, implementation of REDD+ has huge potential to complement the efforts of the Royal Government of Bhutan (RGoB) in conservation and sustainable management of forest resources. REDD+ may be linked with a market mechanism which allows developed countries and private companies to fund the planning and implementation of REDD+ activities in developing countries.

REDD+ also has the potential to generate additional investment for sustainable management and utilization of forest resources through a future international climate change agreement. The level of this investment will depend on Bhutan's success in implementing policies and measures that address the drivers of deforestation and forest degradation, and the barriers to the '+' activities (conservation, sustainable management and enhancement of forests).

Bhutan's REDD+ program started in 2010 with support from UN-REDD Programme. In 2013, Bhutan prepared its REDD+ Readiness Preparation Proposal (R-PP) with support from UN-REDD (UNDP, FAO, UNEP) programme and its country offices which was submitted to and approved by the Forest Carbon Partnership Facility (FCPF) of World Bank in December 2013. The main outcome of REDD+ readiness programme is to develop Bhutan's National REDD+ Strategy and implementation framework including National Forest Monitoring System, Forest Reference (Emission) Level, Monitoring, Reporting and Verification (MRV) mechanism, and Safeguard Information System (SIS) for REDD+.

Adapted from http://redd.dofps.gov.bt

Questions

1. What is REDD+?
2. How can REDD+ initiative help in the mitigation of climate change?
3. REDD+ has huge potential to complement the efforts of the Royal Government of Bhutan (RGoB) in conservation and sustainable management of forest resources.' Support this statement with good justifications.
4. REDD+ implementation focus through results-based payments for results-based actions. State one example.
5. Forest contributes in containment of global warming and in preserving watershed. Support this statement.

B. Adaptation to climate change

Adaptation is an essential measure to address the impacts and opportunities created by changing climate. The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as:

"Adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities."

Adaptation addresses the impacts of climate change, thereby increasing the adaptive capacity of the system. Based on timing, goals and motives for implementation, adaptation is classified into four types:

- Anticipatory or proactive adaptation is a measure put in place before any impacts of climate change are observed.
- Reactive adaptation is a measure carried out after the initial impacts of climate change are evident.
- Planned adaptation is a deliberate policy decision which is based on the awareness of changing climate and understanding that action is required to maintain the desired state.
- Autonomous or spontaneous adaptation is triggered by changes in natural systems and by market or welfare changes in human systems.

Adaptation measures include large-scale infrastructure changes such as building defence to protect against sea-level rise or improving the quality of road surfaces to withstand hotter temperature. It may also include behavioural shifts such as individuals using less water and farmers planting different crops. Table 6.2 shows some of the adaptation measures practised in different sectors.

Table 6.2. Adaptation measures

Sector	Adaptation option/strategy
Water	Rainwater harvesting, water storage and conservation techniques, water reuse, desalination, water-use and irrigation efficiency.
Agriculture	Adjustment of planting dates and crop variety, crop relocation, improved land management.
Infrastructure /settlement (including coastal zones)	Relocation, seawalls and storm surge barriers, dune reinforcement, land acquisition and the creation of marshlands/wetlands as buffer against sea level rise and flooding, protection of existing natural barriers.
Human health	Heat-health action plans, emergency medical services, improved climate-sensitive disease surveillance and control, safe water and improved sanitation.
Tourism	Diversification of tourism attractions and revenues, creating eco-ponds and botanical garden, and increasing tourism taxes..
Transport	Realignment/relocation, design standards and planning for roads, rail and other infrastructure to cope with warming and drainage.
Energy	Strengthening of overhead transmission and distribution infrastructure, underground cabling for utilities, energy efficiency, use of renewable sources, reduced dependence on single sources of energy.

In order to address urgent and immediate adaptation needs against adverse impacts of climate change, adaptation activities are planned through the adaptation process involving various stakeholders.

The degree to which climate changes impact depend on the effectiveness of adaptation measures developed through the adaptation process. Adaptation process is developed by the country based on the particular goal to adapt to climate change. It involves the following steps:

(i) Observation

Observation in adaptation process is place specific and considers climatic condition of the place, socioeconomic and other environmental conditions as the main parameters. The knowledge of the place is also gained from the analysis of historical climate impacts and collecting data on rainfall, temperature and wind direction.

(ii) Assessment

Assessment is done for checking the vulnerability of species, ecosystem and ecosystem processes in a place. The IPCC defines vulnerability as:

"The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes."

The three components of vulnerability are exposure, sensitivity and adaptive capacity given in Figure 6.2. Based on the vulnerability components, various methods such as case studies, scenario analyses, sensitivity analyses, monitoring of key species, and peer information sharing are used for vulnerability assessment. High exposure or sensitivity and low adaptive capacity indicate high vulnerability of the place.

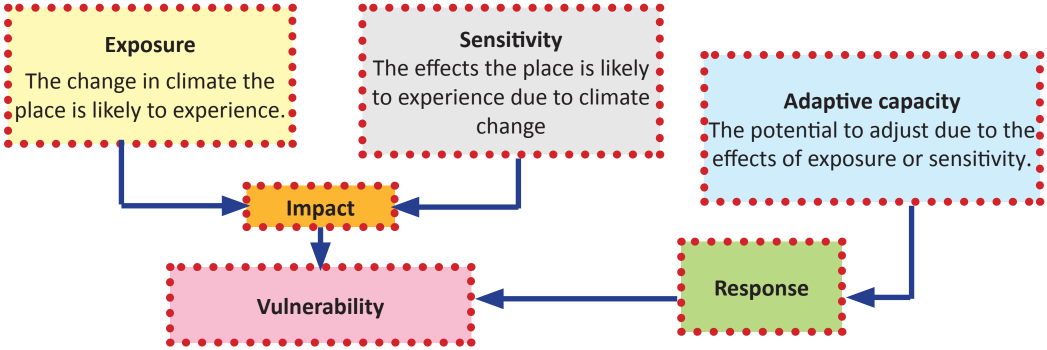


Figure 6.2. Vulnerability assessment

(iii) Planning

Once vulnerability assessment is carried out, the next stage involves identifying, evaluating, and selecting options to support planning methods to adapt the impact of climate change. Participatory approaches, where community members, governing institutions, regional and international parties are included to work collectively to define the problem and plan the adaptation strategies. Common approaches to planning include integrating climate adaptation into existing management plans. For example, hazard mitigation, ecosystem conservation, water management and public health.

(iv) Implementation

After actions and strategies are planned, the implementation stage involves executing the planned activities. Implementing climate change adaptation actions is an ongoing process. Some actions require to be implemented immediately, while others may be long-term goals. It take time and resources to put these actions into place. Implementation actions might include an undertaking aimed towards reducing current vulnerabilities to hazards or extreme weather events.

(v) Monitoring and Evaluation

This stage is for evaluating the effectiveness of adaptation actions. Uncertainty about future climate as well as population growth, economic development, and other social issues can stymie climate adaptation activity. Therefore, through interactive processes with different stakeholders, the appropriateness of planned and implemented activities need to be regularly evaluated and revised as the new information becomes available.

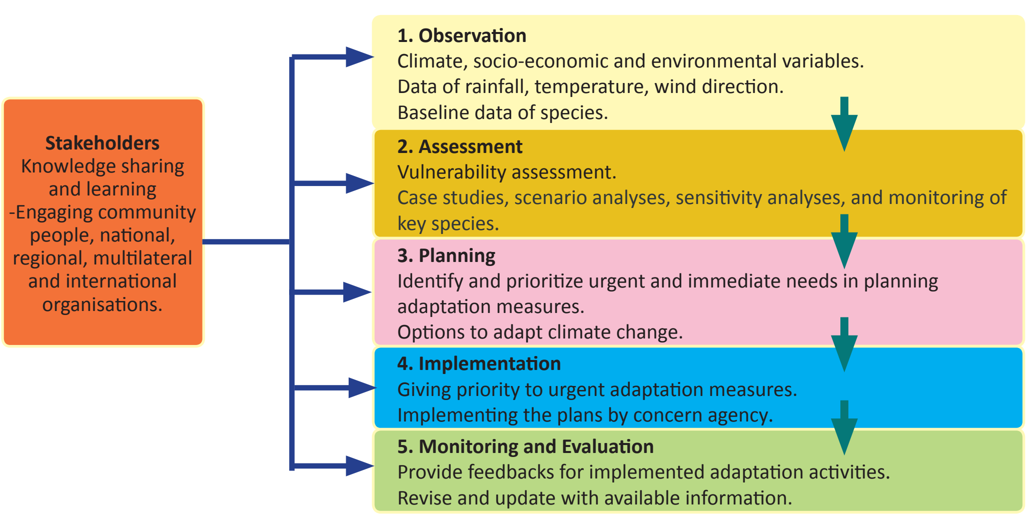


Figure 6.3. Adaptation process

Reprint 2022

Bhutan's development sectors like hydropower, agriculture and forestry are sensitive to climate, therefore, adaptation is a priority for addressing the adverse impact of climate change. Bhutan prepared its National Adaptation Programme of Action (NAPA) in 2006 as a means for adaptation to climate change. Under Bhutan's NAPA, some of the projects carried out include:

- Landslide Management and Flood Prevention.
- Disaster Risk Reduction and Management.
- Enhancing National Capacity for Weather Stations and Seasonal Forecasting in Bhutan.
- Application of Climate Resilient and Environment Friendly Road Construction (EFRC) nationwide by National Engineering Institutes.
- Community-based Food Security and Climate Resilience.
- Flood Protection of Downstream Industrial Area.
- Rainwater Harvesting and Drought Adaptation.
- Community-based Forest Fire Management and Prevention.

Activity 6.2. *Adapting to climate change impacts*

Instruction:

1. Work in groups.
2. Each group will visit different places within the school campus and select one particular place (Agriculture garden, academic building, flower garden, football ground, etc.).
3. Discusses and frame adaptive measures of the place by considering the situation below:

   'Climate change in our place has resulted in the increase in temperature and occurrence of drought.'
4. Complete Table 6.3 and present the group work to the class.

Table 6.3.

Name of the Place	Observation	Assessment (Vulnerability)	Planning	Implementation	Monitoring and evaluation

Questions

1. While doing the vulnerability assessment of your chosen place, what components did you consider?
2. List down the stakeholders you included while formulating adaptation measures.
3. Why are monitoring and evaluation stages important in adaptation process?
4. Suggest some other adaptation measures you would want to implement in your locality.

Questions

1. How does adaptation compliment mitigation? Give one example.
2. Why does Bhutan implement low GHG emission development plan though it is a carbon negative country?
3. 'Vulnerability assessment is always carried out while planning the adaptation measures'. Support this statement.

Reprint 2022

2. Phenology and Climate Change

Learning Objectives

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

- design and conduct a scientific investigation to demonstrate an understanding of scientific enquiry method.
- use relevant tools and techniques to carry out phenology and climate data analysis.
- relate phenology to climate change.
- collect scientifically rigorous data to contribute to climate science in Bhutan.

Phenology is a study of the recurring seasonal life cycle of plants and animals, and its relationship with the environment. It is the simplest process to track changes in the ecology of species in response to climate change. Since phenophases of living organisms are sensitive to climatic conditions, trends in phenology serve as natural indicators of climate change. The study of phenology involves observing and keeping a record of changes in phenophases of living things over long periods of time. The analyses of change in timing of phenophases are used as a basis to evaluate the trends of climate change and the impact on phenological events of species and ecosystems.

A. Investigating phenology

Phenology investigation is one of the ways to understand the climate change and its impact on biodiversity. The timing of phases of events in plant and animal life cycle, known as phenophases is predominantly affected by climatic components such as temperature, rainfall, and day length. Phenology, as an investigative science, follows scientific processes as outlined in Figure 6.4.

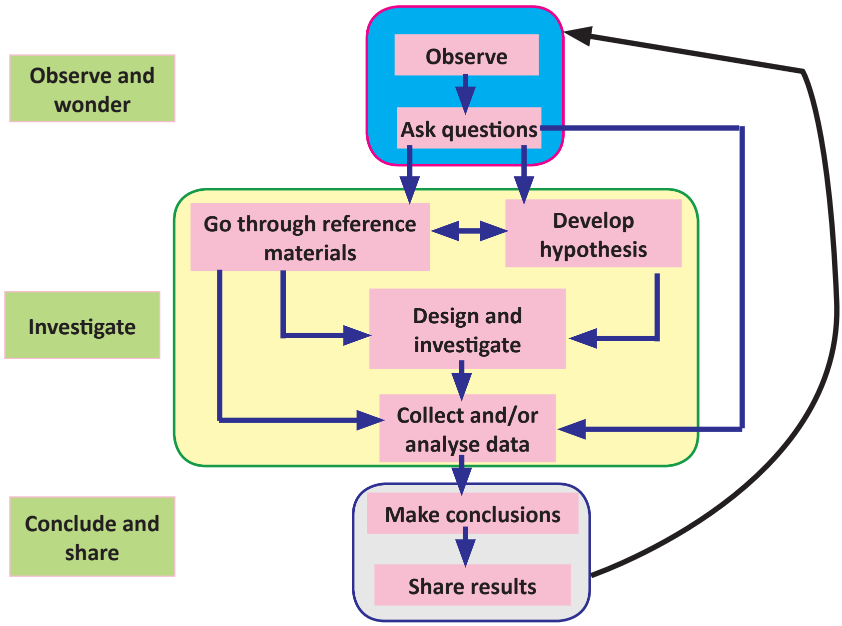


Figure 6.4. The scientific processes of investigation

a. Observing and formulating question

The phenology investigation begins with observing plant or animal in the surrounding environment. Observation includes observing phenological events such as unfolding of leaves, bees visiting flowers, listening to call of birds, smelling of flowers, or observing pupation of larvae from its cocoon. After observation over a period of time, formulation of question is carried out. The framed question can be simple, since it is not meant to have an immediate or obvious answer. However, questions need to be specific and focussed. Figure 6.5 provides some examples of phenology investigation questions formulated after observation.

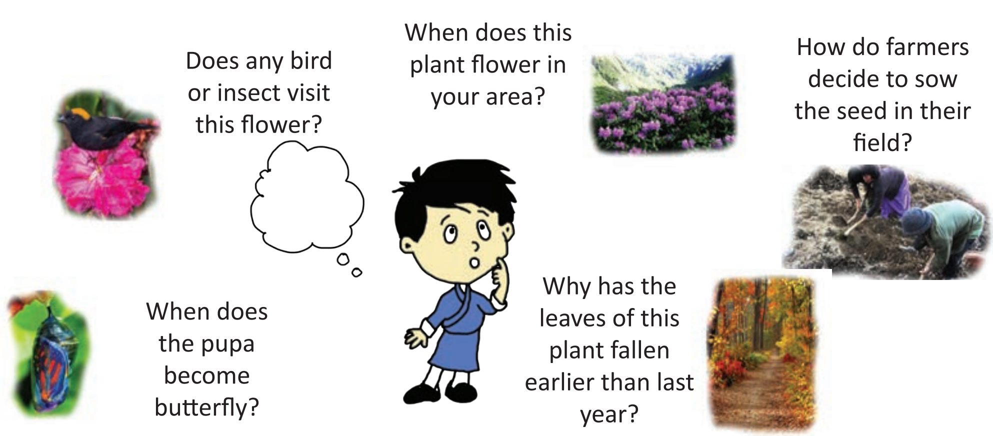


Figure 6.5. Examples of observation questions

Activity 6.3. *Observing and designing phenology questions*

Instruction:

1. Walk around the school campus, preferably to a place of natural setting where you can visit regularly. Spend 15-30 minutes at the place, observing the plants.
2. Select and identify the plant that you are interested to observe or investigate.
3. Record the observation of phenological events of the selected plant and formulate a question for each phenophases observed, in Table 6.4.

Table 6.4. Phenological questions

Sl. No.	Phenophases of plants and animals observed	Framing question.
1.		
2.		

4. Each student will select one best question from the completed Table 6.4 and write on a sticky note, and place the sticky note on the 'Question Pool' corner.
5. Discuss and select one question from the 'Question Pool' that the group is interested to investigate

Questions:

1. Why is careful observation important for developing question in phenology study?
2. What things did you consider while formulating the question?
3. Justify why your group's question is important.

b. Developing hypothesis

A hypothesis is a testable statement about the natural world that is either supported or rejected by experiments or observations. Establishment of hypotheses is not about being right or wrong. It is a supposition or proposed explanation made on the basis of limited evidence as a starting point for further investigation. In the process of carrying out the study, the hypothesis proposed is used as a means to predict the outcome of the study. A prediction or expectation is a statement that tells what will happen under certain conditions or the causes of the change. It can be expressed in the form: if 'A' occurs, then 'B' will happen. Prediction is then tested by gathering evidence using different methods. A match between prediction and the evidence lends support to the hypothesis, while a mismatch refutes the hypothesis. Figure 6.6 is an example of a hypothesis tested by prediction through evidence.

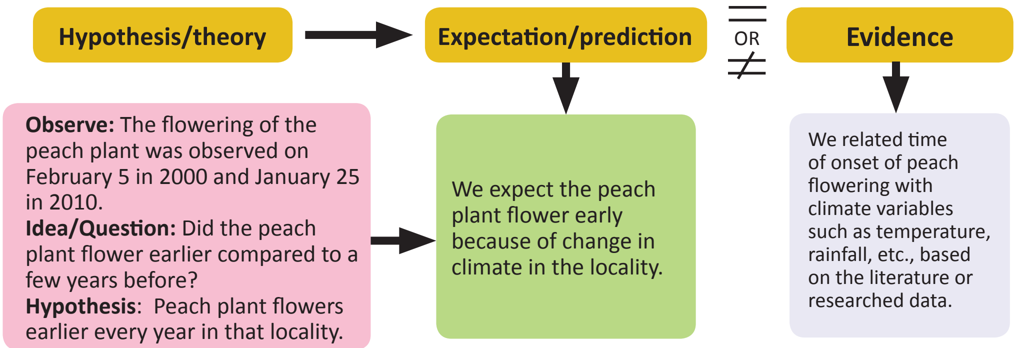


Figure 6.6. Developing Hypothesis

Activity 6.4. *Developing hypothesis and making prediction*

Instruction:

1. Read and analyse the pattern of a hypothetical data set given in Table 6.5.

Table 6.5. First flowering dates of five plant species between 1895 and 2006

Year	Name of plants and the day of flowering in a year (DoY) (Note: DoY stands for "day of year" and is the numeric day of year (day 1=Jan.1, 365=Dec).				
	Blueberry	**Peach**	**Larger blue flag**	**Rhododendron**	**Yellow violet**
1895	132	135	148	132	125
1896	130	135	146	131	131
1897	122	136	143	129	129
1898	121	140	157	135	128
1899	127	134	155	134	127
1900	138	143	158	141	138
1901	128	139	160	135	134
1902	110	135	150	124	124
1903	116	135	152	123	123
2004	120	135	155	129	127
2005	116	132	158	126	113
2006	111	129	158	125	111

2. Based on the analysis, frame the hypothesis.

Reprint 2022

Hypothesis A: ....

3. To make a prediction based on your hypothesis A, draw a line graph in excel sheet using the data from Table 6.5. The X-axis of the graph should be Year, and Y-axis of the graph should be DoY for flowering.
4. Analyse the graph for each species of flower and write down one generalised prediction for hypothesis A.

Questions

1. Why is developing hypothesis important for scientific investigation in phenology?
2. What is the purpose of making a prediction?
3. Write down the hypothesis and prediction for your questions generated in Activity 6.3.

c. Gathering evidence

Evidence is any type of data that may agree or disagree with a prediction. Based on the evidence, the hypothesis may either be accepted or rejected. Evidence in phenology investigation is gathered by various methods such as experiment, observation, and data exploration or by synthesising information from reference materials as shown in Figure 6.7.

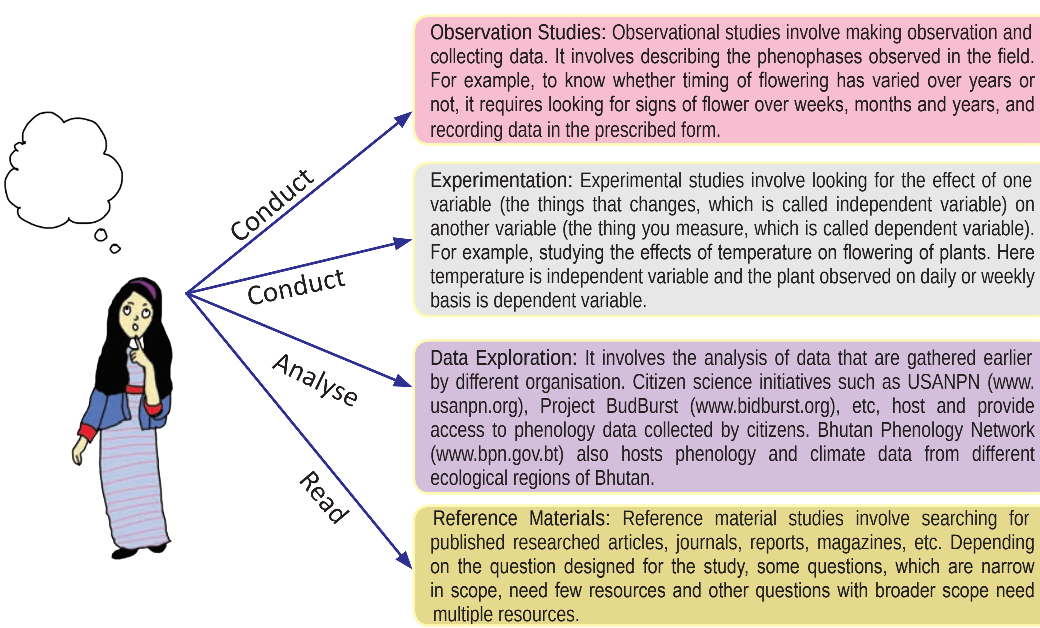


Figure 6.7. Scientific process of gathering evidence

d. Drawing conclusion and sharing result

The evidence gathered through one of the methods in Figure 6.7 are related to the prediction of the hypothesis to draw a conclusion of the study. Based on this, the proposed hypothesis can be supported or rejected and a comprehensive conclusion statement is drawn. In the process of analysing evidence and drawing a conclusion, the necessity of pursuing further investigation and research gaps are identified.

The last step in a scientific investigation is communicating the achieved result with others. Through communication, it allows others to test the same hypothesis. If other researchers get the same results, they affirm to the hypothesis, otherwise, the hypothesis is disproved for further investigation.

Activity 6.5. ***Observing and designing phenology questions***

Instruction:

Based on the selected question from the Activity 6.3, and hypothesis and prediction developed from the question in the Activity 6.4, students in the same group will carry out phenology study on the same plant identified in the Activity 6.3 to gather evidence by observation method.

Instruction

1. Profile your plant

a. Determine the location of the selected plant (You may use GPS, Google earth……).
   Make a sketch map of the location.
b. Measure the height and diameter of the selected plant and record it
c. Create the profile of your plant.

2. Design observation method

a. Discuss in groups and develop a method to gather phonological data
b. Finalise the method based on the feedback and comments of your teacher.

3. Observe, record and summarize data

a. Use the finalised method to collect phenology data for your plant for the next few months on a weekly basis
b. After the investigation is carried out, write a report covering the summary of method, findings and recommendations.
c. Share the report to the class.

Reprint 2022

B. Phenology as citizen science initiative

Citizen science is defined as voluntary public participation in scientific research projects by collaborating with scientist and researchers to increase scientific knowledge. Citizen science plays an important role in educating public about climate change, generating a large amount of climate and phenology data and contributing to an advancement of climate science. There are many citizen science initiatives that engage students in scientific activities, such as monitoring the natural process, conducting species counts, and observing changes to surrounding ecosystem. Among others, following are some of the examples of citizen science initiatives.

(i) Bhutan Phenology Network

Bhutan Phenology Network generates both climate and phenology data on a daily basis. Students observe plants, record phenophases and submit the data to Central Data Repository on a weekly basis. It adds on to existing meteorological observation systems by incorporating long-term phenology and climate data. To ensure relevance, general citizens and students are engaged in these monitoring efforts. Data generated is made available to general public, researcher, and educationists to promote further research and generate advanced knowledge on climate change and its impact in Bhutan.

(ii) BioBlitz

'Bio' means life, and 'Blitz' means to do something quickly and intensively. BioBlitz is an intense biological survey, which counts and records all living species in an area within a given time frame. It attempts to count as many species as possible in a given period of biological survey. In Bhutan, bioblitz such as waterbird count initiative that count the nationwide waterbird population in a single day.

Questions

1. How are questions developed for scientific investigation in phenology?
2. Which method of gathering evidence is easy to carry out the phenology study? Support your answer with reason.
3. Why do you think phenology study is generally carried out for a long duration?

Exercise

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

   i. The difference between mitigation and adaptation is

      A. mitigation adjusts and adaptation controls impacts of climate change.

      B. mitigation controls and adaptation adjust to the impact of climate change.

      C. mitigation is a planning process and adaptation is an implementation process of climate change.

      D. mitigation is implementation process and adaptation is planning process for climate change.

   ii. If there is an outbreak of pest in the agricultural field, the best adaptation measure to adopt is

      A. fallowing the field.

      B. applying pesticides.

      C. catch and kill method.

      D. introducing pest resistant crops.

   iii. Phenophases of plants and animals are used to determine the climate change because

      A. plants and animals are climate resilient.

      B. plants and animals phenophases are observable.

      C. plants and animals are sensitive to climate change.

      D. plants and animals are affected more during climate change.

   iv. Karma of class XII wants to observe phenophases of a walnut tree as part of phenology study. As a friend, what would you suggest to do first to carry out the study scientifically?

      A. Observation.

      B. Gathering evidence.

      C. Developing question.

      D. Developing Hypothesis.

   v. If your working place shows high sensitivity to vulnerability of climate change, the best way to respond is through

A. phenological study.

B. mitigation measures.

C. adaptation measures.

D. vulnerability assessment.

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

The shifts in the ______i_______of plants, such as timing of bud burst and leaf development are considered as one of the simplest indicators of climate change. Long-term observing and recording in plant phenology help us to understand the trends of change in ______ii_______and to predict biological responses to future climate scenarios. These help in responding with appropriate ______ iii_______measure to adjust with the climate change. Government and other stakeholders can also develop appropriate ______iv_______ measure that helps to reduce the climate change. As a student, we can help to reduce climate change by participating in various______v_______science initiative projects.

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

   i. If climate has already changed, it is better to respond through mitigation than adaptation.

   ii. Carbon negative countries absorb less carbon gas than what they produce.

   iii. Phenology study serves as an indicator of climate change.

   iv. In phenology study, hypothesis developed should conform with the evidence gathered.

   v. Reducing greenhouse gas emission is an example of mitigation measure.

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. Rose plant flowering early compared to previous year in the school.	a. Observation
2. Rose plant flowering early in the school is due to increase in temperature.	b. Question
3. Rose plant flowering in the school.	c. Hypothesis
4. Data exploration method using data from Bhutan Phenology Network.	d. Prediction
5. Did rose plant flower earlier compared to previous years?	e. Gathering evidence
	f. Investigation

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

   i. Write down your opinion on the following statements:

      a) It is too late to prevent climate change.

      b) Climate change will impact the lifestyle of Bhutanese people.

   ii. Study Figure 6.8 and answer the following questions:

Figure 6.8.

      a) Planting of trees is an example of both mitigation and adaptation measure for climate change. Justify.

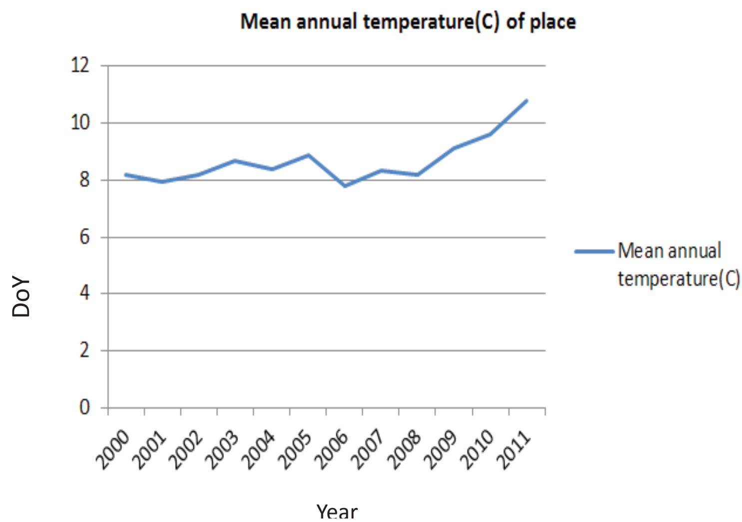
      b) How does plantation help to achieve carbon neutral policy of the country?

      c) If you are to carry out phenology study on these plants for two to three years, list down some of the phenophases that you would observe.

d) How does the community involvement in such activities help in mitigating the climate change?

iii. Sonam, an educated farmer, observes and records the first day of flowering of an apple tree in his orchard every year. To find out the effect of temperature on the flowering of the apple tree, he also collects the temperature data of his place from Hydromet division. His observation and temperature of the place are represented in graphs. Based on the graphs, answer the following questions:

(a)



(b)

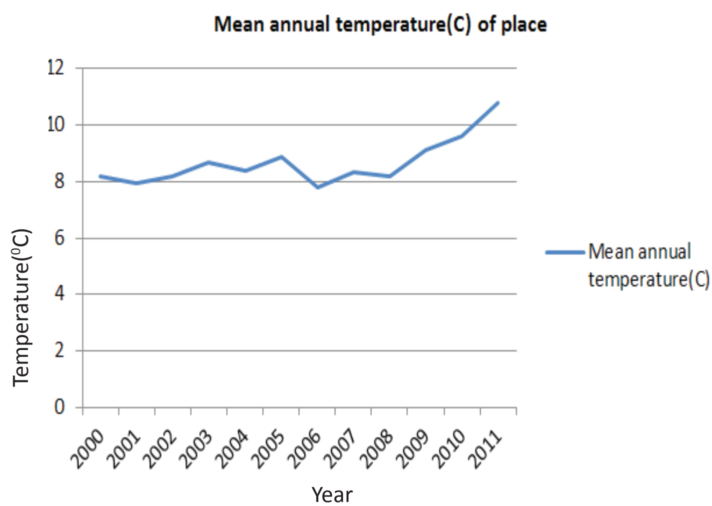


Figure 6.9.

a) What relation can you draw between the flowering of an apple tree and the temperature of the place?

b) Predict the flowering of the apple tree for the following years.

c) How can the change in phenophase of flowering of apple tree affect the nearby ecosystem?

iv. Explain the mitigation process carried out in Bhutan to reduce climate change.

v. What are some of the adaptation measures currently carried out by Bhutan?

vi. Briefly describe the scientific processes to carry out the phenology investigation using flow chart diagram.

Reprint 2022

CHAPTER 7

DISASTER MANAGEMENT

Communities worldwide are increasingly affected by series of disasters arising from natural and anthropogenic causes. These disasters occur in unexpected forms and magnitudes, and make it difficult for some communities or nations to prevent or address them. However, people can reduce the risk of hazards by instituting efficient disaster management systems and processes. It is vital to adopt a holistic disaster management system by taking into account the preparedness, mitigation, response and recovery phases.

Globally, there are various government policies, organisations and agreements that provide a systematic guideline for disaster management. Accordingly, the countries adopt different disaster management systems and processes, guided by their national priorities and global imperatives.

Reprint 2022

1. Disaster and its Reduction

Learning Objectives

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

- describe the disaster management cycle.
- explain mitigation and the ways by which it reduces risk.
- explain measures to achieve disaster-resilient community

Disaster is a sudden, calamitous event that severely disrupts the functioning of a community or a society which causes human, material and economic or environmental losses that exceed ability of the community, society and environment to cope with using their resources. To minimise the impacts of the disaster, a systematic disaster management process is practised worldwide.

A. Disaster management cycle

The disaster management cycle is an ongoing process by which governments, businesses, civil societies and communities plan to mitigate the hazards, reduce the impact of hazards, provide prompt and appropriate assistance to victims, and take steps to recover after disaster has occurred. The disaster management cycle includes four phases as shown in the Figure 7.1. Each phase describes how communities, agencies concerned, and individuals respond to the potential hazard and the disaster associated with it. Individuals and communities become more resilient to a disaster when they have anticipated, prepared, planned and have proper mitigation strategies. However, disaster management strategies differ from one another based on the types of hazard, situation, and location of the place.

Figure 7.1. Phases of Disaster Management

It is noted that no person is discriminated on the grounds of race, sex, language, religion, politics or other status while delivering supports in the disaster management cycle.

a. Preparedness phase

Preparedness is a process, where concerned organisation plans and carry-out corrective measures to reduce hazards, and ensure effective coordination during a disaster response. This phase involves preparation of plans to save lives, minimise disaster damage, and enhance disaster response operation. It is designed before the occurrence of a disaster, therefore, it increases a community's ability to respond effectively during the disaster. Some of the activities that are carried out during preparedness phase are listed below.

- Developing disaster management policies.
- Developing mutual aid agreements and memorandums of understanding among countries and relevant stakeholders.
- Installing warning devices.
- Identifying emergency shelter sites and construct shelters.
- Training response personnel.
- Creating backup life-line services (e.g. food and water).
- Preparing disaster supply kits, which includes food, medicine, flashlights, candles, etc.
- Rehearsing evacuation plans (e.g. mock drills).
- Preparing preparedness checklist as shown in Table 7.1.

Table 7.1. Checklist of disaster preparedness at home and workplace

Reduce home and workplace hazards
Relocate, secure, store or eliminate items that may become a hazard during an emergency: ♦ *Move large heavy objects to lower shelves.* ♦ *Hang pictures and mirrors away from beds and sofas.* ♦ *Fasten shelves and bookcases securely.* ♦ *Brace overhead light fixtures.* ♦ *Properly strap water heater to wall studs.* ♦ *Repair cracks in ceilings and foundations around the home.* ♦ *Secure other heavy items that may move or fall during an earthquake.* ♦ *Clean and repair chimney flue, vent connectors, and gas vents.* ♦ *Repair leaky gas connections and defective electrical wiring.* ♦ *Store weed killers, pesticides and flammable liquids in proper containers with tight fitting lids.* ♦ *Put oily rags in metal containers with tight-fitting lids, not in a pile where they can spontaneously ignite.* ♦ *Dispose of hazardous materials properly.*

The Department of Disaster Management under Ministry of Home and Cultural Affairs has a separate division, Preparedness and Response Division, which looks after the disaster preparedness in the country. The division is responsible for:

- establishing and operationalising Emergency Operation Centres (EOC) at the national, Dzongkhag and Thromde levels.
- ensuring the functioning of the national EOC and the development of related standard operating procedures.
- ensuring an effective and efficient disaster communications network for the country.
- liaising with other relevant sectors and agencies to institute early warning systems for various natural hazards and disaster risks.
- determining community participation in the development of Early Warning Systems and ensuring the last mile communication.
- maintaining a disaster database and information management system to support risk reduction initiatives and effective response.
- development of emergency/contingency plans at various levels and support formation and capacity building of response teams at all levels.
- building partnerships with both national and international agencies and organisations for knowledge-sharing and obtaining support and resources for the division's activities and initiatives.

b. Response phase

The Response Phase is the actual implementation of the disaster plan and preparedness. Disaster response refers to organised actions taken during and immediately after a disaster to ensure that effects of the disaster are minimised and that people affected are given immediate relief and support. It requires a combined effort by different entities. Depending on the location and severity of the disaster, the response team may involve armed forces and fire departments, hospitals, **De-suups**, volunteers, private relief organisations and government agencies.

The primary aims of disaster response are to rescue from immediate danger and stabilisation of the physical and emotional condition of survivors. These go hand in hand with the recovery of the dead and the restoration of essential services, such as water and power. The duration of response varies according to the scale and type of the disaster. It generally takes between one to six months comprising of following stages.

Reprint 2022

(i) Search and rescue

A search is an operation coordinated by a team of trained personnel to locate persons in distress. Rescue is an operation to retrieve individuals from danger, provide fundamental medical or other needs and deliver them to a place of safety. Therefore, the primary function of a search and rescue team is to search, rescue and provide first aid services to save lives, protect property and public health and ensure safety during a disaster. The search and rescue team is constituted at national, Dzongkhag, Thromde and Gewog levels and is composed of members as prescribed in the guidelines issued by the Department of Disaster Management.

(ii) Emergency relief

It is an immediate survival assistance to the victims of the disaster. Relief operations are initiated on short notice and have a short implementation period. The Department of Disaster Management formulates the minimum standards and procedures for relief assistance. The primary purpose of emergency relief is to save lives and prevent escalation of impacts of the catastrophe. Providing emergency kits to affected individuals and families is an example of emergency relief.

(iii) Early recovery

Early recovery, according to United Nations Development Programme (UNDP), is to restore the capacity of national institutions and communities to recover from a natural disaster, enter transition or 'build back better', and avoid relapses. Early recovery has three broad aims:

- augment ongoing emergency assistance operations by building on humanitarian programmes.
- support spontaneous recovery initiatives by affected communities.
- establish the foundations for longer-term recovery.

Early recovery encompasses the restoration of basic services, livelihoods, transitional shelter, governance, security and the rule of law, environment and other socioeconomic dimensions, including the reintegration of displaced populations. It strengthens human safety and aims to begin addressing the underlying causes of the disaster.

(iv) Medium to long-term recovery

Some individuals, families, and communities who are especially hard hit by a disaster may need more time and specialised assistance to recover, and a more formalised structure to support them. During medium to long-term recovery, the work of building permanent physical structures to replace tents, huts or plywood houses begins. As permanent housing is being rebuilt, the social fabric of communities is strengthened. Children return to school buildings from their temporary classrooms. Adults have renewed opportunities to improve their livelihoods and restore their family economies.

(v) Community development

Community development is a process where community members come together to take collective action and generate solutions to common problems. Once the population is back to a relatively stable daily life, work begins to address some of the causes of the circumstance that pose significant challenges to the community. The focus is mainly oriented on making everyday life better for marginalised or vulnerable communities in which people are surviving but not thriving. Some of the prioritised activities of this stage are improving livelihoods, quality of life, and access to education and health care. Stakeholders work in close collaboration with a community to focus on training community health workers, increasing access to primary health care and providing a forum for behavioural change. Livelihood strengthening might involve training a group of women on microfinance and provide them with a seed grant rather than simply a cash hand-out. Therefore, this stage can take decades.

(vi) Disaster risk reduction

Disaster risk reduction describes the concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events. For example, if a coastal community is at risk of a tsunami, a preparedness measure would be putting a warning system in place. That way, when the siren blares, people would evacuate. This could prevent the loss of lives, though they might have to rebuild their houses after it ends. If residents rebuilt their houses in the same place, another tsunami could threaten them again. So, a Disaster Risk Reduction scenario would dissuade people from rebuilding their houses in such a vulnerable location.

Disaster risks can be reduced by many folds through risk assessment. It is a process to determine the nature and extent of risk, by analysing hazards and evaluating conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. A comprehensive risk assessment not only evaluates the magnitude and likelihood of potential losses but also provides the full understanding of causes and impact

Reprint 2022

of those losses. Risk assessment, therefore, is an integral part of the decision and policy-making processes and requires close collaboration among various sections of society. The UNDP assess the risk as shown in figure 7.2.

c. Recovery phase

The Recovery Phase focuses on restoration and stabilisation of the affected area to its previous state through reconstruction, repairing community's infrastructure and facilities, and relocating population to safer places. The duration depends on the magnitude of the disaster, preparedness of the country or community, the vulnerability and accessibility of the affected location. The disaster recovery process consists of following stages:

(i) Disaster assessment and risk analysis

Step 1. Understanding the current situation
- needs and gaps to assess what already exists, avoid duplication of efforts, and build on existing information and capacities. This is done through a systematic inventory and evaluation of existing risk assessment studies, available data and information, and current institutional framework and capabilities

Step 2. Hazard assessment
- identify the nature, location, intensity and likelihood of major hazards prevailing in a community or society.

Step 3. Exposure assessment
- identify population and assets at risk and delineate disaster prone areas.

Step 4. Vulnerability analysis
- determine the capacity (or lack of it) of elements at risk to withstand the given hazard scenarios.

Step 5. Loss/impact analysis
- estimate potential losses of exposed population, property, services, livelihoods and environment, and assess their potential impacts on society.

Step 6. Risk profiling and evaluation
- identify cost-effective risk reduction options in terms of the socio-economic concerns of a society and its capacity for risk reduction.

Step 7. Formulation or revision of DRR strategies and action plans
- that include setting priorities, allocating resources (financial or human) and initiating DRR programmes.

Figure 7.2. A comprehensive risk assessment steps

The first stage of a disaster recovery plan involves assessing the amount of damage caused and the extent of damage that will occur if a recovery plan is not used as remediation. The disaster recovery plan must identify the team members who will be responsible for identifying, notifying and accounting the damage. The assessment usually includes:

- tracing the origin of the problem.
- likelihood and extent of further damage.
- prime areas that have been affected.
- damage done to the equipment, inventory, resources or finished products.
- things that must be replaced.
- current state of the problem.
- gathering critical information.
- estimated time available for dealing with the disaster without hampering the overall progress.

(ii) Activation and planning

This stage involves pulling together a team who will actively participate in planning and executing a disaster recovery plan. Some important aspects of this planning are:

- listing and prioritising what will be restored.
- detailing out the procedures to be followed.
- allocating roles to team members.
- setting up communication, reporting, and review system.
- creating time lines and schedules for activities to be performed.
- allocating resources and equipment.
- creating operating and quality standards.
- documenting the recovery plan.

(iii) Execution of the disaster recovery plan

In the execution stage, the recovery team finally gets into action and begins executing the recovery activities as per the procedures specified in the plan. At the end of each stage of recovery, or after execution of the necessary recovery activities, a review or appraisal must follow to monitor the progress and ensure compliance with the established quality standards.

(iv) Reconstitution and restoration

This stage indicates that the disaster has been completely managed and it is time to get back to restoring normalcy. Once the execution and testing of the recovery plan are over, reconstitution stage begins and may last for a few weeks. The resources and team members that were diverted towards the disaster recovery must be moved back to their original places. Here are some of the activities that form a part of the restoration and reconstitution stage:

- Ensure that there are no remaining after-effects of the disaster and that no threats have remained unaddressed.
- All team members have returned to their original roles.
- All resources deployed for the recovery have been secured and relocated to where they are needed.
- The disaster recovery efforts are completely over.

d. Mitigation phase

The Mitigation Phase is characterised by measures taken to limit the severity of the impact of a disaster on human health, community function, and economic infrastructure. Primarily, the objective of mitigation phase is to encourage people to protect themselves as far as possible. For instance, a reliance on insurance, improvements in building design and construction, and careful land-use planning are some mitigation activities.

During mitigation phase, strategic steps are taken to prepare communities at high-risk to minimise disaster impact before it occurs. Any mitigation strategy is inclusive of a range of measures, such as engineering measures, spatial planning, a degree of economic management and community participation. It also encompasses improved policies and public awareness. Thus, mitigation strategies include both structural and non-structural components.

Structural mitigation is any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard-resistance and resilience in structure or systems. Structural mitigation components include resistant construction, building codes and regulatory measures, relocation, structural modification, lintel beam, column, masonry wall, plinth beam/bend, foundation, and corrosion. On the other hand, any measures not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, raising public awareness, training and education are non-structural mitigation. Non-structural elements of a building do not carry the weight of the building.

They include windows, doors, stairs, partition walls, pipes, ducts and building contents that the users bring with them.

B. Characteristics of a Resilient Community

Resilience is the ability of a system, community or society to resist, absorb, adapt and quickly recover from the effects of a hazard in an efficient manner without compromising their long term prospects. Since no community can ever be completely safe from natural and anthropogenic hazards, it may be helpful to think of a disaster-resilient community as the safest possible community. Achievement of disaster-resilient community necessitates knowledge to design and build in a natural hazard context, minimising its vulnerability by maximising the application of Disaster Risk Reduction measures. It is primarily emphasising more on what communities can do by themselves, and how their capacities can be strengthened rather than concentrating on their vulnerability to disaster or their needs in an emergency.

Community resilience involves the full range of community-based organisations and agencies in preparedness, response, and recovery planning activities, and broadening the understanding of disaster preparedness to include community health and well-being. The resilience of a community is determined by the availability of necessary resources and its capability to anticipate threats, mitigate potential harm, plan and prepare to adapt to adversity both before and during times of stress. However, the key characteristics that define resilient community include functioning well under stress, successful adaptation to new challenges, self-reliance, social capacity, social cohesion, and kinship network.

Activity 7.1. ***Assess the resilience of your school***

1. Work in groups.
2. Involve the members of the School Disaster Management Committee to answer the questionnaire.
3. Present your finding to the class. (Put a tick for 'Yes' and a cross for 'No.')

Note: Higher the number of ticks better will be the resilience of your school.

Table 7.2. **Pre- Disaster Phase**

Sl. No.	Question	Yes	No	Process initiated
1	Our school has the School Disaster Management Plan (SDMP)?			
2	The school carries out Disaster Awareness Programs regularly?			
3	The school conducts simulation drills?			
4	The SDMC reflects on what went right and what went wrong during the simulation drill?			
5	If your school is a boarding school, has the school carried out night time simulation drill for the students in the hostels?			
6	The school has carried out some form of non- structural hazard mitigation activities in all the major buildings?			
7	If any new constructions are going in the school campus: Is the school or the Dzongkhag carrying out regular quality check?			

Table 7.3. **During Disaster**

Sl. No.	Question	Yes	No	Process initiated
1	The school has inventory of resources to be used during an emergency?			
2	The school has emergency contact numbers of relevant people from the Dzongkhag, hospital and police in the locality?			
3	The school has trained counsellor for trauma cases during an emergency?			
4	The school caretaker and night guard is trained to respond to certain emergency which has potential to cause an emergency in the school?			
5	The school has demarcated safe evacuation sites for academic block, MPH and the hostels?			

Table 7.4. **Post disaster**

Sl. No.	Question	Yes	No	Process initiated
1	The school has identified temporary learning space?			
2	The school has trained teachers for education in emergencies?			
	Total			

Questions

1. Is your school, as a community, disaster resilient?
2. Identify some of the best practices of implementation of disaster management and explain them in Table 7.5 given below:

Table 7.5.

Preparedness Phase	
Response Phase	
Recovery Phase	
Mitigation Phase	

3. Suggest disaster risk reduction measures for your school.

Questions

1. What are some of the roles of Information Technology in the prevention of disaster?
2. Why is it important to consider non-structural mitigation measures in disaster management?
3. List some preparedness activities that are carried out by your school to mitigate earthquake.

Reprint 2022

2. Disaster Management System

Learning Objectives

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

- describe international initiatives on disaster management.
- describe national disaster management policies.
- explain biosafety practices in Bhutan.
- explain disaster management practices in Bhutan.

Disaster management is a collective term encompassing all aspects of planning and responding to emergencies and disasters, including both pre-event and post-event activities. It is not just a matter of providing response and relief but a systematic process aimed at reducing the adverse impact or consequences of adverse actions. Therefore, disaster management system is necessary to mitigate various risks associated with the hazard, preparedness, response, and recovery, to minimise the loss of life and properties.

A. Disaster Risk Management Polices at the Global Level

The frequency and the trend of natural disasters are becoming an increasing problem for the countries around the world. Often a disaster is so devastating that a state cannot manage the situation within its capacity. Therefore, international frameworks on disaster management act as a conduit for countries to receive external assistance.

Bhutan is situated in the seismically active zone with high risk of glacial lake outburst flood (GLOF), since there are numerous glacial lakes. Therefore, Bhutan has an advantage in becoming a member of international frameworks on disaster management. For example, if severe disaster hits the country, the government may appeal for international or regional assistance to deal with the disaster effectively. Therefore, due to the dire need for a collaborative approach to address disasters around the world, the United Nations Organisation facilitates the preparation of plans and agreements on disaster preparedness, relief, and recovery. Some examples of the international framework for disaster management are discussed below:

(i) Hyogo Framework for Action (HFA) 2005 – 2015

The Hyogo Framework for Action (HFA) was the outcome of World Conference held in Kobe, Hyogo, Japan in January 2005 initiated by United Nations

International Strategy for Disaster Reduction (UNISDR). The main agenda of the framework are the five priority of action that covers a wider area of disaster management. They are:

- Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.
- Identify, assess and monitor disaster risks and enhance early warning.
- Use knowledge, innovation, and education to build a culture of safety and resilience at all levels.
- Reduce the underlying risk factors.
- Strengthen disaster preparedness for effective response at all levels.

The primary goal of the HFA is "building resilience of nations and community to disaster". It focusses on capacity building of those people who live in the hazard-prone area to improve the disaster recovery.

(ii) Sendai Framework for Disaster Risk Reduction 2015 – 2030

The Sendai Framework for Disaster Risk reduction 2015-2030 was the outcome of the third UN World Conference held in Sendai, Japan on 18th March 2015. It is the successor to the HFA and was designed considering all the loopholes in it. It is an inter-governmental decision which is based on the four top priorities of actions as follows:

- Understanding disaster risk.
- Strengthening disaster risk governance to manage disaster risk.
- Investing in disaster risk reduction for resilience.
- Enhancing disaster preparedness for effective response and to "build back better" in recovery, rehabilitation, and reconstruction.

It focusses on the vulnerability, nature of the hazard and improving disaster governance at global, national and local levels and deliberates on the institutions for financial assistance after a disaster has occurred. It gives the global platform for the development of international cooperation and partnership; commercial loans and donations; avoiding creation of new risks; and developing resilience of health infrastructure, cultural heritage and work places. It also promotes the culture of 'Build Back Better' after any disaster. (building back infrastructures that is better than the one before).

(iii) SAARC Agreement on Rapid Response to Natural Disasters

This agreement was the outcome of the conference held between the eight SAARC members at Addu, Maldives on 11th November 2011. It deliberates on

Reprint 2022

the cooperation to be given during the disasters for improving the disaster relief and recovery in any country during the occurrence of a mass natural disaster. The obligations of the member countries are as follows:

- Cooperate in developing and implementing measures for Disaster Risk Reduction including identification of disaster risk, development of monitoring, assessment and early warning systems, standby arrangements for disaster relief and emergency response, exchange of information and the provisions of mutual assistance.
- Immediately respond to a disaster occurring within their territories and share information if the disaster is likely to impact other member states, intending to minimise the consequences.
- Promptly respond to a request for assistance from an affected party.
- Share technical know-how and information on the best practices and lessons learned in reducing disaster losses.
- Take legislative, administrative and other measures as necessary to implement their obligations under this agreement within the framework of the legal system prevailing in the respective Member States.

B. Disaster management policies in Bhutan

The Department of Disaster Management (DDM) under the Ministry of Home and Cultural Affairs facilitates disaster management system in the country. It is the responsibility of DDM to develop guidelines and legislation on disaster management, coordinate awareness-raising and building capacities on disaster mitigation, preparedness and response.

In general, disaster management acts of Bhutan ensure the safety of the people, and security of the public assets and services by reducing and managing disaster risk. Primary objectives of the ACT are to:

- ensure mainstreaming of disaster risk reduction into Dzongkhag, Gewog, and Thromde plan, policy, programme, and project.
- monitor and evaluate measures taken for prevention, mitigation, preparedness, response and capacity building by various sectors.
- direct the relevant agencies to put in place early warning system as a monitoring and advisory tool to identify the hazard and notify all vulnerable population and responding agencies of threatening disaster situation or disaster.
- educate and raise awareness on various hazard, risk, and vulnerability in the community and support community capacity building.

- institute a system to determine the condition of disaster, resources needed for response and relief operations and other requirements.
- promote the implementation of structural and non-structural measures.
- ensure effective communication among relevant agencies, private sectors and community before, during and after a disaster.
- allocate resources and budget for recovery, reconstruction of rehabilitation.

Some of the other important policies, framework and guidelines existing in the country are as follows :

a) National Disaster Risk Management Framework, 2006
b) Disaster Management Act of Bhutan
c) Disaster Management Rules and Regulation
d) National Recovery and Reconstruction Plan
e) Disaster Management and Contingency Plan Guideline
f) School Disaster Management Planning Guideline
g) Guideline on Proper Construction Practices for Non-Engineering Buildings (Stone Masonry)
h) National Action Plans for School Earthquake Safety
i) National Action Plans for Earthquake Safety of Health Facilities
j) Non Structural Mitigation Guidelines
k) National Disaster Risk Management Strategy
l) Ministry of Education DM CP

Activity 7.2. ***KKnowing about School Disaster Management Plan***

Instruction:

1. Get a copy of your School Disaster management Plan (SDMP) and work in groups. (you may ask your subject teacher for help)
2. Read the School Disaster management Plan (SDMP).
3. Design a slogan for promoting awareness on Disaster Management in your locality

Questions:

1. Analyse your School Disaster Management Plan and propose necessary amendments to improve it.
2. Why are disaster management policies important for a school?

C. Disaster management practices in Bhutan

(i) Biosafety

Biosafety means procedures or measures designed to protect the population against harmful biological or biochemical agents. Biological agents include harmful microorganisms, GMOs, and parasites that would lead to a biological disaster. Therefore, biosafety measures are important to protect ourselves and environment from the effects of pathogens and hazardous substances.

The packaged food, live plants, animals, and GMOs, which are imported from other countries may contain hazardous chemical substances. These substances may have potential to affect the health of animals, plants, and the environment of our country. The biosafety measures aim at the safe transfer, handling and use of modern biotechnological products for the security of the people and the pristine environment. To ensure a high level of human and animal health safety and the food security, Bhutan Agriculture and Food Regulatory Authority (BAFRA) monitors and implements biosafety regulations. In addition, National Environment Commission (NEC), Ministry of Trade and Industry (MTI), and Department of Revenue and Customs (DRC) are also involved in international negotiations, making decisions on biosafety trade and transboundary movements of GMOs and other food products.

(ii) National Biosafety Framework

The National Biosafety Framework (NBF) provides a legal framework to formulate appropriate policies, laws, regulations, and administrative measures for the safety of citizens and the pristine environment. It provides a legal basis for administration and decision-making for management of genetically modified organisms (GMOs) in Bhutan. The primary objectives of NBF are to:

- monitor the imports of foods and seeds to control any illegal transboundary movement of GMOs.
- monitor the illegal planting of GMOs through seeds smuggled from neighbouring countries.
- evaluate reports on applications to import GMOs.
- monitor the field trials for GMOs introduced by Consultative Group on International Agricultural Research (CGIAR) centres in conjunction with the research Centres of the Ministry of Agriculture and Forest.

Biosafety policy enables Bhutan to benefit from modern biotechnology by following import protocols and categorisation of GMOs that may be imported. Biosafety policies ensure the health of the citizen and biodiversity of the country from potentially adverse effects of modern biotechnology. The Bhutan Agriculture and Food Regulatory Authority (BAFRA) is designated as the competent national authority to regulate and coordinate all biosafety related activities in the country.

(iii) Flood

Bhutan is prone to floods owing to its location in the ecologically fragile Himalayas characterised by steep terrain with a huge range of elevation. Bhutan is situated within active seismic zone suffering frequent earthquakes that may trigger floods. GLOFs are the imminent hazards that require intensive monitoring and preparedness. Geographical features of the country escalate the possibility and magnitude of flood hazards through the formation of natural dams and occurrence of seasonal flash floods as shown in Figure 7.3.

(a) GLOF (b) Flash Flood (c) Dam formation

Figure 7.3. Flood and its causes

Flood mitigation measures are crucial and include flood warning system for transmitting river level data and forecasting flood; GLOF monitoring system for checking the water level of the lakes; and river bank protection to save life, land and other properties. Other measures are the artificial lowering of glacial lake level; GLOF hazard zoning, rain water harvesting, flood protection of downstream industrial and agricultural areas, and installment of early warning system on river basins.

(iv) Earthquake

Geophysically, Bhutan is located in one of the most seismically active zones in the world. Despite the high risk of earthquakes occurring in the region, there is a limited way of tracking official historical records of earthquakes and consolidating relevant data. However, considering the recent devastating earthquake that hit the Himalayan belt, it is of paramount importance for Bhutan to enhance its mitigation measures. Some of the measures practised are guidelines for earthquake resistant building, seismic hazard zonation map for the country, collaboration with the foreign institutions within the Himalayas that involved in monitoring seismic activities and behaviour in the Himalayas, reporting protocol, development of Disaster Management Contingency Plan for all the Dzongkhags, Sectors and agencies and carrying out simulation exercises.

(v) Fire

Fire causes significant loss to individuals and the country economically, socially and environmentally. For example, Bhutan has lost 92,596.97 acres of forest to fire in between 2008 to 2014. Structural fire is also getting rampant in the recent decade. In a span of less than a year, from October 2010 to May 2011, Chamkhar town in Bumthang was razed down by fire thrice destroying 106 structures and affecting 156 families. The cause of both forest fires and structural fires are either human negligence or malicious intent.

Some preventive measures of fire outbreak are to promote community-based forest fire management and prevention measures; install electrical materials that meet appropriate regulations and standards; issue public notices on risks of fire; train firefighters; and ensure everyone is aware of the primary response in the event of a fire.

(vi) Windstorm

The world is witnessing extreme variations in climate and weather patterns due to climate change. Windstorms have become more frequent and widespread cause of the disaster in recent years in Bhutan. Information on past windstorm damages reveals that the roofs of traditional Bhutanese houses (Figure 7.4) are particularly vulnerable to windstorms given the nature of construction practices.

Bhutan is increasingly experiencing large scale destruction due to windstorm year after year. It has become so important that the communities likely to be affected are made aware and educated about the mitigation measures. The most important mitigation measure against windstorm is to construct houses and buildings that meet the minimum standard set by Bhutan Building Rules (2002) and Building Code of Bhutan (2003).

Figure 7.4. Roof torn apart by windstorm

(vii) Landslide

Landslide is closely linked with flood events and is a regular phenomenon in Bhutan. Slopes in the country are very vulnerable to landslides, especially during the rainy season. Earthquake tremors also trigger landslides in fragile terrains of the country. Landslides mostly occur in the eastern and southern foothill belt where the terrain is steep, and rocks underlying the soil cover are highly fractured, allowing natural seepage of water. One contributing factor is the undercutting of slopes by high-energy rivers and streams during a period of heavy rainfall. In particular, the urban areas experience the secondary effects of landslides due to the importance of road infrastructure (Figure 7.5) for the dispatch of vital goods. Farmers on steep slopes in the foothills of the south and the eastern region of the country are regularly affected by the hazard.

(a) Landslide encroaching agriculture field (b) Road blocked by landslide

Figure 7.5. Landslides hazards

As a mitigation measure, landslide monitoring systems are established in the most vulnerable locations. Other mitigation measures include landslide hazard and risk mapping along the stretches of national highways; landslide management and flood prevention project by NEC; afforestation programmes carried out by various agencies in the landslide prone areas; and construction of walls by Department of Road (DoR) to prevent minor landslides.

Questions

1. Why is community participation important in disaster management?
2. Why is risk assessment important for disaster management plan?
3. How would Bhutan benefit from International Agreements on disaster?
4. Disasters can provide development opportunities. Elucidate.

Reprint 2022

Exercise

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

   i. Which phase of disaster management involves predicting a possible crisis before it occurs?

      A. Mitigation
      B. Preparedness
      C. Recovery
      D. Response

   ii. The primary document that guides the development of effective disaster management plan in Bhutan is

      A. Disaster Management Act of Bhutan.
      B. Disaster Management Rules and Regulations.
      C. Disaster Management Strategic Policy Framework.
      D. National Disaster Risk Management Framework.

   iii. Identify the objectives of the National Biosafety Framework (NBF) from the list provided below:

      I. Monitor the export of foods and seeds to control any illegal transboundary movement of GMOs.
      II. Monitor the illegal planting of GMOs through seeds smuggled from neighbouring countries.
      III. Evaluate reports on applications to export GMOs.
      IV. Monitor the field trials for GMOs initiated by different organisations.

      A. I and II
      B. I and III
      C. II and III
      D. II and IV

   iv. All the following are components of recovery phase EXCEPT

      A. activation and planning.
      B. execution of the disaster recovery plan.
      C. reconstitution and restoration.
      D. search and rescue.

v. The strategy which does not conform to non-structural mitigation is

   A. building flood embankments.
   B. locating objects on a safer place.
   C. mounting furniture.
   D. safe electrical wiring.

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. Hyogo Framework for Action	a. people come together to take collective action and generate solutions to common problems.
2. Emergency relief	b. restore the capacity of national institutions and communities to recover from a natural disaster.
3. Early recovery	c. systematic efforts to analyse and manage the causal factors of disasters.
4. Community development	d. building permanent physical structures to replace tents, huts or plywood houses.
5. Medium to long term recovery	e. building resilience of nations and community to disaster.
	f. immediate survival assistance to the victims of the disaster.

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

   i. Identifying vulnerable group is __________ __________ component of disaster management.
   ii. ______________ ____________ enables Bhutan to benefit from modern biotechnology by following import protocols and categorisation of GMOs that may be imported.
   iii. The lack of development can make countries more ______________ and susceptible to disaster.
   iv. Earthquake tremors not only cause structural disasters but also trigger _______________ in fragile terrains.
   v. The ability of the community to adapt and resist the stress during the disaster is called _____________________ .

Reprint 2022

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

   i. A disaster becomes a public tragedy when it requires a societal response and collective action.

   ii. The response to a disaster usually requires only one level of response.

   iii. The location of a disaster event does not affect the timeliness and sustainability of support.

   iv. Biosafety is the application of combinations of laboratory practice and procedure, laboratory facilities, and safety equipment when working with potentially infectious microorganisms.

   v. River bank protection to save life, land and other properties is meant to mitigate landslide.

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

   i. Write a short note on disaster management cycle.

   ii. Explain the roles of the following divisions under the Department of Disaster Management:

      a) Risk Prevention and Reduction Division

      b) Preparedness and Response Division

      c) Rehabilitation and Reconstruction Division

   iii. Which disaster event is likely to cause a national tragedy in Bhutan? Why?

   iv. Carefully observe Figure 7.6 and answer the questions that follow:

(a) Figure 7.6. (b)

      a) What do picture (a) and (b) in Figure 7.6 represent?

      b) Explain the factors that may bring changes in the physical features in the pictures.

c) Identify the disaster associated with the figures and propose mitigation measures.

v. Compare the Hyogo Framework for Action with Sendai Framework of Action based on the priorities of actions?

vi. Complete Table 7.6 by writing the mitigation activities carried out against each disaster.

Table 7.6.

Disaster	Mitigation activities
Landslide	
Earthquake	
GLOF	
Structural fire	

vii. Explain flood mitigation measures in your own words.

viii. Food produced within Bhutan is not sufficient to feed the whole population. This compels the Bhutanese to import varieties of food items. However, imported foods are not always safe as they might be contaminated with biochemical substances.

a) Which agency is entrusted to monitor the flow of food materials into the country?

b) What is the type of disaster associated with the scenario?

ix. Study Figure 7.7 and answer the questions that follow:

Figure 7.7.

a) Which hazard, structural or non-structural, is the most prevalent in the figure?

b) Suggest some ways through which hazards can be minimised.

c) Comment on the safety of the space from the perspective of disaster management.

CHAPTER 8

BIODIVERSITY CONSERVATION

The natural world is composed of biotic and abiotic constituents. The variety of life forms on the Earth is called biodiversity. The health of the natural world largely depends on the existence of varieties of flora and fauna and their interactions amongst themselves and with their physical environment. Biodiversity can be studied at three main levels as species diversity, genetic diversity and ecosystem diversity.

Biodiversity is important in a number of ways. It not only promotes the aesthetic values of the natural environment but also contributes to our material well-being through utilitarian values. Biodiversity maintains the balance in the environment by regulating the chemistry of the atmosphere, the hydrological cycle, climate, and by maintaining soil fertility and land productivity. It also helps in dispersal of seeds, breakdown of wastes, pollination and absorption of pollutants. Therefore, conservation of biodiversity is extremely critical to meet the ecological, social, economic, spiritual and recreational needs of the humankind.

Reprint 2022

1. Biodiversity and Poverty Alleviation

Learning Objectives

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

- explain the role of biodiversity in the functioning of the ecosystem.
- explain endemism with some examples.
- analyse the economic values of protected areas.
- examine the linkages between protected areas and poverty.

Biodiversity conservation and poverty reduction are two separate global challenges which are inextricably linked. The sustainable development goal, "ensure environmental sustainability and poverty reduction," explicitly pronounces the need for conservation without compromising societal benefits and harmony.

The conservation of biodiversity is a sustainable measure that helps in keeping the natural resources intact. Diversity of species promotes healthy interaction and maintains balance in the ecosystem. Rich biodiversity can create avenues for the people to generate income and in turn alleviate poverty.

A. Biodiversity and endemism

Diversity of species is essential for the functioning of the ecosystem. They help in maintaining carbon dioxide and oxygen balance; regulation of biochemical cycles; absorption and breakdown of pollutants and waste materials through decomposition; and regulation of climate.

Figure 8.1. Biodiversity in nature

Although every organism contributes to ecosystem processes, the nature and magnitude of individual contributions vary considerably. Ecosystem processes are driven by the combined biological activities of species which lead to the creation of a balanced ecosystem.

While some species can perform the same type of processes within an ecosystem, many others make unique contributions to the efficient functioning of the ecosystem. As more and more species are lost from an ecosystem, the ability of an ecosystem to function efficiently is reduced. Biodiversity increases the flexibility and resilience of the ecosystem in the process of change.

Reprint 2022

Owing to the suitability of environmental conditions and adaptive abilities of organisms, there is an unequal distribution of plant and animal species in the world. Some plants and animals are native to only one particular location, while others are predominantly found in more than one location. The ecological state of a species being unique to a defined geographic location, such as an island, country, habitat or other defined zone is called endemism. Those plant and animal species which are found only in a particular location are called endemic species. They can be very rare and can be restricted to a particular locality within the country. Endemism is affected by factors such as mountains, hot deserts, diversity of substrates and microclimates. Some examples of the endemic species are given in Figure 8.2.

Macropus giganteus (Australia) | Ceropegia bhutanica (Bhutan) | Ursus maritimus (Arctic region)

Figure 8.2. Endemic species in the world

Kangaroo is endemic to Australia. When Australia got detached from Antarctica as a result of tectonic plate movement, a family of marsupials got isolated from the rest of the world, and over time this isolation resulted to allopatric speciation of these marsupials to kangaroo. The Galapagos penguin (*Spheniscus mendiculus*) is endemic to the Galapagos Islands (Figure 8.3). It is the only penguin adapted to live north of the equator that has cool temperature due to the cool saline ocean current.

Some of the endemic species of Bhutan are *Truncatellina bhutanensis*, a species of a snail; *Scutiger bhutanensis*, a species of frog; *Parachiloglanis bhutanensis,* a torrent catfish; *Rhododendron kesangiae* and *Rhododendron bhutanense*, species of rhododendron; and *Meconopsis bhutanica*, a species of the blue poppy as shown in Figure 8.4.

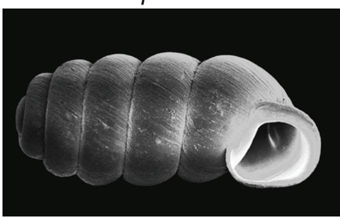
Figure 8.3. Galapagos penguin

With rapid development and change in environmental conditions, some of the endemic species have become extinct while others are critically endangered.

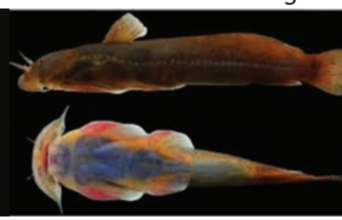
Meconopsis bhutanica

Rhododendron kesangiae

Rhododendron bhutanense



Truncatellina bhutanensis



Parachiloglanis bhutanensis

Scutiger bhutanensis

Figure 8.4. Some endemic species of Bhutan

One of the effective strategies to conserve endemic species is by declaring the biodiversity hotspots as protected areas. It was recognised as a strategy for sustainable development during the Earth Summit in 1992. The summit mandates all countries to establish protected areas to manage and support the conservation, promote sustainable use of biodiversity, and have equitable benefits for poverty alleviation in the world.

Activity 8.1. *Finding endemic species*

Instruction:

1. Work in groups.
2. Each group will investigate on as many endemic species as possible in a single continent.
3. You may browse internet or visit library and find the following information for each endemic species:

- Continent
- Region/country
- Endemic species
- Habitat
- The cause of endemism:
- Category as per the red list
- Strategies/programs for conservation
- Pictures and photographs

4. Discuss and prepare a report. Make a presentation to the class.

B. Benefits of biodiversity conservation

Biodiversity is the most precious gift of nature to humankind. All the organisms in the ecosystem have their specific roles which helps to sustain the ecosystem through their interactions and interdependence. Humans have close association with biodiversity as we depend on it for our cultural, economic and environmental well-being.

Biodiversity conservation is an essential part of Bhutan's rich heritage. As an agrarian society, biodiversity holds great economic, social, ecological, cultural and spiritual importance and has always been a source of sustenance. The distinct customary practices and traditions associated with biodiversity are evidence of a harmonious and vibrant relationship that exists between nature and culture.

A well protected and conserved biodiversity can be commercially viable, socially and environmentally benefiting in many ways as mentioned below:

a. Mitigation of natural hazards

Natural hazards cause damage to lives, livelihood and properties on a large scale. They incur a huge economic loss in terms of expenditure for relief and recovery activities. If the frequency of natural hazards is high, then there is a rise in poverty because people lose assets which are means for their survival. For example, frequent flood and landslides destroy crops and increase poverty among farmers who depend on agriculture. A rich biodiversity can minimise the impacts to a great extent contributing to poverty alleviation.

Biodiversity plays an important role in prevention and mitigation of the natural hazards and other hazard-related impacts. A place with rich biodiversity usually shows fewer disturbances by the natural hazards. For example, soil erosion is considerably less in areas with more vegetation. A good vegetation makes the soil more stable which minimises soil erosion, landslide, rock falls and minimise

Figure 8.5. *Maireana oppositifolia* and *Zygophyllum apiculatum*

the impacts of grazing. Some native plants like Healthy Bluebush (*Maireana oppositifolia*) and Pointed twinleaf (*Zygophyllum apiculatum*) shown in Figure 8.5 are more fire resistant and can prevent spreading of fire in the forest.

Forests provide physical resistance to natural hazards like avalanches and prevent desertification. Drought is a potential hazard that can lead to desertification. Areas that have a higher number of drought-resistant plants can prevent desertification by supporting the survival of other organisms in that area. Mangroves, coral reefs, and offshore barrier islands help to reduce the impacts of tsunamis, hurricanes, coastal erosion and other tidal surges by providing a physical barrier and overspill space for water. Regions with rich biodiversity have better resilience and recover rapidly from impacts of natural hazards.

b. Recreation and tourism

Biodiversity provides an avenue for recreational activities like trekking, bird watching, adventure sports and educational research. Rich species of flora and fauna gives people a sense of love and affinity for nature. Rich biodiversity has a high potential for nature-based tourism that helps to generate revenue and support poverty alleviation in the community, mainly through the following opportunities that tourism services offer:

- employment for the local community as guides, guards, porters, etc.
- earn revenue through collection of tariff, taxes, royalty, etc.
- business establishments like hotels, guesthouse, traditional/handicraft item shops, restaurants, etc.
- establish service centres for hiring equipment like rafting facilities, trekking items, parachutes, diving materials, vehicles, horses, etc., as shown in Figure 8.6.

Figure 8.6. Tourism and recreational activities

Reprint 2022

c. Agriculture and food security

Biodiversity is essential for food production and security. Food production is dependent on soil formation and land productivity, pest and disease control in agricultural systems and pollination. Interaction of diverse forms of plants and animals results in making the soil fertile and more productive. Greater the diversity of plants, higher is the rate of production because some species will survive the changes brought in by climate conditions even though others cannot. The condition that is favourable to those species community enhances the production of varieties of food crops and guarantees the food security for the community. The excess produce can generate income to alleviate poverty in the community.

d. Genetic resources

Biodiversity serves as a source of genetic resources in the following ways:

- The existence of variation helps in an increased chance of survival of species during epidemics and other natural calamities.
- Formation of hybrids that are better adapted to the changing environmental conditions. This contributes to the process of evolution whereby, the best ones survive and reproduce leading to the progressive change in the species.
- Source of Germplasm of threatened species, which are preserved in Gene Banks. This helps in the rejuvenation of those species if they disappear in nature.
- Provides a variety of organisms, from which organisms with desirable traits are selected and modified by genetic engineering to produce Genetically Modified Organisms (GMOs). These are used to enhance food production to meet the food security.

Figure 8.7. Genetic resources

e. Source of food and raw materials

Rich biodiversity provides a variety of foods and raw materials for human beings. A wide range of food products, such as fruits, vegetables, nuts, meat, and food additives in the form of food colourings, flavourings and preservatives are obtained from the environment with rich biodiversity. Likewise, biodiversity is the source of raw material for both traditional and modern medicines. A diverse group of animals are also used for medical research during the testing of new drugs. It also provides a varying range of material for making paper, construction, fuel production, etc. Different types of fibres are obtained from nature and used for producing a variety of products. The highly valued insect fungus, *Ophiocordyceps sinensis*, (Figure 8.8), which has medicinal properties, is a great biological resource available in Bhutan. In pursuit of equitable economic benefit through sound ecological management, highlanders are permitted to harvest *Ophiocordyceps sinensis* so that they get the direct benefit out of the resource for better livelihood.

Figure 8.8. *Ophiocordyceps sinensis*

f. Balance in the ecosystem

Biodiversity creates a well-functioning ecosystem through various biogeochemical cycles and interactions between biotic and abiotic components to maintain

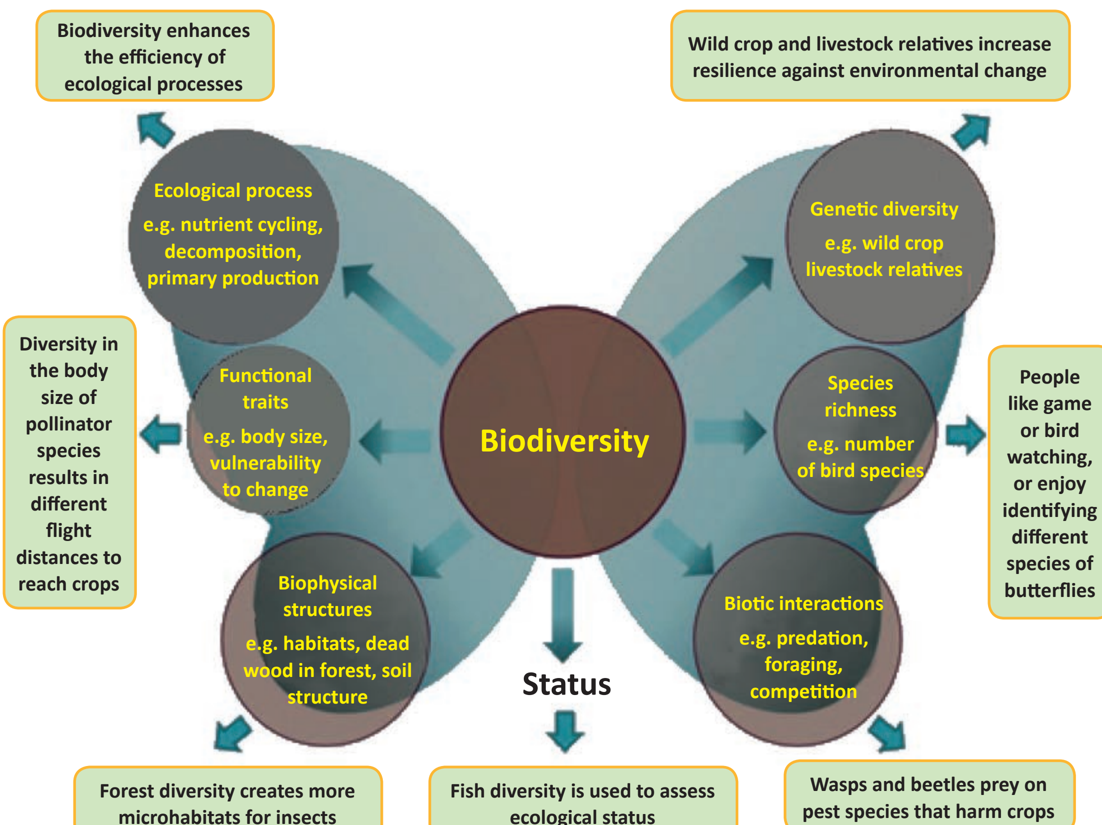


Figure 8.9. Benefits of biodiversity conservation

Reprint 2022

equilibrium in the ecosystem. The organisms in an ecosystem depend on each other for energy flow, cycling of water and nutrients, controlling erosion, controlling pests and climate regulation. These interactions and processes affect soil fertility, pollination, plant growth, predation and waste decomposition, and regulate biological production. Therefore, the more diverse an ecosystem, the more stable and productive it becomes. Biodiversity provides vast genetic pools and varieties of habitats, which preserve the existence of life on Earth, ensuring productivity, sustainability and co-existence as shown in Figure 8.9.

C. Protected areas and poverty alleviation

A protected area is an area of land or water body especially dedicated to the protection and maintenance of biological diversity. A protected area can be a wetland, a tropical or deciduous forest, a cultivated landscape, an alpine region, Savannah or water bodies. The protected areas are managed through policies, laws and standard guidelines.

Generally, protected areas are located in places where the rural inhabitants have the least participation in the country's economy. Thus, poor people and protected areas tend to be inextricably linked in a diverse and complex manner.

In an attempt to analyse the links between poor people and protected areas, the Center for International Forestry Research (CIFOR) has explored the relationship between poor people and protected areas. It has proposed the following three types of relationships:

(i) No linkage

This is the traditional way of creating protected areas where protection is the primary aim, and people are viewed as a threat. It segregates between biodiversity priorities met through protected area establishment, and poverty reduction met through different forms of assistance, essentially donations and other financial aid. An area designated as biologically important is fenced off, and in many cases, anyone within its perimeter is removed. For example, in the Democratic Republic of the Congo, the Bambuti and Batwa was evicted from their ancestral lands when the Kahuzi-Biega National Park was created in the 1970s.

(ii) Indirect linkage

This method of creating protected areas takes into account the socio-economic development of communities living around protected areas. This is done primarily by providing economic substitutes in the form of compensation to communities who are affected by the establishment of protected areas. The Integrated

Conservation and Development Projects (ICDPs) are site-based projects aiming to achieve both socio-economic and ecological goals. For example, in Honduras, in the Rio Platano Biosphere Reserve, an ICDP was set up to provide alternative income-generating activities to local communities to reduce the pressure they were putting on the core areas of the protected area.

(iii) Direct linkage

This method of creating protected areas recognises that the people's livelihood is directly dependent on conservation. This approach integrates people's needs in the process of protected area establishment and management. For example, the landmark creation of Colombia's Alto Fragua-Indiwasi National Park was done with full participation of the Inga people who are recognised by the government as primary actors in the design and management of the park. This approach also empowers the affected communities with a greater proportion of governance over management decisions.

Presently, the creation of protected areas follows direct linkage approach whereby it provides ample opportunities for the people to derive provisioning, regulating, cultural and supporting services. Even the most strictly protected areas could provide additional food security for local communities in times of famine. The Bumdeling Wildlife Sanctuary was designated as a protected area in 1993 and the implementation of the conservation management plan started in July 2001. It was established to ensure that there is a balance in the ecological conservation and socio-economic development. More than 2,200 subsistence farmers and herders, live in the sanctuary and adjoining buffer zone. The people are allowed to extract forest products such as timber and fuelwood, animal fodder, roofing shingles, leaf litter for farmyard manure, bamboo, and cane, daphne bark for paper-making, incense, and medicinal plants, etc. This ensures that the pressure on the core area is reduced.

Reprint 2022

Activity 8.2. *Understanding the benefits of protected areas*

Instruction:

Read the case study and answer the following questions:

Benefits from Chitwan National Park

Chitwan National park was established in 1973 under the state ownership of Nepal, covering an area of 932 km^2. It is home to over 40 species of mammals including threatened species such as the rhinoceros, tiger, wild dog, sloth bear, gaur and hispid hare.

The Chitwan National park management provides avenue for the communities living in the buffer zone to receive a percentage of benefits derived from tourism in the protected area and Village Development Committees (VDCs) allow for community decision-making and equitable benefit sharing mechanisms.

Eco-tourism is the major source of revenue. Nepal is a major tourist destination and Chitwan is one of the most popular destinations for foreign tourists. In 1994, 60,000 foreign tourists visited the park, this increased to more than 100,000 in 1998 and the total revenue earned by the park was NPR 50.6 million (over US$800,000).

Chitwan is one of the most severely flood-affected districts in Nepal. The park, however, provides a range of environmental services such as soil stability, flood control and water purity. The buffer zone council also sets aside a fixed proportion of its revenue for flood victims in the buffer zones. The park also plays a role in mitigating the effects of climate change.

Other benefits from the park include the collection of thatching grass by local people for roofing; which is permitted once a year and is subject to a monitoring system with the local buffer zone user group members. The park also contains a shrine considered culturally important to the indigenous or traditional people living in the buffer zone. The national park authority allows free entry to these devotees for a period of 3-7 days in March every year to worship. A historical place described in the epic Ramayana is also within the national park and the sculptures and other items are registered by the Department of Archives. People visit this area on a regular basis.

http://nbsapforum.net/sites/default/files/The%20Arguments%20for%20Protection%20Series%20-%20safety_net.pdf

Questions

1. List down the benefits derived by the local people from the Chitwan National Park.
2. Besides benefitting the locals in the area, how do you think this protected area contributes to biodiversity conservation?
3. Identify one such protected area in Bhutan which has direct linkage with the community and describe how it has benefitted the locality in poverty reduction.

Questions

1. Why are endemic species confined to a definite area?
2. Biodiversity conservation alleviates poverty. Justify the statement with appropriate example(s).

Reprint 2022

2. Efforts to Manage Biodiversity

Learning Objectives

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

- analyse national policies and legislations in the conservation of biodiversity.
- examine roles of international treaties and conventions for the conservation of biodiversity.

Considering the continued threat and loss of biodiversity, it is important to safeguard biodiversity at a wider scale. Conservation action is carried out within policy frameworks and legal systems established by governments and international unions. A wide range of different national policies and legal measures for the conservation of biodiversity exist that vary from country to country depending on the social, political and economic scenarios. The policy includes national policies and acts, international treaties, legislation and convention where individual country agrees to abide by and adopt measures to safeguard biodiversity.

The policies and acts on biodiversity are important mechanisms to implement the strategies and action plans for its conservation. The upholding of policies and acts on biodiversity ensures to address the underlying drivers of biodiversity loss through socio-political, economic, demographic, technological, and cultural pressures.

A. National Policies and legislations

In Bhutan, the policies and legislations related to biodiversity were enacted after the formal conservation programs of biodiversity started in the country in the early 1960s. The first act to be enacted in the country was the Forest Act of Bhutan 1969, followed by the National Forest Policy in 1974. They underscore the importance of conserving biodiversity as both mandate the maintenance of a minimum of 60 percent of the total land area of the country under forest cover. This has been further enshrined in the Constitution of the Kingdom of Bhutan, 2008.

Some of the important policies and regulations adopted so far by Bhutan to safeguard the biodiversity are provided in Figure 8.10. The national policies and legislations governing the conservation of biodiversity are usually framed considering some of the following key areas shown in Figure 8.11.

Environmental Assessment Act 2000	The act directs the government to ensure that environmental concerns are taken into account when formulating, renewing, modifying and implementing any policy, plan or program. It requires the issuance of environmental clearance as a pre-requisite to the approval of any development activity.
The Biodiversity Act of Bhutan 2003	The act provides for the conservation and sustainable utilisation of biological resources and associated traditional knowledge and ensures the protection of plant varieties. It also authorises the implementation of the Access and Benefit-sharing regime to derive additional benefits in a fair and equitable manner.
National Environment Protection Act 2007	The Act focuses on the conservation of natural resources to be based on a participatory approach and equitable sharing of the costs and benefits among resource users. It also promotes the use of clean energy and alternative technologies to reduce the use of fuel wood or timber from primary forests. The Act also calls for conservation and protection of wetlands, alpine regions, watersheds, and other vulnerable ecosystems in addition to the existing protected areas.
Biosecurity Policy of the Kingdom of Bhutan 2010	This Policy ensures the protection of the Bhutanese people and Bhutan's biodiversity from the harmful effects of pests and diseases, invasive alien species, toxic chemicals and food additives.
The National Forest Policy, 2011	The Policy ensures forest resources and biodiversity are managed sustainably to provide a wide range of social, economic and environmental benefits while still maintaining minimum of 60 per cent of forest cover. This Policy includes a science-based participatory approach to forest governance and sustainable forest management with emphasis on efficient and environment friendly technologies for value-addition and waste minimisation.

Figure 8.10. National policies and legislations on environment

Controlling the introduction of exotic species

This system of control is usually regulated by quarantine laws. Typically it allows the import of exotic species only for limited purposes such as for zoological or botanical gardens or for research purposes and in many cases only after it is ascertained that specimens are disease-free.

Protection of ecosystems and habitats

The most important form of legislative measure for the conservation of biodiversity is for the protection of ecosystems and habitats. Control over the use of land is the essential means by which such systems are managed and protected.

Land use controls

Many countries have legislations limiting the use to which land may be put. Land use control activities include controlling construction, industrial development and mining activities.

Restriction of collection and possession.

Most countries which have such legislation have a differentiated system of protection, with some species being fully protected and others receiving partial protection. In some countries, legislation provides for the protection of all species in certain areas. The possession control is a necessary complement to prohibit collection.

Trade restrictions

The extent of restriction varies considerably from one country to another. Some national laws contain exhaustive lists of prohibited activities like banning possession, transport, exhibition, sale and purchase, while others merely state that the sale or possession of protected species without a permit is prohibited.

Providing incentives

The provision includes providing of incentives or disincentives to influence the activities of land users. Such mechanisms includes tax exemptions, providing subsidy payments to farmers to maintain the natural environment on their land, and the granting of land tax credits for the preservation of wetlands or natural prairie areas, or for the conservation of river.

Policy and Legislation for biodiversity

Figure 8.11. Key areas- policies and legislation for biodiversity

B. International treaties and conventions

International treaties and conventions related to biodiversity are governed by international laws and deals entirely or in part with conserving biodiversity. Some of the international treaties on the conservation and management of the elements of biodiversity are Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on Wetlands of International Importance (Ramsar), and the Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage).

Activity 8.3. ***Analysing international treaties and conventions on biodiversity conservation***

Instruction:

Carry out a literature research on the following international treaties and conventions - CBD, CITES, Convention on Wetlands, World Heritage Convention, Convention on Migratory Species (Bonn Convention). Base your literature research on the following questions:

1. Write the purpose or objective of initiating the treaties and conventions mentioned above.
2. How do these treaties and conventions contribute to conservation of biodiversity of the countries?
3. What are the strengths and weaknesses of the existing Strategic Plan of the Convention on Biological Diversity?
4. What are the commitments of parties joining the Ramsar Convention?
5. What are the criteria used by the World Heritage Committee to select World Heritage Sites?
6. What are some of the challenges faced by the countries in the implementation of the strategic plan of the conventions and treaties at the local, national, regional or global levels?
7. In your opinion, which one of the treaties or conventions would be very useful for biodiversity conservation in our country? Why?

Questions

1. Why is it necessary to have national policies and legislation on biodiversity conservation?
2. Describe the benefits that Bhutan derives from the international treaties and conventions?
3. Explain the purposes of Biosecurity Policy of the Kingdom of Bhutan 2010.

3. Genetically Modified Organism (GMO)

Learning Objectives

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

- describe Genetically Modified Organism (GMO) and its benefits.
- explain the negative impacts of GMO on biodiversity conservation.
- explain the significance of GMO in Bhutan.

Genetically modified organisms (GMOs) refer to those organisms (plant, animal, bacteria or virus) that possess foreign gene(s) transferred from a selected donor organism, into their genome, typically conferring desired traits. For example, the genome of a corn species has been modified to include a gene from the soil bacterium *Bacillus thuringiensis,* to produce Bt corn. The genetically modified Bt corn produces a poisonous protein that can kill the European corn borer, an insect that damages corn crops.

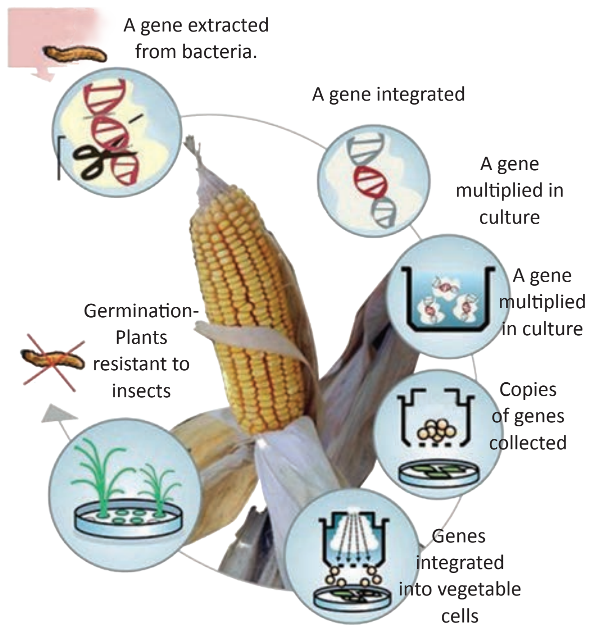


Figure 8.12. Use of Recombinant DNA technology

The purpose of recombinant DNA technology is to combine desirable genes from various species to create new genetically altered organisms or transgenic organisms with enhanced vigour. In recent years, this technique is largely used in the production of genetically modified foods, which includes crops, vegetables and fruits.

A. Advantages and disadvantages of GMOs

a. *Benefits of GMOs on biodiversity conservation*

The application of GMOs in pollution reduction, agriculture, biofuels, etc., has contributed to the conservation of biodiversity. Generally, GMOs have indirect influence in the conservation of biodiversity, some of which are discussed as follows:

(i) Biofuels

With genetic engineering, plants having more ethanol content and resistance to harsh climatic conditions are developed and grown. Their products are used for the production of biofuel. Producing more biofuel minimises the dependency on the forest products, which enhances the biodiversity conservation.

(ii) Agriculture

Genetically modified crops with desirable traits, such as high yielding varieties, resistance to pest, diseases and drought, etc., are produced by genetic engineering. Use of such crops has reduced the dependence on chemical fertilizers, pesticides, and weedicides. The reduced use of chemicals can lead to decrease in environmental problems like land pollution and eutrophication. This favours sustenance of soil and aquatic ecosystems and thus, helps in conservation of organisms living in those ecosystems.

(iii) Bioremediation

The GM microorganisms can degrade waste plastics and petroleum products into less toxic substances and are used for dealing with pollution resulting from pollutants produced by plastics, petroleum products, etc. The process by which microorganisms degrade the pollutants into less toxic or non-toxic substance is called bioremediation. The use of GMOs for bioremediation to minimise habitat loss helps to conserve biodiversity.

b. Negative impacts of GMOs on biodiversity conservation

Though this technique has ample benefits on the production of high yielding, pest resistant, drought resistant and fortified food crops, it also has some possible adverse effects on people, environment and other organisms.

(i) Soil

Soil fertility depends on the presence of diverse microorganisms with different roles in balancing and operating the nutrient cycle. This maintains the health and fertility of the soil. Bacteria and fungi are capable of capturing and using genetic material from the decaying plant matter or other microorganisms. The soil microorganisms may, therefore, use genetically engineered material from decaying GM plants and pass on the GM traits to a wider microbial population. This transfer of DNA from the GM plant may enable unrelated microorganisms to mate resulting in loss of natural microbial diversity in soil ecosystem and thus decrease soil fertility over the time.

(ii) Genetic contamination

GM plants can cross pollinate with closely related native plants species growing in the same area resulting in the loss of identity of wild species. This phenomenon is called genetic contamination or pollution of the natural gene pool. Since GM plants are more resistant to pests and diseases and are more viable, they tend to dominate the native species in an ecosystem. Such dominant effect of the GM plants over the native species can have an adverse impact on the conservation of biodiversity. For instance, cultivation of GM crops concentrates on the breeding of a smaller number of high-value cultivars which may result in a decrease of crop genetic diversity.

(iii) Super-weeds

The superior genes from GM plants could pass on to the weeds through cross pollination. This could result in the development of super-weeds which are tolerant to a chemical weed killer, and resistant to insect and diseases. These super-weeds would require stronger herbicides. As stronger weedicides or herbicides are used in the soil, it can lead to suppression or even death of native organisms. This may pose a potential threat to biodiversity conservation.

(iv) Loss of wild species

GMO has the potential to become highly invasive because of their superior traits in productivity and pest resistance. This could result in endangerment or even extinction of native species.

B. GMO and Bhutan

GMOs are introduced to improve agricultural production and raise the per capita income of the rural population. According to the Biosafety Act of Bhutan 2015, import of GMO for any purpose that is capable of reproduction is prohibited. However, the act allows the import of GMOs or GM products only for direct use as food, feed and processing. Bhutan Agriculture and Food Regulatory Authority (BAFRA) ensures that GMOs entering into the country are safe for consumption, and do not pose a risk to the native environment.

Many countries use high yielding genetically modified plants to meet the increasing demand for food and also import foods resulting from genetically modified plants. However, very few people think about the safety of the genetically modified food and the impacts of introducing GM plants into their locality.

Reprint 2022

Activity 8.4. *Analysing the risks and benefits of importing GM plants*

Instruction:

1. Divide the class into two groups; one group will analyse the risks and the other, the benefits of importing GM plants.
2. Appoint a group leader who will note all the points from the group members. Use additional resources such as library books and internet to get more information on advantages and disadvantages of GM plants and GM foods. Consider the following as you do your research:
   a. What could be the potential risks and benefits of importing genetically modified foods to the environment.
   b. What plants or foods have been allowed or banned in Bhutan? Why?
   c. What are some of the ethical issues related to GMOs?
3. Collect all the opinions from the group members and present to the class.

Questions

1. How do GMOs contribute to food security?
2. Why is microbial diversity important in the soil?
3. How does genetic contamination hinder biodiversity conservation?

Exercise

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

   i. If biodiversity is affected by natural disaster, organisms will have the best chance of survival if

      A. their environment has few abiotic factors.

      B. the organisms are large.

      C. the population size is small.

      D. the species exhibits genetic variation.

   ii. Refer Figure 8.13 and answer the question that follows:

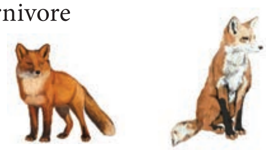
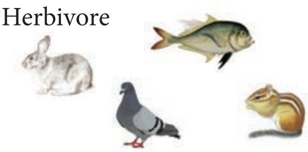
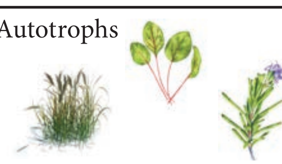
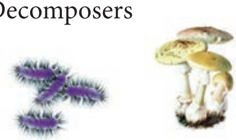
Ecosystem A	Ecosystem b	Ecosystem c
Carnivore 	Carnivore 	Carnivore 
Herbivore 	Herbivore 	Herbivore 
Autotrophs 	Autotrophs 	Autotrophs 
Decomposers 	Decomposers 	Decomposers 

Figure 8.13.

The level of biodiversity in ecosystem A is high because it has the

A. least variety of energy levels.

B. greatest number of decomposers.

C. greatest variety of genetic material.

D. least number of ecological niches.

iii. In nature reserves and parks containing varieties of flowering trees and shrubs, there are signs that say "Take nothing but pictures, leave nothing but footprints." These signs are necessary because

A. humans can destroy habitats by removing flowering trees and shrubs.

B. all animals feed directly on flowering shrubs that may be removed by people.

C. removal of flowering trees and shrubs does not affect biodiversity.

D. flowering shrubs foster aesthetic values in the visitors.

iv. When a species is only found in a particular location, it is said to be

A. endemic.

B. native.

C. exotic.

D. cosmopolitan.

v. Which human activity creates the least threat to biodiversity?

A. Overuse of resources.

B. Pollution of water with heavy metals.

C. Pollution of air with sulphur gases.

D. Reuse of plastic bags.

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

i. The dispersal of altered genes from GM organisms to natural organisms is called genetic ________________.

ii. A population that has limited ________________ diversity is much more likely to become extinct.

iii. The use of biological organisms to help clean contaminated or polluted environmental site(s) is known as ________________ .

iv. The CITES ensures that the sustainability of trade is important to safeguard __________________ for the future.

v. The Bonn Convention adopts the strict protection measures of terrestrial, marine and avian __________________ species.

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. Buffer zone	a. Commercial and economic benefits to the local community.
2. Indirect linkage approach	b. Community is adjacent to the protected area.
3. Tourism	c. Takes into account the socioeconomic development of the community.
4. Ecological process	d. Encourages actions which will lead to a sustainable future.
5. Convention on Biological Diversity	e. Enhances the nutrient cycling in nature.
	f. Recognises that the people's livelihood directly depend on conservation.

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

   i. No linkage approach integrates people's needs in the process of protected area establishment and management.

   ii. Meconopsis bhutanica, Rhododendron kesangiae, Scutiger bhutanensis are examples of exotic species identified in Bhutan.

   iii. Genetic diversity increases the resilience against environmental changes.

   iv. The environmental assessment act 2000 mandates the conservation and sustainable utilisation of biological resources.

   v. Biofuels offer plant-based solutions to the Earth's growing energy problem.

6. ***Answer the following questions.***

   i. How is biodiversity conservation a route to poverty alleviation?

   ii. For a productive and resilient ecosystem, interactions within the floral and faunal species are so crucial. In line with this, examine the role that endemic species play in biodiversity conservation?

   iii. How do the direct linkage and indirect linkage approach differ in creating protected areas? Analyse and conclude with valid reasons.

   iv. Why is it so important for Bhutan to join Convention on wetlands and establish Ramsar sites? Discuss with pertinent reasons.

   v. What benefits does Bhutan derive after having signed the international treaties and conventions?

   vi. After adoption of CBD in Bhutan, how do you think it helped the country to conserve biodiversity?

   vii. The use of GMOs for further reproduction of organisms is banned in Bhutan. What do you think are the reasons for doing so?

   viii. Read the extract provided in the box and answer the following questions:

Bhutan's Crown Jewel, the Manas National Park represents the largest example of tropical and sub-tropical ecosystems in Bhutan. With its thousands of animal and plant species, many globally endangered, it is not only the most diverse protected area in the Kingdom but also one of the world's biologically outstanding sites. Lying in south central Bhutan, Manas is connected at the southern border with India's Manas Tiger Reserve, a World Heritage Site. To the north, it borders the Jigme Singye Wangchuck National Park. Royal Manas was designated a wildlife sanctuary in 1966 making it Bhutan's oldest protected area. The area was upgraded to a National Park in 1993.

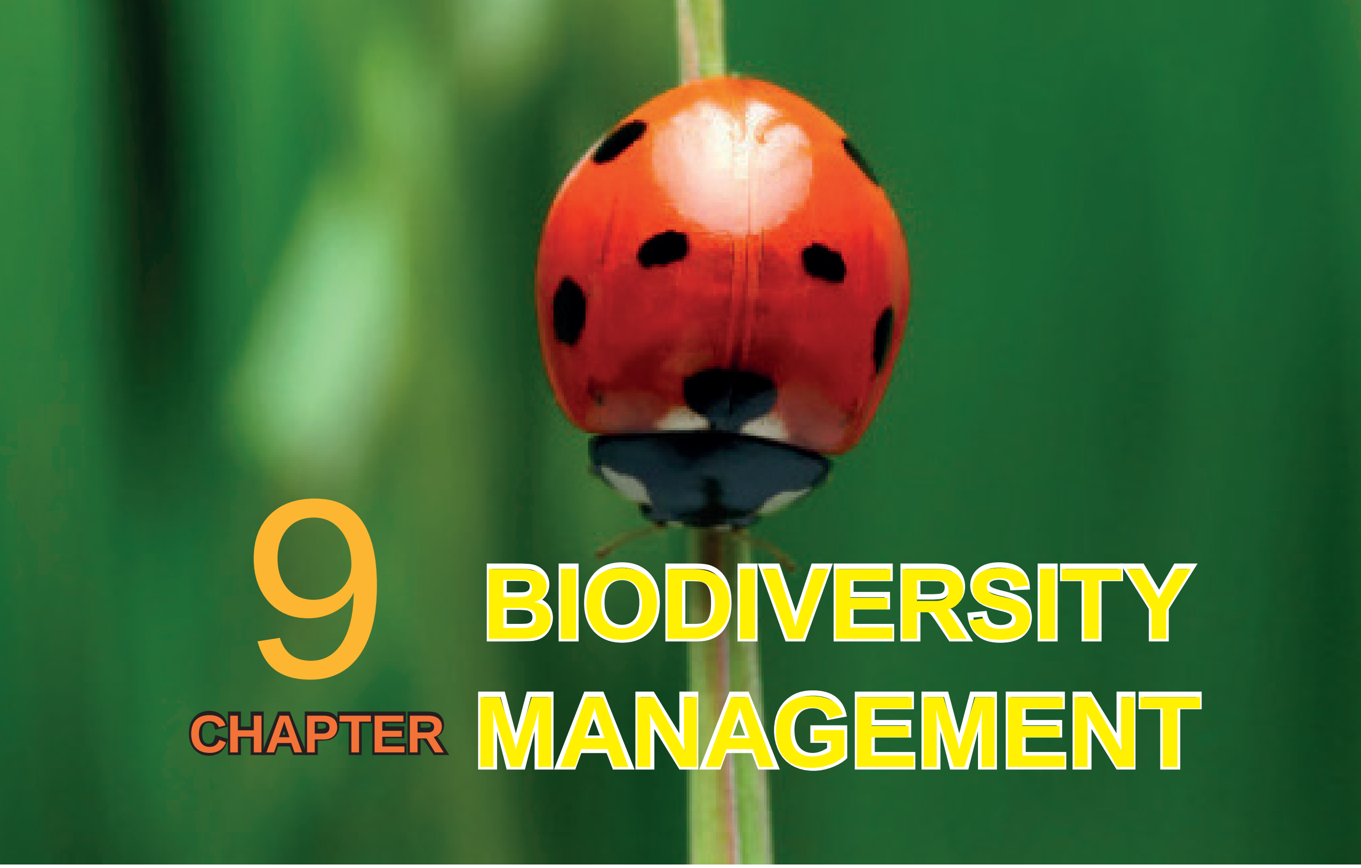
   a) Where is the Manas National Park located?

   b) Why is this park nationally and globally important?

   c) What could be the factors that have favoured this areas to have diverse flora and fauna?

   d) Discuss some of the economic benefits derived from the area by the people in the locality.

Reprint 2022



9 CHAPTER BIODIVERSITY MANAGEMENT

Natural resources and biodiversity offer huge potential for livelihood, food security, eco-tourism, hydropower and many more. However, they are increasingly threatened to destruction by unsustainable practices such as deforestation, land fragmentation, land use change, mining, construction of infrastructures and many other anthropogenic activities. Without a well-planned biodiversity management, many endangered species will soon become extinct upsetting the balance in the ecosystem.

Therefore, management of biodiversity is regarded as an important activity to maintain the equilibrium in nature. It includes policies, strategies, adoption of effective biodiversity conservations and indigenous practices that contribute to the conservation of biodiversity.

Reprint 2022

1. Measures to Promote Biodiversity Management

Learning Objectives

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

- describe the measures to promote biodiversity conservation in Bhutan.
- explain the importance of indigenous methods in biodiversity management.
- explain National Biodiversity Strategies and Action Plan (NBSAP).
- Interpret the application of Biodiversity Management System (BMS) in biodiversity conservation.

The proper management of biodiversity is important for the conservation of biodiversity. Biodiversity management includes policies and acts, establishment of agencies related to biodiversity, and management protocols at different levels. The failure to manage the biodiversity affects its ability to provide ecosystem services such as ecological services, regulating services, cultural services, and socio-economic services.

The management can vary from one country to another depending on the difference in their biodiversity and socio-economic conditions.

A. Community level biodiversity management

Since the community is directly involved in the use of natural resources, community level biodiversity management is important to make it sustainable. There is little chance of protecting the biodiversity without community participation. As part of the process, local organisations engage with local people in strengthening capabilities and decision-making process for biodiversity management. For instance, the establishment of community forest and community-based forest fire management are some of the community level biodiversity management initiatives. Similarly, promotion and conservation of local agro-biodiversity is also considered one of the important livelihood assets.

On the other hand, there are indigenous practices which are associated with the social, cultural and spiritual beliefs of the people in regard to their environment. They consider trees, rocks, lakes, rivers, and mountains sacred and believe that any disturbances and pollution to such places bring misfortunes like natural disasters, famine, and sickness in the community. In Bhutan, before the enforcement of legal instruments on the conservation of biodiversity, people observed indigenous practices like **'ladam', 'ridam'** and **'sokdam'**. Such indigenous beliefs and practices

Reprint 2022

directly or indirectly promote conservation of biodiversity.

Activity 9.1. ***Exploring indigenous practices for biodiversity conservation***

Instruction:

1. Work in groups and prepare a set of questions to gather information on indigenous practices for biodiversity conservation.
2. Use all the available sources of information, such as internet, interviews, library books, etc.
3. Discuss in two groups and debate on pros and cons of indigenous practices of biodiversity conservation.

Questions

1. Which of the indigenous practices you learned through the debate can be considered the most suitable for the locality? Justify.
2. How can these practices be relevant to the biodiversity management at the national level?
3. What are some of the challenges that the community faces in its effort to conserve biodiversity through indigenous biodiversity management practices?

B. National level biodiversity management

Biodiversity management at national level involves the establishment of specific biodiversity organisations and legal frameworks to manage the biodiversity conservation efficiently. Bhutan is a member country of Convention on Biological Diversity (CBD), an international agreement established by the United Nations. It has three main objectives: to conserve biodiversity, to enhance its sustainable use and to ensure an equitable sharing of benefits linked to the exploitation of genetic resources.

In Bhutan, National Biodiversity Centre (NBC) is identified as the coordinating agency in view of its mandate and technical competencies aligned with the objectives of the CBD. Some Non-governmental Organisations like Royal Society for Protection of Nature (RSPN), and Bhutan Trust Fund for Environmental Conservation (BTFEC) also play important roles in biodiversity management at national level.

(i) NBSAP of Bhutan

As mandated by the CBD, Bhutan has adopted the National Biodiversity Strategies and Action Plan (NBSAP) which is the principal guiding document that consists of specific strategies for biodiversity planning and management. It has been developed based on the country's vision, conditions and capabilities to fulfil the objectives of the Convention. It ensures that the strategies are mainstreamed into the planning and developmental activities of all those sectors whose activities can have an impact on biodiversity. It also comprises laws, administrative procedures, scientific research, programmes, projects, and public awareness activities related to biodiversity.

In Bhutan, National Biodiversity Centre coordinates with various implementing agencies for the implementation of NBSAP through five thematic areas as given in Figure 9.1.

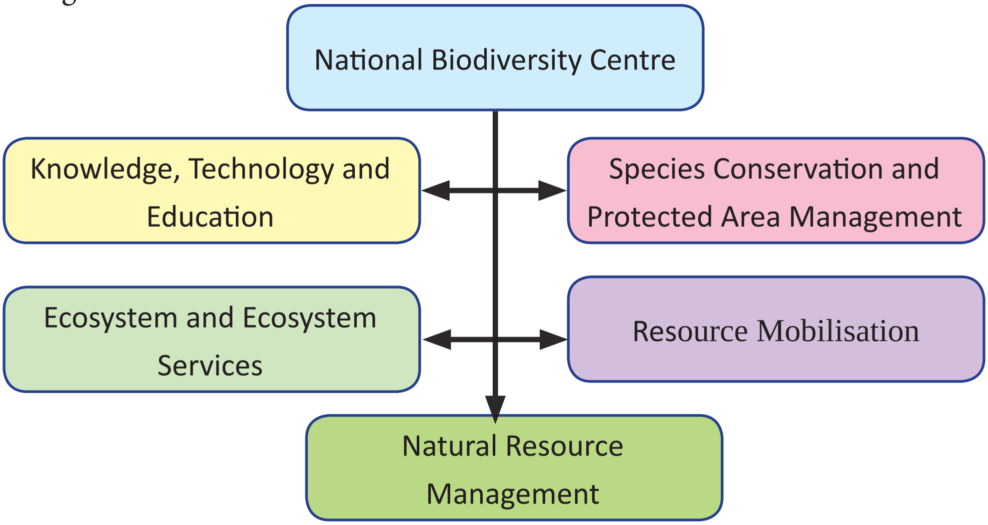


Figure 9.1. Thematic areas for NBSAP

(ii) Biodiversity Management System (BMS)

Some organisations or projects which have the impact on biodiversity, adopt Biodiversity Management System (BMS) to systematically guide the organisation in its approach to conserve biodiversity. BMS is designed to provide measurable trends, baselines and targets to conserve biodiversity. To ensure a credible approach to biodiversity management, BMS is appropriately integrated into all stages of planning and operation of an organisation or project. It includes identifying of biodiversity risks and opportunities, providing operational instructions and guidance on how to measure progress to deal with biodiversity issues.

Activity 9.2. *Understanding the significance of BMS*

Instruction:

The case study given below is an example of how cement and construction company Holcim collaborated with IUCN (International Union for Conservation of Nature) in developing BMS. Read the passage and answer the following questions.

Holcim and IUCN - Implementing BMS

In 2007, Holcim began working with IUCN in order to understand better the risks and opportunities facing the company in relation to biodiversity. The relationship has helped Holcim develop a corporate approach to the issue and to define biodiversity-related activities at site level over the full life cycle of its operations. One result is a new biodiversity management system (BMS), which is used to assess biodiversity issues in new projects and to determine appropriate corrective actions in sites of varying environmental sensitivity.

A key step in the BMS is the establishment of a biodiversity risk matrix, followed by the introduction of measures appropriate for the level of risk encountered at each site. The risk level is determined first in terms of biodiversity value or importance (i.e. proximity to high biodiversity value areas) and second by the potential direct impact of Holcim operations. This methodology also takes into account the biodiversity value expressed by relevant local stakeholders. On this basis, certain sites are categorised as 'sensitive': namely sites of national or global importance for biodiversity conservation where operational impacts are considered to be 'very high', 'high' or medium.

Table 9.2. Biodiversity risk matrix

Biodiversity Importance	Potential Impact			
	Very High	High	Medium	Unlikely
Global	Critical	Significant	Medium	Low
National	Critical	Significant	Medium	Low
Local	Significant	Medium	Low	Low

The matrix is used as part of three implementation steps in the BMS:

Step 1. *Know the potential impact:* an annual environmental questionnaire is used to collect (self-reported) biodiversity information at the site level and used for risk mapping. Where risks or impacts are unknown, the knowledge gap is flagged.

Step 2. *Match the level of effort to risk:* sites categorised as sensitive are required to implement biodiversity action plans and monitor progress. Expert partners may be enlisted to help conduct biodiversity inventories as needed, set appropriate targets and determine actions.

Step 3. *Monitor results to demonstrate progress towards the targets:* At most Holcim sites, monitoring can be conducted by company staff. For sensitive sites, however, external monitoring can provide additional credibility. Biodiversity activities need to be integrated into existing operational management process, such as rehabilitation planning and environmental management systems.

Step 4. An initial inventory of all 500+ extraction sites owned by Holcim in over 70 countries was conducted and all sites were categorised using the risk matrix. Senior managers were informed about which sites needed attention first and a global target was set in order to monitor progress: by 2013, 80 per cent of sensitive sites will have a biodiversity action in place. Progress will be published in the company's sustainability reports and Holcim will continue to work with external partners, where appropriate, while also building capacity internally to assess biodiversity and monitor progress.

Source: The Economics of Ecosystems and Biodiversity in Business and Enterprise.

Questions

1. Explain the importance of biodiversity risk matrix in the scenario.
2. Why did Holcim implement BMS?
3. If you are implementing BMS in a given area, what are the probable characteristic features that you might take into consideration to flag it as 'sensitive'?
4. Identify at least five activities in our country and suggest BMS for one of the activities.

Questions

1. How does indigenous knowledge help in conservation of biodiversity?
2. How does the adoption of NBSAP help Bhutan in biodiversity management?
3. List down some of the consequences of biodiversity dependent industries and projects without biodiversity management system.

2. Challenges in Biodiversity Management

Learning Objectives

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

- explain some of the challenges in biodiversity management.
- describe human-wildlife conflict.
- investigate the causes of human-wildlife conflict.

There are numerous organisations working at different levels with specific protocols and mandates to manage and conserve biodiversity. Management protocols are employed to mitigate the loss of biodiversity. Despite extensive planning, organisation and implementation, there is a rise in the loss of biodiversity. This is because there are numerous factors and challenges that affect the biodiversity management in Bhutan and across the world.

A. Challenges

The high economic values and uses associated with certain biological species have led to over-exploitation, poaching and illegal markets. Such practices have endangered, threatened or have even resulted in the extinction of some species. Therefore, numerous plans and strategies are implemented worldwide, but such efforts towards biodiversity conservation management are confronted with series of challenges, for example:

(i) Low education level

Environmental knowledge, skills and values play an important role in implementation of biodiversity management plans. People with limited knowledge on biodiversity and its sustainable use tend to exploit the habitat and wildlife for various purposes. In addressing the biodiversity conservation, change of people's mind-set and practices is crucial. However, in many communities, this change is affected by cultural beliefs and practices, which pose challenges in gaining support from all sectors of communities for biodiversity management.

(ii) Poverty

Poverty escalates the dependency of human on nature. Community living under poverty extracts more resources from nature for their basic livelihood. Under such situation, communities have the tendency to disregard the national policies and legal protocols on biodiversity conservation.

(iii) Climate change

Climate change poses immense threat to biodiversity. It leads to migration, habitat change and behavioural change, which may cause human-wildlife conflict. The changes in habitat and behaviour of wildlife demand the conservationists to change the conservation strategies, which generally is expensive in terms of finance, equipment, and human resources. Climate change is a global phenomenon and it is difficult to contain its impact on biodiversity loss.

(iv) Limited human resource

Biodiversity management is a scientific approach which demands professionals with competent knowledge and technical skills to execute plans and policies for biodiversity conservation. In the absence of technical expertise, compounded by the inadequacy of resources, the conservation initiatives in terms of strategising the plans and actions are generally a big challenge for any nation.

(v) Illegal market and corruption

Besides poaching wildlife for livelihood, people also poach wildlife for economic benefits owing to its high market values by defaulting the legal protocols. There are some instances of poaching: Tokay gecko for medicine, rhinoceros for its horn, elephants for tusks, etc. Since such economic transactions happen in the illegal market, law enforcement becomes difficult and breeds corruption.

Corruption in biodiversity management may include a default in management systems, breach of laws, or collusion for financial gain and social status. Generally, these practices go unnoticed and impact the efficacy of the biodiversity conservation management protocols.

B. Human-wildlife conflict

Human-wildlife conflict refers to the interaction between human and wild animals resulting to a negative impact on people or their resources, or wild animals or their habitat. Various forms of human-wildlife conflict lead to loss of human life and livestock, damage to crops and properties, destruction of habitats and death of wild animals. Human-wildlife conflict is a serious obstacle to wildlife conservation and the well-being of the people.

a. Causes of human-wildlife conflict

The communities in the vicinity of forests and protected areas are often prone to attacks and damages to properties by wild animals resulting to human-wildlife conflict. This is generally because of the following causes:

Reprint 2022

(i) Human population growth

With growing human population, settlements expand in and around the animal habitats. The encroachment into wildlife habitats confines the animal species into marginal habitat. The competition between growing human populations and wildlife for the same space aggravates human-wildlife conflict.

(ii) Climatic factors

The seasonal changes shift the suitability of habitat for many species and the changing climate also stimulates species to change their behaviour. There is a generally strong correlation between seasonal change and frequency of livestock predation. Figure 9.2 shows the relationship between seasonal change and livestock predation.

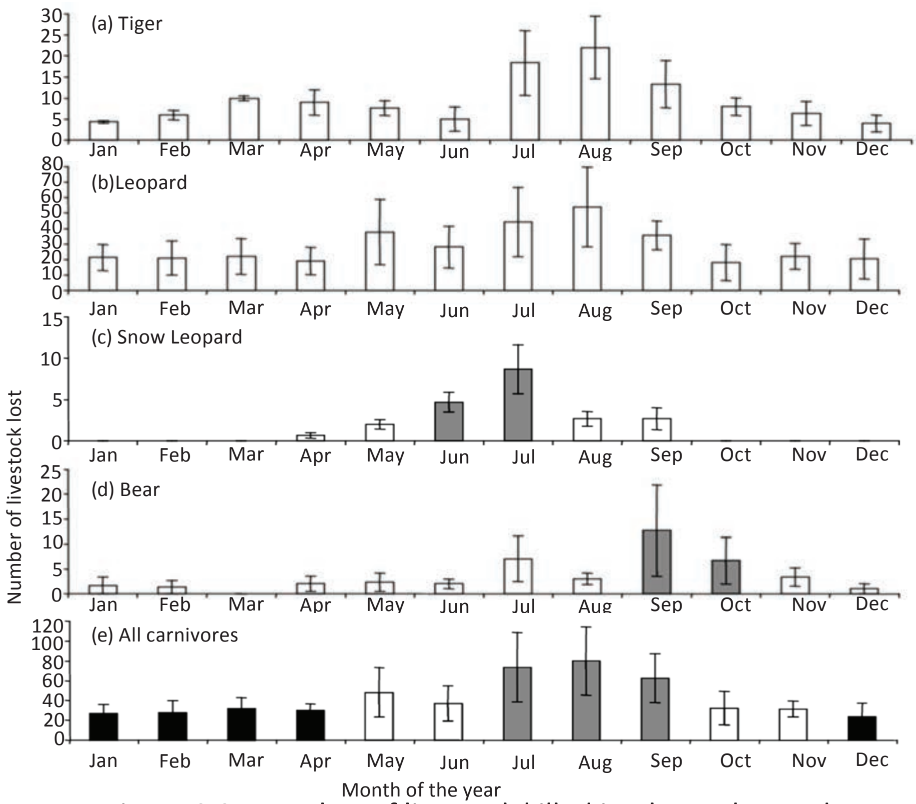


Figure 9.2. Number of livestock killed in Bhutan by predators

(iii) Land use transformation

The transformation of forests and other ecosystems for economic purposes disturbs or shrinks the animal habitat, causing human-wildlife conflict. Species habitat loss, degradation, and fragmentation are also interconnected with population growth and land use transformation.

(iv) Livestock population

Overlap of food chain between livestock and wild animals creates competition for food. This interference in the normal food chain results in the movement of wild animals towards agricultural lands. Farmers in Bhutan generally leave their cattle to graze freely in the forest. This attracts predators. Livestock also attracts predators due to decline in the population of wild herbivores.

b. Management of human-wildlife conflict

Measures to manage human-wildlife conflict based on different ecological, social, cultural and economic realities that are specific to the species is crucial to minimise the human-wildlife conflict. The following are some of the strategies practised by the communities:

(i) Barriers

Barriers prevent the infringement of wild animals into the local communities; they are usually made up of walls, barbed wire or electric fencing.

(ii) Guarding

Monitoring herds and active defence are essential features when human herders are effective and fearless in warding off predators. The presence of human guards and dogs are associated with lower rates of livestock attacks by predators and damage to properties and crops by wild animals.

(iii) Relocation

The relocation of local communities to the areas offering better access to natural resources and socio-economic opportunities can address human-wildlife conflict.

(iv) Waste management systems

A standard waste management system is important to avoid infringement of wild animals into human settlements to sustain on food waste.

(v) Proper waste disposal

To avoid the wild animals encroaching into human settlements in search of food waste, and other wastes, it is essential to dispose waste in proper sites.

(vi) Compensation systems

Human-wildlife conflicts incur significant economic loss to humans, and compensation is a measure which aims to alleviate conflict by reimbursing people for their losses.

Reprint 2022

(vii) Insurance programme

The insurance scheme covers crops and livestock from the risk of wildlife attacks. It involves the community to pay a premium share of the insurance that ensures payback for the entire loss during the human-wildlife conflict.

(viii) Incentive programmes

Incentive programmes are based on subsidies. They offset the cost of conservation and demand the adoption of conservation-friendly practices, creating tolerance towards wildlife through the exchange of benefits. For example, to prevent the overlap of grazing ground of livestock with wild animals, farmers are given improved cattle breed to prevent free grazing in the forest.

Activity 9.3. *Understanding human-wildlife conflict*

Instruction:

Table 9.3 shows the loss of crops as a result of human-wildlife conflict in one of the Dzongkhags. Study the table and answer the following questions:

Table 9.3. Metric tons of crops lost to wildlife in 2014

Chiwog	Wildlife	Paddy lost	Wheat lost	Maize lost	Barley lost	Buckwheat Lost	Potato lost	Vegetable lost	Total MT lost
Kuengarabten Changrey	Wild Pigs	12	0.5	6	0.1	8.4		6	33.1
	All other wildlife	0.4						6	6.0
Yussa	Wild Pigs	11.8	1	18	1.1	7	4	3	46.0
	All other wildlife							4.5	4.5
Takse - Tashidingkha	Wild Pigs	14.7	1.5	7.2	1.4	4.2	2	6	37.1
	All other wildlife							9	9.0
Samcholing Khatoe	Wild Pigs	10.2	1.7	14.4	2.8	9.1		6	44.3
	All other wildlife							3	3.0
Samcholing Khamey	Wild Pigs	15.3	2.8	18	0.5	7		3	46.7
	All other wildlife							3	3.0
TOTAL		64.6	7.5	63.6	6.0	35.7	6.0	49.5	233.1

NB: All other wildlife includes deer, sambar, monkeys and porcupines.

Questions

a) Draw a bar graph using the data provided in the table.

b) Which crop is more prone to be damaged by wild animals?

c) Which **chiwog** has the maximum human-wildlife conflict incidents?

d) Which wild animal has caused more crop damages?

e) How does the human-wildlife conflict affect the food security in those communities?

f) Suggest some ways to mitigate crop depredation by wildlife.

Questions

1. Explain the challenges of effective biodiversity management.
2. "After a forest fire, the chances of human-wildlife conflict increases." Justify the statement with a suitable example.
3. Narrate one example in Bhutan to justify how incentive programme helps to manage human-wildlife conflict.

Exercise

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

   i. Which one of the following best explains the suitability of some of the indigenous practices in biodiversity management?

      A. They are methods that ensure effective biodiversity management.

      B. Some of the indigenous practices are deeply rooted in the community with a positive attitude towards biodiversity.

      C. All forms of indigenous practices exemplify the sustainable use of natural resources.

      D. They are very effective for large scale application of biodiversity management.

   ii. "Floral and faunal species of a particular site is studied extensively and appropriate mitigation strategies are designed." Which of the following BMS steps is best described by the statement?

      A. Scoping and feasibility

      B. Environmental and Social Impact Assessment.

      C. Operational phase

      D. Post-operational rehabilitation

   iii. Translocation of wild animals is one of the alternatives to reduce human-wildlife conflict. However, it can pose negative impact because

A. the new habitat could be far away from the reach of humans.

B. it may replicate the problem in the new habitat.

C. the animal's innate behaviour changes in the new habitat.

D. the new location might have a diversity of natural resources.

iv. National Biodiversity Strategies and Action Plan is the outcome of

A. Bonn Convention.

B. Ramsar Convention.

C. World Heritage Convention.

D. Convention on Biological Diversity.

v. Which of following thematic areas, as per NBSAP Bhutan 2014, is responsible for addressing rehabilitation of landscape for the protection of degraded ecosystem and habitats?

A. Resource Mobilisation.

B. Ecosystem and Ecosystem Services.

C. Species Conservation and Protected Area Management.

D. Knowledge, Technology and Education.

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

i. At the national level, ________________ is the principal document for implementing the Convention on Biological Diversity.

ii. Most human-wildlife conflict interventions in the biodiversity conservation management are targeted to reduce the loss of _________________.

iii. The impact of climate change poses challenge to the biodiversity management because it alters ____________ and behaviour of living organisms.

iv. Indigenous practices are helpful in conservation and management of biodiversity. Such practices have evolved from beliefs and interaction with their_____________.

v. The operational phase of Biodiversity Management System works for the _________________ of impacts on biodiversity.

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

   i. Biodiversity in Bhutan is immune to threats as major portion of the country is covered with forests.
   ii. Livestock insurance and compensation for animal attack help in minimising human-wildlife conflict.
   iii. Ecotourism is a measure to find a balance between biodiversity management and human-wildlife conflict.
   iv. NBSAP is prepared by those countries that are members of Convention on Biological Diversity.
   v. Establishment of community forest is an example of sustainable biodiversity management strategy.

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

   i. Describe the benefits of NBSAP.
   ii. Explain the significance of monitoring processes in Biodiversity Management System.
   iii. How does CBD contribute towards conservation of biodiversity in Bhutan?
   iv. Assume that there is a feasibility study going on for the establishment of mineral extraction plant in a nearby forest that is rich in biodiversity. Identify some parameters that can be included to carry out Environmental and Social Impact Assessment.
   v. Draw relationship between socio-cultural beliefs of Bhutanese and biodiversity management.

Reprint 2022

CHAPTER 10

LAND AND WATER MANAGEMENT

Land and water are essential natural resources for the survival of all living organisms. Although land and water are considered renewable resources, their potential to provide inherent services are declining at an alarming rate mainly due to anthropogenic and socio-economic factors. It has become necessary to protect and conserve these resources with appropriate management strategies, at both local and global level.

1. Land Management

Learning Objectives

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

- explain land use and land cover change.
- familiarise with the prevailing national Acts and Policies on land.
- explain the sustainable land management approach and practices in Bhutan.
- evaluate the soil quality standards for agriculture.
- carry out the soil test.

Land is one of the most essential natural resources for the survival of human beings and all other organisms. However, human need is causing the land cover to change by altering the ways of land use. These changes are the greatest environmental concerns because they trigger climate change and loss of biodiversity. Assessment and monitoring of land cover changes are fundamental for the sustainable management of land use, environmental protection, biodiversity conservation and development of sustainable livelihoods.

A. Land use land cover change (LULCC)

Land cover refers to the Earth's region which is covered by forests, wetlands, impervious surfaces, and agriculture. Land use shows how people use the landscape for development, conservation and other purposes.

In Bhutan, urbanisation and infrastructural development accelerate land cover change, resulting in unprecedented changes in ecosystems and environmental processes at local, regional and global scales. Figure 10.1 shows land cover dynamic in Bhutan from 2000 to 2013.

Figure 10.1 indicates that there is a drastic decline in agriculture and barren land area, while there is a huge increase in built-up areas. These changes in LULC may be due to the population growth of the country.

Reprint 2022

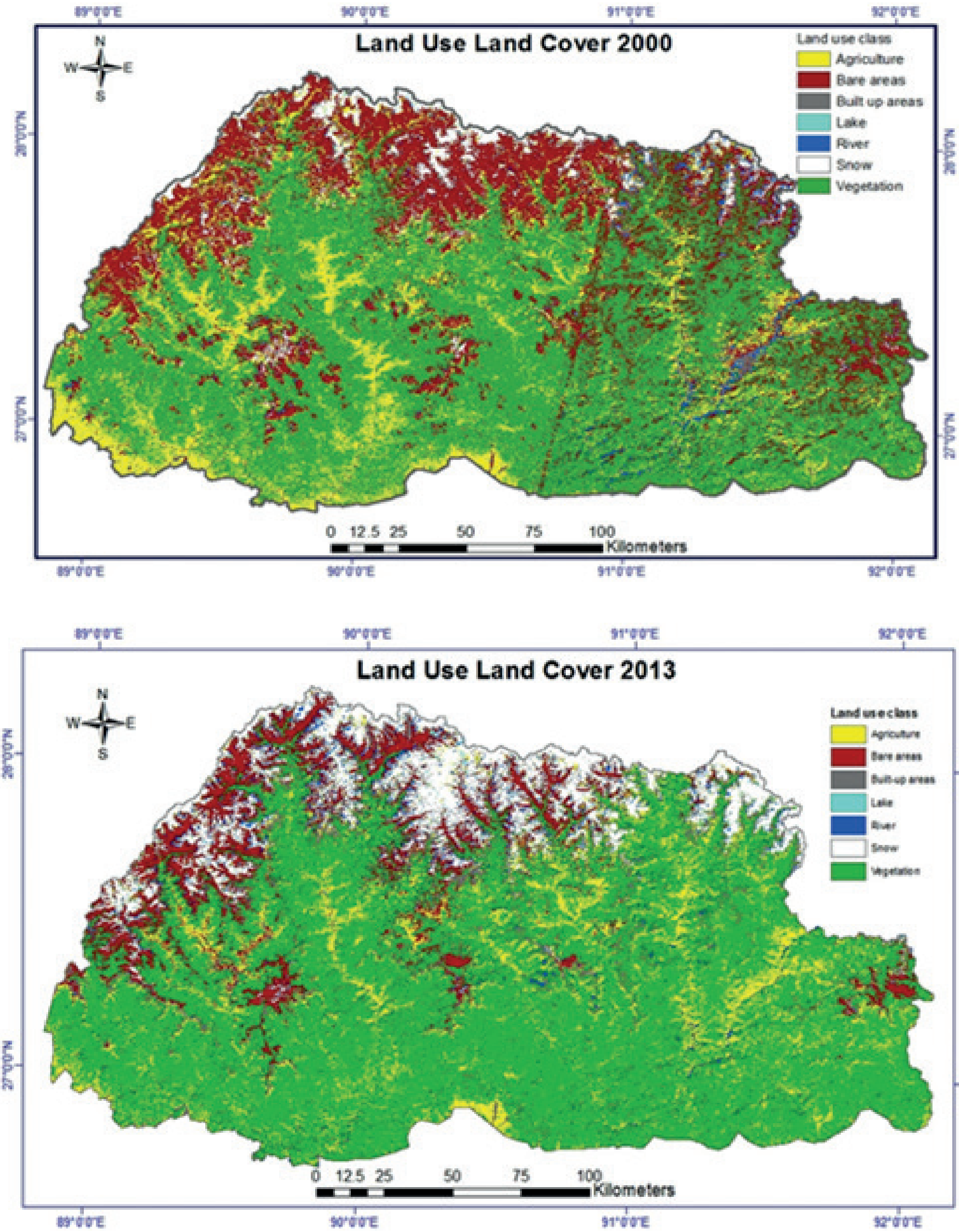


Figure 10.1. Land use land cover changes of Bhutan- 2000-2013

Activity 10.1. *Studying land use and land cover change*

Instructions:

1. Carry out this activity in computer laboratory.
2. Visit the given site of Mountain Geoportal: http://geoapps.icimod.org/BhutanLandCover/#
3. Study land use land cover changes online and answer the following questions:

Questions

1. Study land cover change of Thimphu and calculate the change in the area of land cover between the year 2000 and 2010.
2. Identify the differences in the barren land area in 2000 and 2010.
3. What differences do you find in the land cover pattern of Thimphu and Lhuntse Dzongkhag?
4. Suggest reasons for the difference in the rate of land cover change.
5. Evaluate the land use land cover pattern change in Bhutan in the period 1990 to 2010.

B. Sustainable land management approaches in Bhutan

Land conservation is a practical approach to protect land and prevent the loss of soil by erosion due to anthropogenic activities or natural processes. The need for land conservation is essential to support continued human activities in a sustainable way. It is carried out through the implementation of legal instruments, adopting good agriculture practices and revering beliefs and culture.

(a) Legal instruments for land conservation

The legal instrument includes acts, policies and plans for sustainable management of land use. It provides guidelines for efficient use of land and land resources. Some of the legal instruments in Bhutan are described in Table 10.1.

Reprint 2022

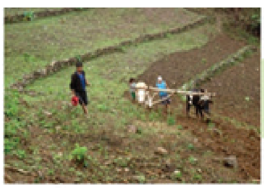
Table 10.1. Legal instruments pertaining to conservation of land

Legal Instruments	Purpose
The National Forest Policy, 1991	Ensures the protection of the land and its soil against degradation, and the improvement of all degraded forest land areas through proper management systems and practices.
he Bhutan Water Policy, 2003	Recognises the land use having a direct impact on water resources and it calls for the land use planning at the river basin level. Identifies soil erosion control as one of the special areas of attention for applied research in water resources development and management.
National Urbanisation Strategy, 2008	Addresses the environmental degradation in urban areas by outlining the strategy for zoning of the ecologically-vulnerable lands and institutional strengthening of the environmental units of the municipal bodies.
Forest and Nature Conservation Act, 1995	Covers sustainable forest management, protection of government reserved forests against illegal use, social and community forestry, and establishment and management of protected areas; all of which would contribute to combating land degradation and its impacts.
Mines and Mineral Management Act, 1995	Ensures that adverse environmental impacts, including those on land, from mining are minimal to the extent possible and are restored with the objective of creating a suitable and acceptable environment.
Regulation for Strategic Environmental Assessment 2002	Promotes and encourages the development of comprehensive natural resource and land use plans at the local, dzongkhag and national levels. Calls for conservation and protection of wetlands, alpine regions, watersheds, and other vulnerable ecosystems in addition to the existing protected areas.
Road Acts of Bhutan, 2004	Requires that all road construction and maintenance works conform to environmental considerations, geological stability considerations and preservation of agricultural lands.
The National Environmental Protection Act (NEPA) 2007	A minimum of 60 percent of Bhutan's total land shall be maintained under forest cover for all time. The NEC is entrusted to ensure conservation and protection of wetlands, alpine regions, watersheds, and other vulnerable ecosystems in addition to the existing protected areas.
The Land Act of Bhutan 2007	Outlines rights, responsibilities and legal conditions for the management, regulation and administration of the ownership and use of land.

(b) Sustainable land management through agricultural practices

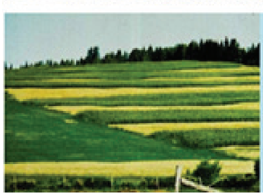
In Bhutan, agricultural lands are generally located on steep slopes except in few valleys in the Western region. These are prone to erosion by water and wind, which in turn would compromise the future food production due to loss of soil fertility. There are several methods in place to ensure sustainable land management through agricultural practices. These are briefly mentioned below.

Traditionally, Bhutanese farmers practice contour ploughing, terracing and strip cropping as shown in Figure 10.2. These are well established farming techniques that were in place for a long time. The method reduces the steepness of the slope improving workability. In doing so, this method also help in reducing the velocity of runoff that is generated by storm water and enhance water infiltration.



Contour Ploughing: Tilling and planting across the slope following its elevation contour

Terrace Farming: Planting in the terrace, a piece of slopped plane that has been cut into series of seceding flat surfaces which resemble steps.



Strip Cropping: Different crops are cultivated in alternating strips along the contour. Strips of erosion resistant plants are grown with erosion prone crops. For example, legumes (erosion resistant) are grown in strips parallel to corn (erosion prone).

Figure 10.2. Three types of traditional land practices in agriculture

i. These days, traditional method of cultivation is adapted to suit the current socio-economic and environmental economic needs. As opposed to past practices, farmers cultivate on land parcels which is partially or fully developed in line with scientific principles. In what is called as modern farming, the appropriate land management technologies such as hedgerows or alley cropping, terracing, contour bunding, and plantations are introduced. These are simple, low cost and effective technologies endowed with providing maximum soil and water conservation functions. Furthermore, for steep-land agriculture farming in Bhutan, small machineries for ploughing, harvesting and thrashing are also in use.

Hedgerows: This technology consisting of shrubs and grass slips planted along the contour is introduced in the field since it provides multi-function. Hedgerows not only conserve soil nutrients and moisture by reducing the water runoff and sediment transportation, but also provide fodder to livestock animals.

Terracing: Terraces are constructed on the slopes firstly to ease the workability while carrying out farming activities and also to retain water. This is particularly important wetland cultivation where it requires abundance of water.

Contour Bunding: Terracing and stone bunds are constructed along the counter lines to ease workability, retain soil nutrients and moisture.

Figure 10.3. Adapted land management practices for hilly terrain across Bhutan

ii. Another method of making farming effective and sustainable in sloppy areas is the use of aspect map. Aspect map is the representation of the direction of a slope that faces the sunlight (Figure 10.4). It can be determined by using a Digital Elevation Model (DEM), or just using a compass. Slopes can be identified as the northerly aspect or north-facing slope, the southerly aspect or south-facing slope, determining the amount of sunlight received.

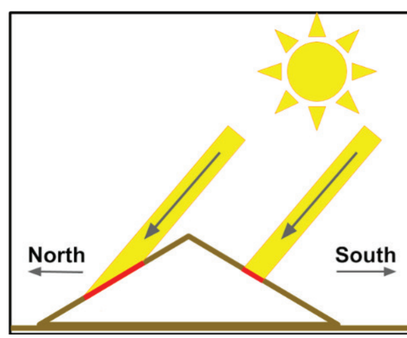


Figure 10.4. Aspect map

Different slopes receive different amount of sunlight and have different micro- climate. Based on this, type of crops to be grown is determined. For example, cardamom plantation can be planned and carried out in the areas receiving less sunlight while maize in areas receiving more sunlight. These practices would yield good harvest; otherwise more land would be exploited for the equal productivity.

Questions

1. What are the advantages of sustainable land management?
2. Differentiate between contour ploughing and terrace farming.
3. How do the legal instruments help the people of Bhutan in land conservation?

4. Is it important to conserve non-arable land? Why?
5. If you were a farmer, which methods would you adopt to conserve your farmland? Justify.

Activity 10.2. *Making of 'A' Frame and its Calibration*

How to make an 'A' frame

Materials required:

1. Materials required:
Two pieces of wooden or bamboo poles of about 2-4 cm in diameter and 2 m length.

a. One piece of wood or bamboo of about 2-4 cm diameter and 0.6 m length.

b. Nails and sturdy strings.

c. A stone or any heavy object about the size of a fist to serve as a plumb.

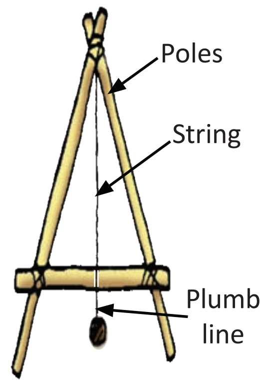


Figure 10.5 A-frame

2. Make a shallow notch about 10 cm from one end of each of the two longer poles. Place the two notches together and tie or nail these two poles together. Notches do not allow the poles to slip. These two poles form the legs of the 'A' frame.

3. Spread the two legs and tie crosspiece to make a letter A.

4. Tie one end of a string to the point where the two legs of 'A' frame are joined.

5. Tie the other end of the string to the stone or any heavy object. The stone should hang about 20 cm below the crosspiece.

How to calibrate the 'A' frame?

1. Before using, the 'A' frame should be calibrated to find its centre.
2. On a fairly level ground surface, place the 'A' frame in an upright. Mark the points on the ground where legs A and B are placed. Mark the position C on the crossbar where the weighted string comes to rest.

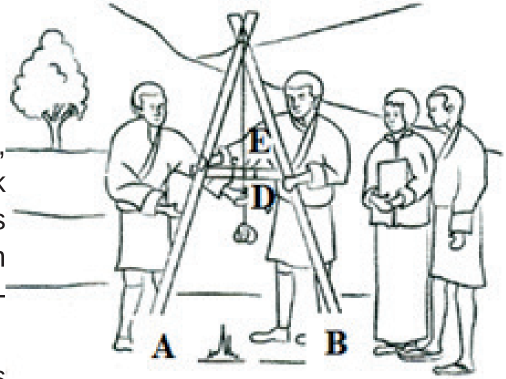


Figure 10.6. Calibration of 'A' Frame

3. Then exchange the place of legs A & B and mark the position D on the

crossbar where the weighted string rests. If C & D coincides, it means the midpoint has been found.

4. If C & D do not coincide, then measure the length between C & D & mark the midpoint E.

Activity 10.3. *Designing a model for contour bund*

Materials required:

'A' frame, wooded pegs, string, measuring tape and stones

Instruction:

1. Work in groups.
2. Use the 'A' frame which you have made.
3. Identify a land slope in your school campus, preferably in a school vegetable garden
4. Hammer a wooden peg close to the boundary of the identified slope on which contour bund will be made.
5. Place the A-frame horizontally on the slope. Make sure one of the legs of the A-frame is nearer to the peg (Figure 10.6)
6. Repeat this process, hammering a peg each time you move the A-frame until the whole length of the slope or the specified area is covered.
7. Connect the pegs at its top with a string to form the contour line.
8. Construct a ridge using stones along the counter line. The height of the ridge should be tall enough to reduce the runoff and prevent the soil erosion.

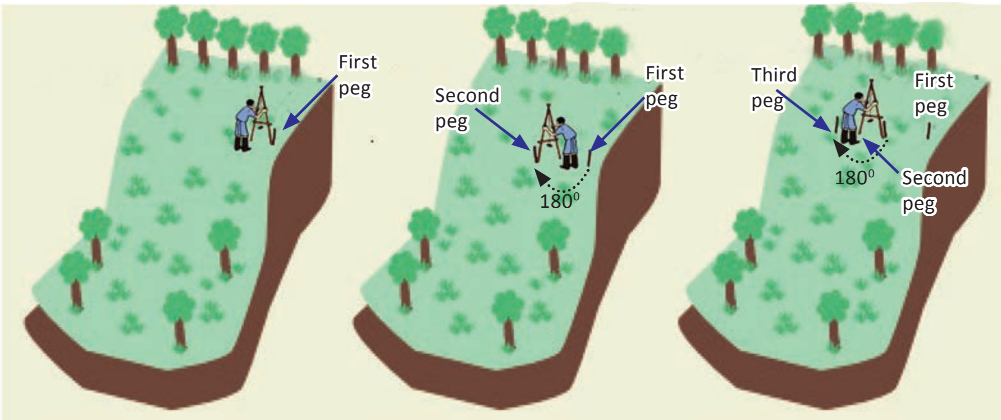


Figure 10.7. How to use A-frame

Questions

1. What is the purpose of carrying out this activity?
2. What is the advantage of using A-Frame in making a contour bund?
3. How does contour bund help in conserving soil and water in the field?

(c) Mine reclamation

Mining is the extraction of valuable minerals or other geological materials from the Earth. Mining activities are generally under severe scrutiny and highly regulated as they degrade land and have adverse impacts on the environment, ecosystem and biodiversity in the locality. The land degraded due to mining, needs to be restored to create land for definite purpose and facilitate ecological succession. The process by which the land is restored after mining activities is known as mine reclamation (Figure 10.8). Although the process of mine reclamation occurs once mining is completed, but the planning of mine reclamation activities occurs before mining is approved. Mine reclamation process includes preparation of land after mining, stabilisation of soil and the slope, and re-vegetating with appropriate plants.

Bhutan's Mineral Development Policy (2017) states that mining will be subject to strict, clear and uncompromising guidelines and regulations that will ensure that mining is carried out in the most systematic, transparent and efficient manner. In order to carryout mine reclamation activities; sufficient fund under Environment Restoration Bond (ERB) fund is allocated. Therefore, progressive reclamation needs to be carried out by mine operators and monitored by mine inspectors.

Figure 10.8. Pictures showing Haurikhola limestone mine, Samtse: before (Left) and after mining activities

(d) Ethnecologyd

'Ethno' refers to human culture and 'ecology' refers to interactions between organisms and the physical environment. Ethnoecology is the cross-cultural study of how people perceive and understand the environment around them through their beliefs and knowledge, and how humans accordingly use or manage these natural resources. In the Buddhist perspective, beliefs, culture and the environment are interwoven. Land is considered sacred and believed to be inhabited by deities. This symbolic meaning and belief attached to land or water are explained recognising cause and effect relationship. For instance, Meri Phuensum Mountains of Haa is believed to represent scared protecting deities 'Manjushri' (Jampelyang), 'Vajrapani' (Chana Dorji) and 'Avalokiteshvara' (Chenrezig)). People believe cutting down trees on such mountains would cause misfortune or sickness. This belief motivates people to revere those mountains, which in turn help to conserve mountains and its rich vegetation.

C. Soil Quality

Soil quality refers to the capacity of a specific kind of soil to sustain plant and animal productivity within natural or managed ecosystem boundaries. It is a necessary indicator of land management which ascertains the suitability of soil for plant growth and agricultural uses, and prevents an unregulated use of land. Prior knowledge of soil quality is essential while managing land or converting the natural ecosystem into agriculture ecosystem. Soil quality is measured through analysis of its physical, chemical and biological properties.

(a) Physical properties

(i) Soil texture

Soil texture indicates the relative content of particles of various sizes through which soil is classified as loam, sand, silt and clay (Table 10.2). Texture influences the aeration, water retention, water percolation and organic matter content. The properties of soil types are given in Table 10.3.

Table 10.2. Tabulated procedure for determination of soil texture

Textural class	Feel of fingers	Ball formation	Stickiness	Ribbon formation
Sand	Very gritty	Does not form ball	Does not stain fingers	No
Sandy loam	Moderately gritty	Forms fairly firm ball which is easily broken	Definitely stains the fingers	No
Loam	Neither very gritty nor very smooth	Forms firm ball	Definitely stains the fingers	No

Slit loam	Smooth or slick "buttery" feel	Forms firm ball	Definitely stains the fingers	Slight tendency to ribbon with flaky surface
Clay loam	Slightly gritty feel	Moderately hard ball when dry	Definitely stains the fingers	Ribbon out on squeezing but ribbon breaks easily
Clay	Very smooth	Forms hard ball, which when dry cannot be crushed by fingers	Definitely stains the fingers	Squeezes out at right moisture into long ribbons

Table 10.3. Soil attributes based on soil texture

Property	Sand	Silt	Clay
Surface area to volume ratio	Low	Medium	High
Ability to store plant nutrients	Poor	Medium to high	High
Porosity	Large	Small	Small
Permeability	Rapid	Slow to moderate	Slow
Water holding capacity	Limited	Moderate	Large
Internal drainage	High	Slow to medium	Very slow
Aeration	Good	Medium	Poor
Organic matter levels	Low	Medium to high	High to medium
Susceptibility to water erosion and wind erosion	Low	High	Low if aggregated, high if not

(ii) Water content

Water content in the soil is helpful in transporting the dissolved nutrients for plant growth. It regulates soil temperature, helps in biochemical activities, and determines the rate of mineralisation. However, the excess water content in soil reduces the activity of aerobic microorganisms due to less diffusion of oxygen in water (about 104 times) than in air.

(iii) Soil aggregate

Soil aggregate is a group of soil particles that bind each other firmly. Soil aggregate can resist disturbances and damages caused by disruptive forces such as tillage and water or wind erosion. It contains pores, which provide passage for air, water, nutrient and biota movement within the soil. Large pores associated with large, stable aggregates favour high infiltration rates and appropriate aeration for plant growth. Pores also create zones of weakness for root growth and penetration.

Surface crusts and filled pores occur in weakly aggregated soils. Surface crusts prevent infiltration and promote erosion; filled pores lower water-holding and air-exchange capacity and increase bulk density, diminishing the conditions for root growth.

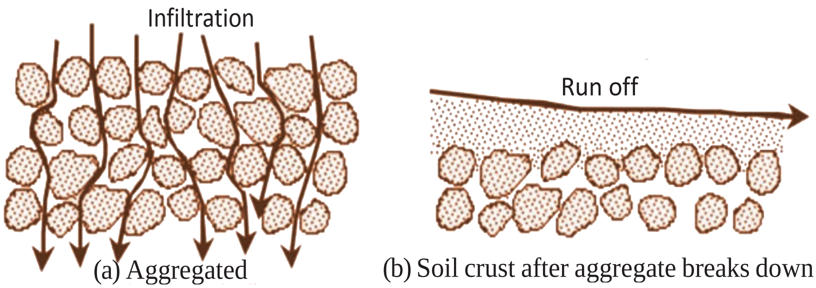


Figure 10. 9. Soil aggregate showing infiltration (a) and resistant ability against dispersed soils

Activity 10.4. ***Determination of soil texture***

Materials required:

Soil samples from three places (forest, nearby spring or river bed, and school garden), water bottle, plastic tray, a wooden spatula and hand wipes.

Instructions:

1. Work in groups.
2. Spread the soil samples onto a tray and remove any pebbles and visible bits of organic matter.
3. Use spatula to break larger soil aggregates into smaller ones as shown in figure 10.10 (a) or by simply kneading the soil.
4. Take a small amount of soil from each sample and put it in the palm of your hand.
5. Add a little water and then using your finger rub the soil against your palm until it becomes a moist putty.
6. Add water or soil to the putty to form a ball which is neither too soft nor too hard as in figure 10.10 (b).
7. Take the ball of soil and gently push it with your thumb against the index

finger to produce soil ribbons as shown in figure 10.10 (c).

8. Repeat step 3 using fresh soil sample from the same source. Take a small amount of each sample in your palm. Add a little water and then using your fingers rub the soil against your palm to test whether the soil is gritty, smooth or sticky as depicted in figure 10.10 (d).
9. Use Table 10.4 to draw your inference on the type of soil texture and present your findings.

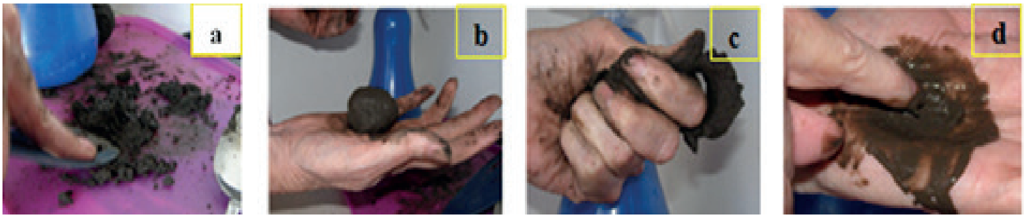


Figure 10.10. Procedure for determining soil texture

Table 10.4. Observation Table

Source of the sample	Feel of fingers	Ball formation	Stickiness	Ribbon formation
Forest				
Spring/river bed				
School garden				

b. Chemical content

(i) Nutrients

Nutrients in the soil determine the fertility of the soil. A fertile soil contains the macronutrients such as nitrogen, phosphorus and potassium as well as micronutrients such as calcium, magnesium, sulphur, iron, zinc, copper, boron, molybdenum and nickel. A fertile soil will also contain organic matter that improves soil structure, soil moisture retention and nutrient retention.

(ii) Soil pH

Soil pH refers to the degree of soil acidity or alkalinity. Soil pH has a great effect on the availability of minerals or nutrients. A pH range of approximately 6 to 7 promotes the availability of plant nutrients. The availability of nutrients in the soil varies at different pH level as represented in Figure 10.11. Strongly acidic soil prevents the breakdown of organic matter by microorganisms, reducing the fertility of the soil.

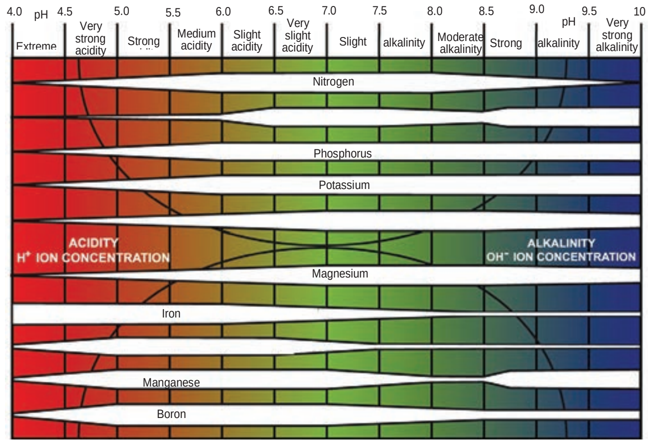


Figure 10.11. Soil pH and plant nutrient availability in soil solution

(iii) Electrical conductivity (EC)

Electrical conductivity (EC) is a measurement of the dissolved minerals found in the soil, which relates to the ability of the minerals to conduct current through it. Higher the concentration of dissolved minerals in the soil sample, higher is the EC. Electrical conductivity is an indicator of total salinity of the soil. Soil with high EC indicates salinity, which may impede crop growth and microbial activity. For example, soil with high EC due to sodium concentration has poor structure and drainage. Therefore it is toxic to plants.

c. Biological contents

Soil biota includes all microorganisms such as bacteria, fungus, flagellates and amoeba, ciliates, nematodes, soil insects, earthworms and plants. These organisms are essential in improving soil quality and are required for the healthy growth of plants. Organisms of the soil play major roles in nutrient cycling, biochemical weathering of minerals and soil development, and ameliorating physical and chemical properties of the soil. Micro-organisms decompose plant and animal residues into humus and nutrients. Bacteria and fungi excrete sticky substances that hold the soil together into aggregates. Fungi excrete enzymes such as chitinase, which break down tough-to-digest material. Nematodes promote nutrient mineralisation by feeding on microbes and also excreting ammonia which is an important source of nitrogen for plants. Earthworms play important roles in air, nutrient, and water cycling in the soil. During the process of feeding and producing worm casts, earthworms improve aggregate stability, promote soil mixing, and increase the surface area of residue for decomposition.

Activity 10.4. *Identifying suitable soil type for the crop*

Instructions:

1. Discuss in groups and select a favourite fruit or vegetable plant.
2. Browse internet or library books and find out the soil quality requirement for your plant.
3. Complete Table 10.5.
4. Present your findings to the class.

Table 10.5. Observation table

Soil quality parameters	Basic soil requirement
pH	
Soil texture	
Soil salinity	
Nutrients	
Water content	
Soil aggregates	

Answer the following questions

1. What kind of soil does your favourite plant require?
2. Why do you think different species of plant growing in the same area require different nutrients?
3. Discuss the importance of soil quality analysis.

2. Water Management in Agriculture Systems

Learning Objectives

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

- explain the importance of water management in agriculture.
- identify various water conservation approaches in agriculture systems.
- explain the technique of rain water harvesting.
- describe the types of irrigation techniques.
- Identify the challenges of adopting water conservation in Bhutan.

Water is one of the most important resources for the survival of all living things. The Earth has an abundant source of water, but only 0.3 percent is freshwater available for human consumption.

In Bhutan, freshwater sources are drastically declining. Perennial streams have become seasonal, and many springs and lakes are drying up. Therefore, the freshwater sources need to be protected and conserved.

One of the key activities to conserve water is implementing water management practices that ensure efficient and sustainable use of water. Water management for sustainable use involves planning, developing, distributing and optimising the use of water resources. Water management practices include various water conservation methods.

A. Approaches to water conservation

Water conservation methods include all the acts and policies, planning and implementation of plans and programs to efficiently use and manage the freshwater resource, protect the environment, and meet the current and future demand for water.

a. Legal instruments for water conservation

It is important that the citizens of a country understand and comply with legislations, policies and regulation of the conservation of water. The legal instrument for effective conservation of water in Bhutan is The Water Act of Bhutan 2011. The main purpose of this act is to ensure that water resources are protected, conserved, and managed in an economically efficient, socially equitable and environmentally sustainable manner.

The Water Act of Bhutan 2011 enables to:

1. ensure national integrated water resource management; adopt strategies, plans and programmes for achieving the purpose of this Act.
2. set water quality standards and guidelines.
3. set effluent discharge standards for discharge of certain substances into water resources.
4. set minimum environmental flows of watercourses and develop criteria for wastewater charges, abstraction charges and other fees.
5. establish procedures for monitoring water quality standards and discharge standards.
6. review, revise and advise the government on water policy, regulations, standards, guidelines and other matters related to emerging water issues.

The Act complements the internationally accepted concept of integrated water resource management, and prioritises management of water for drinking and sanitation over agriculture and hydro energy.

B. Water conservation practices in agriculture

In agriculture, we use a large amount of water for irrigating fields and managing farms like poultry, fishery and dairy. Huge amount of water is lost through runoff over the steep lands, excessive infiltration and evaporation during the agricultural activities. Improved methods of farming and irrigation can reduce such water losses significantly.

(i) Land management technologies for water conservation

Introduction of hedgerows, stone bunds and terracing in fields are some of the techniques that are widely practised by farmers to check runoff water and control soil erosion. These land management technologies once placed in the field act as a barrier to reduce the velocity of water runoff down-slope, helping water to percolate into the soil and spread evenly over the land and consequently reduce translocation of nutrient rich topsoil. Furthermore, the slowing down of water runoff also helps in building up a layer of fine soil and manure particles rich in nutrients.

Placement of adaptive sustainable land management technologies is so crucial in Bhutanese agriculture as farming is usually carried out on steep lands. Beside its soil and water conservation functions, technologies such as contour stone bunding and terracing bring about greater convenience to agricultural operations.

Reprint 2022

At the same time, these structures check water at a point where it attains erosive velocity (Figure 10.12.)

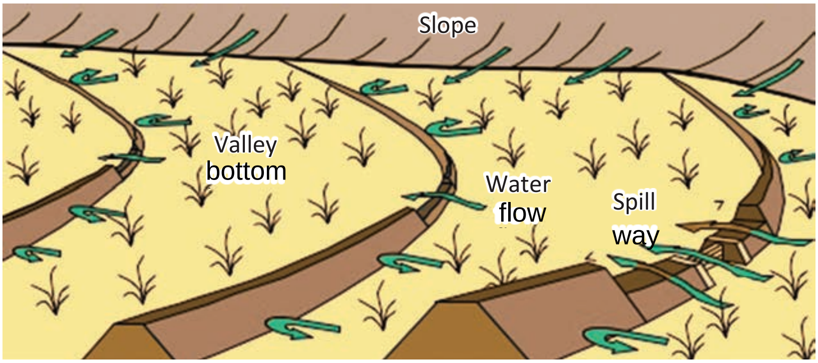


Figure 10.12. Contour bunds preventing water runoff

(ii) Irrigation methods

Agriculture demands a large amount of water for proper growth of crop plants. A large amount of water is lost due to evaporation, runoff or subsurface drainage. Therefore, fields and farmlands should be designed to conserve and deliver water uniformly to the crops by using efficient irrigation systems. Some of the efficient irrigation systems are surface irrigation, sprinkler irrigation, drip irrigation and pitcher irrigation.

(a) Surface irrigation

The practice of surface irrigation is thousands of years old. It represents as much as 95 percent of common irrigation today. Surface irrigation is a method in which flowing water is introduced at one edge of the field so that water gradually covers the whole field. The rate of flow of water depends on the surface and slope of the field. The water in the field can be controlled by regulating the rate of discharge onto the field. There are several types of surface irrigation techniques used to maximise the utility and conservation of water. Some commonly practiced surface irrigation techniques are shown in Figure 10.13.

Basin Irrigation

- Field is divided into units surrounded by small levees or dikes.
- Water is applied rapidly covering the entire land surface.
- It favours soil with low infiltration rate.
- Provides an undirected flow of water onto the field.
- Prevents water runoff and formation of tail water.

Furrow Irrigation

- Water runs in small channels (furrow) constructed across the slope of the land.
- Water infiltrates slowly into the soil as it moves along the channel.
- The performance of this irrigation can be improved by increasing the speed at which water flow.
- Reduces evaporation.

Border Irrigation

- It is hybrid of basin and furrow irrigation.
- Parallel earth ridges, called borders, guide a sheet of flowing water across a field.
- Soils can be irrigated efficiently which have moderately low to moderately high intake rates.
- Prevents water runoff by blocking at the downstream.

Figure 10.13. Three types of surface irrigation

(b) Sprinkler irrigation

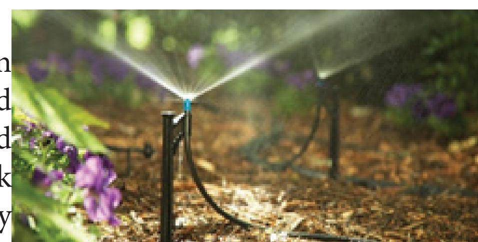


Figure 10.14. Spraying water with sprinkler

As shown in Figure 10.14, sprinkler irrigation is a method of applying water in which water is pumped and distributed through a system of pipes and then sprayed through sprinklers. The sprinklers break up the water into small drops and spray evenly onto the crops. The sprinkler irrigation system is widely used in sandy areas as it checks the wastage of water through seepage and evaporation. It minimises deep surface runoff and erosions.

(c) Drip irrigation

Drip irrigation is a form of irrigation that saves water and fertiliser by allowing water to drip into the soil at very low rates of 2-20 litres/hour. Water is applied close to plants so that only part of the soil in which the roots grow is wetted, drastically reducing the loss of water. There is also no water logging and the salinity problems caused are almost zero. Drip irrigation is also called trickle irrigation, and it is a very efficient method of irrigation. The system of drip irrigation is shown in Figure 10.15.

Figure 10.15. Drip Irrigation dripping water near the plant root zone

(d) Pitcher irrigation

The simplest form of pitcher irrigation consists of unglazed baked earthen pitchers buried to their neck in the soil and filled with water (Figure 10.16). When the pot is filled with water, natural pores in the pot walls allow water to seep out and spread laterally in the soil. This creates moist condition in the soil which is necessary for plant growth. Pitchers are filled with water as needed to maintain a continuous supply of water directly to the plant root zone. Hollow bamboo culms can also be used for pitcher irrigation after making fine pores. It is also one of the efficient techniques for conservation of water.

Figure 10.16. Pitcher irrigation using earthen pot

(iii) Water harvesting methods

Most farmers have traditionally relied on unevenly distributed seasonal rainfall for agriculture. In Bhutan, about three-quarters of the rainfall occur between June and September each year. There is water shortage during spring which is the most critical part of growth and development of the crop plants. Early or late monsoon also disrupts the progression in the physiological development of crops. Also, rugged terrain and the geological conditions make it both challenging and expensive to divert water from other watersheds for utilisation at homes and farms. Therefore, water stored during periods of excess can safeguard farmers from crop failures, loss of animal productivity and have safe drinking water.

Rain water harvest is another method of conserving water. Rainwater harvesting is defined as a method for collecting, storing and conserving surface runoff water and roof top rainwater. Rainwater harvesting may also help control erosion and flooding during periods of excessive rainfall. Generally, two methods of rain water harvesting practices are used in Bhutan.

(a) Surface runoff harvesting

Surface water harvesting includes all systems that collect and conserve surface runoff water after a rainfall or from intermittent streams and wetlands. The water collected is stored in artificial ponds and reservoirs. This can provide water for household use, irrigation, livestock and aquaculture.

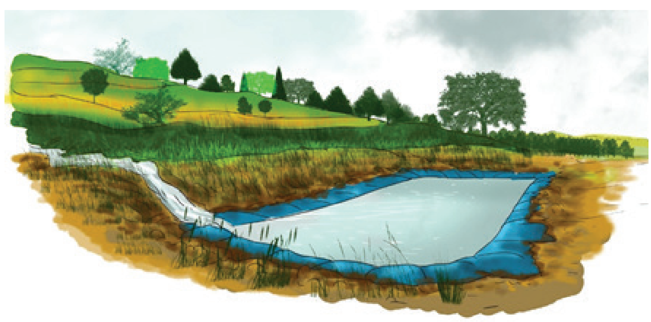


Figure 10.17. Water harvesting from surface runoff

In Bhutan, water from natural springs or rain water runoff flows down the hill due to the slope. The water can be trapped by constructing artificial ponds at lower parts of the hills. A sample surface runoff harvesting pond is shown in Figure 10.17.

(b) Rainwater Harvest

The roof of a house acts as catchments and the rainwater that drains from the roof is collected using gutter. The water collected may be diverted to be stored in a pond. The most common way to store water is above ground in concrete or plastic tanks. Water collected by this system can be used in some household activities and irrigation of crops. The rainwater harvest system is shown in figure 10.18.

Figure 10.18. Rainwater harvest for domestic purpose

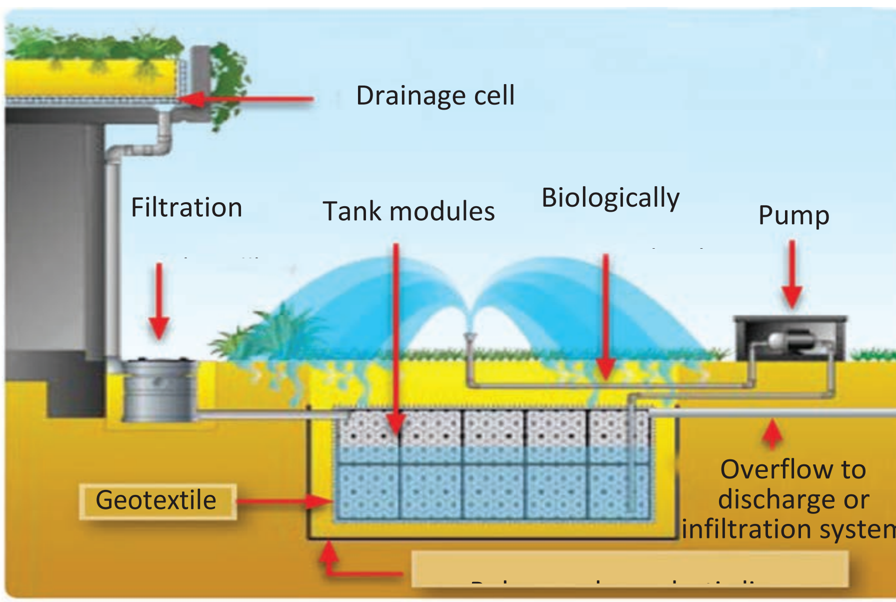


Figure 10.19. Rainwater collected stored in underground tank

If a large amount of water is to be stored for agricultural purposes, a leak-proof underground system is recommended (Figure 10.19). In Bhutan, underground systems are made from concrete with a simple metal screen or a sophisticated system like a slow sand filter. A pump or pressure tank may be needed for water distribution. This method of storing water underground is comparatively expensive but it is very effective.

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?

D. Water Quality

Learning Objectives

- relate the biological and chemical content of water to its quality.
- carry out dissolved oxygen test for water.
- explain the importance of biological oxygen demand in relation to water quality.

Water quality describes the condition of the water in terms of physical, chemical and biological properties. The concentration of microscopic algae and quantities of pesticides, herbicides, heavy metals, and other contaminants are also measured to determine water quality. Depending on the use of water, the water quality test varies from simple test in the field to multicomponent instrumental analysis in the laboratories.

1. Analysing the chemical content

The use of chemicals in industries and agricultural fields often pollute water. These chemicals get into the water bodies by leaching or run-off. They affect the water quality in terms of pH, dissolved Oxygen (DO), and biological oxygen demand (BOD). These parameters of water are analysed by using the chemical tests.

Dissolved oxygen (DO) is the presence of free oxygen molecules that are dissolved in water. The oxygen dissolved in water is vital for all aquatic plants and animals. The DO level is a useful indicator of water quality. The value of DO can range from 0-18 parts per million (ppm). Water body with DO level of 8 ppm is considered healthy. Reduction in DO level results in the loss of some species indicating the presence of organic pollutants. The presence of organic matter in the water bodies leads to the increase in bacterial activities, thereby decreasing the DO level. Therefore, a decrease in the DO level is an indication of an influx of organic pollutant in water.

Biochemical oxygen demand or biological oxygen demand (BOD) refers to the quantity of oxygen used by microorganisms in the process of oxidation of organic matter. Organic matters get into water from various sources such as domestic sewage, fertiliser runoff and industrial sources. Natural sources, such as floods, landslides and erosion also increase the presence of organic matter in the water. When these organic matters are decomposed by microorganisms,

Reprint 2022

lots of dissolved oxygen in water is used up. Thus, the level of DO decreases due to increase in the level of BOD caused by the actions of microorganisms. Macroinvertibrate, such as caddisfly larvae and mayfly nymphs cannot survive in environment of high BOD while leeches and sludge worms are tolerant to low DO and therefore thrive in such conditions. BOD level in the water is monitored by conducting a BOD test. Water that is not contaminated has a BOD value from 0.8 to 5 mg/L. The contaminated water will have DO value of more than 6 mg/L and needs to be treated before discharging into water bodies.

2. Analysing the biological content

The monitoring of quality of water by using biological content involves testing of water for the presence of coliform bacteria and observing the presence of benthic macro-invertebrates.

(i) Coliform bacteria

Coliform bacteria are present in the environment and faeces of all warm-blooded animals. Coliform bacteria are unlikely to cause illness however; their presence in drinking water indicates the presence of other disease-causing organisms in the water system. Pathogens present in polluted water causes intestinal infections, dysentery, hepatitis, typhoid fever, cholera and other sickness. Testing of water for all possible pathogens is complex, time-consuming and expensive. However, it is easy and inexpensive to test for coliform bacteria.

(ii) Benthic macroinvertebrates

Benthic macroinvertebrates are small stream-inhabiting organisms that can be seen with the naked eye, and they spend all or part of their life cycle in or on the bottom of the stream. The macroinvertebrates belonging to the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are highly sensitive to pollution. Therefore, their presence in water indicates that the quality of water is good.

Caddisfly Mayfly Stonefly

Figure 10.20. Benthic macroinvertebrate

Questions

1. How does monitoring of water quality help in water conservation?
2. Explain the importance of dissolved oxygen in the water.
3. Coliform bacteria are usually harmless to human, yet their presence is tested during water quality test. Give reasons.

Exercise

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

   i. It is usually desirable to manage soil in ways that maintain high infiltration rate so that more

      A. water flows into the river, especially during rainy weather.
      B. water becomes available to sustain plant productivity.
      C. leaching of chemicals takes place from the soil surface.
      D. erosion take place from the soil surface.

   ii. Organic matter is an important part of the soil because it

      A. is a component of the soil.
      B. provides required nutrition for plants growth.
      C. helps in preventing soil erosion.
      D. drains out excess water.

   iii. Which type of irrigation system would be better for plants growing in the greenhouse?

      A. Basin irrigation
      B. Furrow irrigation
      C. Sprinkler irrigation
      D. Drip irrigation

   iv. Benthic macroinvertibrates are used as indicator for water quality test because

      A. they are easy to capture for study.
      B. they are very sensitive to pollution of water.
      C. their population increases with contamination of water.
      D. they are only organisms found in the bottom of water.

v. The secondary treatment of sewage water can reduce .... into less harmful substances.

A. toxic chemicals

B. organic substance

C. inorganic substances

D. heavy metals

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

i. Fishes will die in a pond if DO is less than ....mg/ L.

ii. The principle of pitcher irrigation is similar to that of irrigation.

iii. Increase in BOD indicates ....in DO of water.

iv. Sticky soil particles that clump together and do not break easily will have ________________aeration and water drainage.

v. An organism which helps in nutrient mineralisation and water recycling in the soil is.

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

i. Water and land conservation plan needs to be approved by the concerned agency before implementation.

ii. Decrease in dissolved oxygen in water leads to change in the constituents of water.

iii. Presence of coliform bacteria in the water indicates the presence of faecal matters.

iv. Strip cropping is the best agricultural practice that is used to enhance the nutrients in the area.

v. The belief and culture which help in conserving land and its resources is called ethnoecology.

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

i. What are the significance of having legal instruments for water and land management?

ii. How can the knowledge of soil properties be useful to farmers?

iii. Explain the effect of temperature on the solubility of oxygen in water.

iv. It is wise to leave fields tilled and barren in winter. Justify.

v. Why are farmers encouraged to practice contour bunds in terrain landscape?

vi. Study Figure 10.21 and answer the following questions:

Figure 10.21. Old land use system of Thimphu valley

a) Describe land cover dynamics depicted in the figure.

b) Explain one of the land conservation techniques practised in the figure.

c) Why is it important to raise the contour bunds to the same elevation?

vii. Design an experiment to determine the water holding capacity of the soil sample. Your design should show materials required and procedure to carry out the experiment.

CHAPTER 11

ENERGY CONSERVATION

Energy is one of the key factors in determining the economic development of a country. Urbanisation and industrialisation would not have taken place without the utilisation of energy. Fossil fuel has generated tremendous wealth and made our life easier. However, the continuous overuse of fossil fuels results in its depletion and increases its cost. The effect of using fossil fuels on the environment and climate is becoming a major concern worldwide. Therefore, it is important that we widen the energy mix through harnessing other forms of clean and renewable energy. Further, efforts must be made to conserve energy using devices and technologies that are energy efficient.

1. Alternative Energy Sources and Devices

Learning Objectives

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

- explain biofuel as an alternative energy source with examples.
- explain alternative energy devices.
- evaluate pros and cons of alternative energy devices.

The increasing rate of depletion of fossil fuels and its cost have forced many countries around the world to explore for alternative sources of energy to meet the energy demands and also to ensure national energy security. Efforts are made to generate clean, eco-friendly and economical form of energy from renewable sources of energy, such as wind, water, sun and biomass by designing innovative devices. Advanced methods and technologies have also become necessary to conserve and use energy efficiently and reduce energy consumption in buildings, vehicles and industries.

A. Biofuel as an alternative energy source

Alternative energy sources are clean energy sources that can substitute fossil fuels and nuclear energy. The use of alternate sources of energy can help mitigate environmental and climatic problems.

Some of the alternative energy sources are solar energy, wind energy, geothermal energy, hydro energy and biofuel.

Biofuels are fuels derived directly from the plants or indirectly from industrial, agricultural and domestic wastes that are used as a substitute for petroleum-derived fuel. The substitutions for petroleum and cooking fuels are shown in Figure 11.1. Biofuels address concerns such as energy cost, energy security and global warming associated with fossil fuels. Ethanol produced from plant material, and biodiesel processed from vegetable oils or animal fats are the two most commonly used biofuels. Ethanol in its pure form is burned directly in pure ethanol engines, or it is mixed with gasoline to be used in any normal engine. When used as an additive in gasoline, the fuel burns cleaner and helps the engine run better. Ethanol fuel is much cleaner and eco-friendly compared to fossil fuels. Engines which use ethanol require less maintenance cost as compared to engines using conventional forms of fuel. Ethanol is primarily used in cars. Biodiesel can be used in any diesel engine when mixed with petroleum diesel.

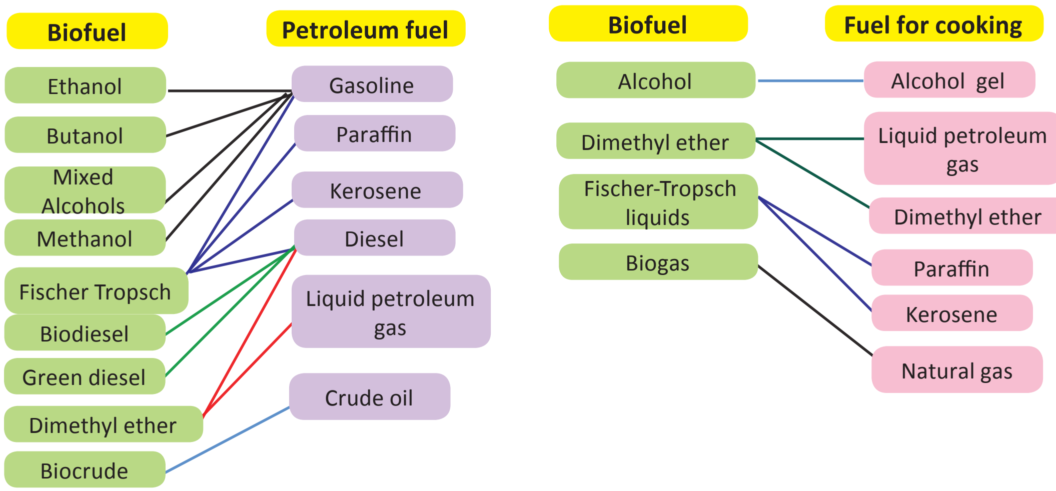
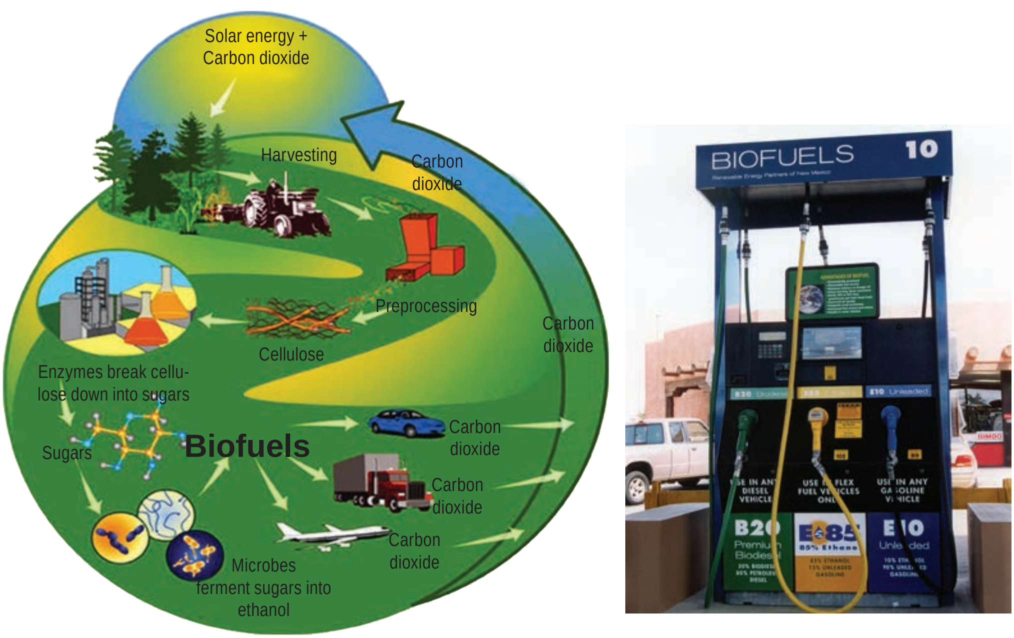


Figure 11.1. Substitutability of biofuels with common petroleum and cooking fuels



(a) Production process of biofuel (b) Biofuel used for transportation

Figure 11.2. Production and uses of biofuel

B. Alternative energy devices

Alternative energy devices harness energy from renewable energy sources and reduce dependence on the consumption of fossil fuels. Alternative energy devices like photovoltaic cell, wind turbine and fuel cell generate electricity from alternative energy sources, while, hydrogen storage and batteries store energy for future use.

(i) Photo-voltaic (PV) cell

A photovoltaic cell converts solar energy into electricity. The photovoltaic cell absorbs photons of light and releases electrons which produce electrical energy. This property or effect of absorbing photons and releasing electrons is known as the photoelectric effect. The cell consists of two layers of silicon. The lower layer has electrons that are easily lost. The upper one readily gains electrons. When light energy strikes the cell, electrons are discharged from the lower layer , and jumps to the upper layer. When the circuit is constructed between the two layers, as shown in Figure 11.3, the electrons flow back from upper layer to the lower layer, this flow of electrons generates electric current.

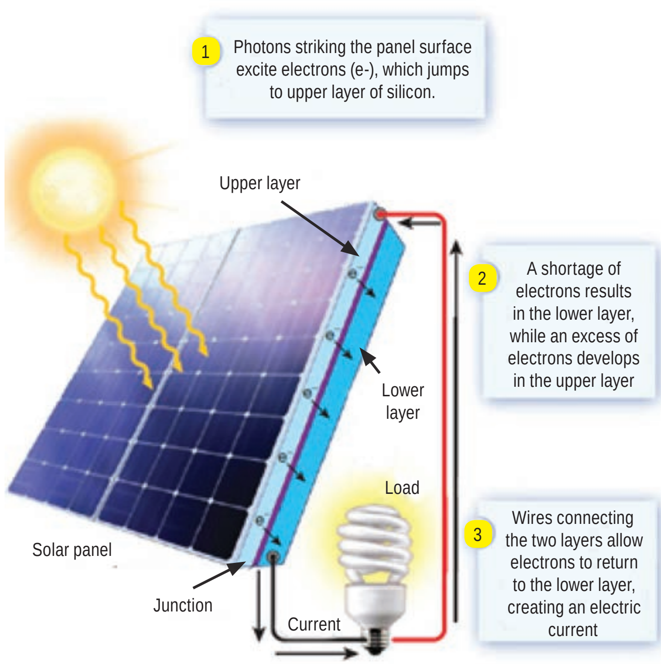


Figure 11.3. A photovoltaic cell generating electricity

Each PV cell generates a small amount of power. However, if many cells are placed together, it creates enough power to run an appliance. The power from

Reprint 2022

a PV panel is usually stored in a battery, to which the appliances are connected. Thus, the energy is generated and stored when the sun is available. PV cells are also used in watches, pocket calculators, toys, etc. Larger solar panels can light up the house, run an irrigation pump, operate traffic lights and so on.

(ii) Fuel cell

Fuel cell is a device that generates electricity through an electrochemical reaction. Fuel cells convert the chemical energy of fuel into Direct Current (DC) electricity and heat.

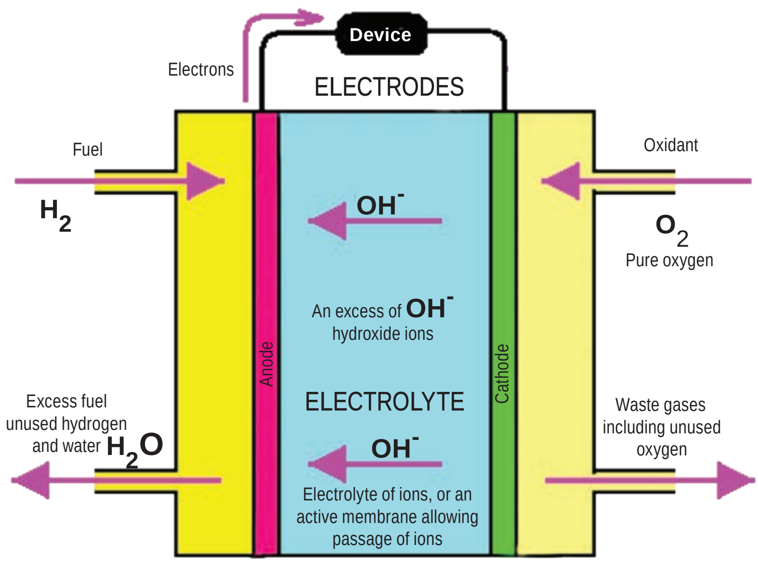


Figure 11.4. Hydrogen-Oxygen fuel cell

A fuel cell has two electrodes, an anode and a cathode, separated by an electrolyte. The chemical reactions that generate electricity take place at the electrodes. Electrolyte allows only certain electrically charged particles to pass between the two electrodes. In Hydrogen-Oxygen fuel cell, when hydrogen gas is supplied to the anode, hydrogen is split into protons and electrons. Protons pass through the electrolyte towards the cathode, but electrons cannot. Therefore, an external circuit is constructed between the anode and cathode for electrons to stream towards the cathode, thus generating electricity. The proton and electron combine with the oxygen supplied at the cathode, forming water and releasing a small amount of heat. Figure 11.4. shows the working of a hydrogen fuel cell.

In combustion engines, the chemical energy is first converted into heat, and then heat into mechanical work. Fuel cells convert chemical energy directly into electrical energy. Thus, fuel cells are more efficient than combustion engines. A single fuel cell generates a tiny amount of direct current electricity. In practice, many fuel cells are usually assembled into a stack to generate a large amount of electricity.

(iii) Hydrogen storage

Hydrogen is increasingly acknowledged as the alternative source of energy in the twenty-first century. Hydrogen is the basic requirement for fuel cells. It is extracted from natural gas or water and is present in a number of other chemical compounds. Hydrogen on combustion produces water vapour and reduces the emission of harmful gases in the atmosphere. An equal-sized tank of hydrogen fuel gives a vehicle more power than when filled with gasoline.

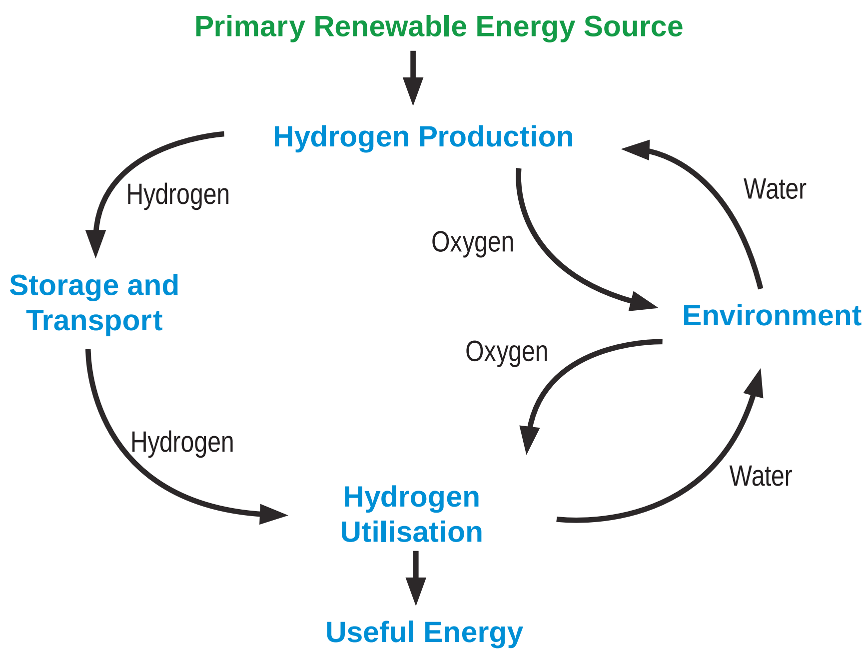


Figure 11.5. Hydrogen life cycle

Hydrogen fuel is used to propel space shuttle, cars, boats, and airplanes. It can be stored either as a gas at a high pressure or as a liquid at a cryogenic temperature. Hydrogen can also be stored on the surfaces of solids (by adsorption) or within solids (by absorption). The storage of hydrogen in the high pressure tank or a cryogenic tank, however, provides the problem of using hydrogen fuel in cars. Hydrogen is highly inflammable and explosive in nature.

(iv) Battery technology

An electrochemical cell stores energy in a chemical form and convert that stored chemical energy into electrical energy when needed. The cell consists of two electrodes, anode and cathode separated by an electrolyte. The aggregate effect of the chemical reactions taking place between the two electrodes discharges electricity. The anode undergoes oxidation to release electrons. Simultaneously, the cathode undergoes a reduction reaction by accepting electrons. The cell continues to discharge until either or both of the electrodes run out of reagents for their respective reactions.

For some battery systems, this process can be reversed, and the battery is recharged. As a consequence, two different battery systems exist, primary cell and secondary cell. Regarding storing energy or discharging electricity, they are similar. However, secondary cells can be recharged. In the secondary cell, the recharge process is the reverse of the discharge process. When recharging, electrical current removes electrons from the cathode and supplies to the anode, until the cells charge is restored.

(v) Wind energy

Windmills or wind turbines can convert the kinetic energy of the wind to electrical energy. The wind turbines are very tall with long blades devised to harness wind energy efficiently. When the kinetic energy of the wind moves the blade attached to the shaft, the shaft rotates, this causes magnet to spin inside the stationary coil called stator, resulting in generation of alternate current.

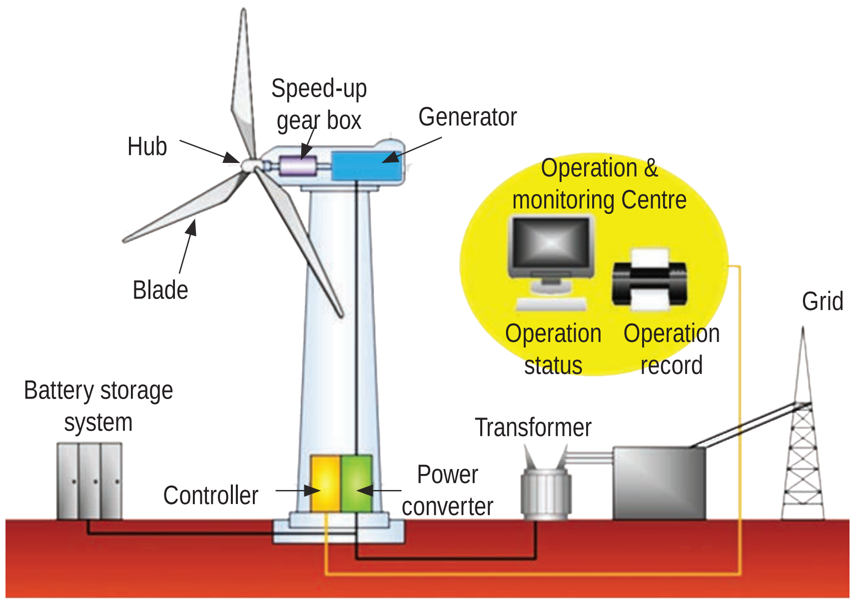


Figure 11.6. Wind turbine generating electricity

The power generated is either stored in batteries or fed into grid for electric current supply. Harnessing wind energy will be of huge benefit to those areas that receive sufficient amount of wind continuously. In 2015, Bhutan introduced two windmills in Rubesa, Wangdue Phodrang, which can generate 600 KW of electricity. It was initiated with an expectation to alleviate power shortage from hydropower plants during the lean seasons.

Activity 11.1. *Designing an alternative energy device model*

Instruction:

1. Divide the class into groups.
2. Design a model of an alternative energy device, and show how it can generate electricity from any one alternative energy source.
3. Organise an alternative-energy-device fair in the classroom. You can also invite students from the other classes.

Questions:

1. What are the criteria set while designing the model?
2. What are the resources used for making the model?
3. List the challenges faced while designing the model.
4. Write down the possible applications of the device.
5. How compatible is your device? If given enough time and resources, what further changes do you want to have in your device?

Questions

1. Complete the Table 11.1.

Table 11.1

Alternative energy devices	Advantages	Disadvantages
1. Photovoltaic cell		
2. Fuel cell		
3. Hydrogen storage		
4. Battery technologies		

2. How does alternative energy answer to the global and national energy issue?
3. Does the use of bio-fuel contribute to sustainable fuel supply? Justify.

Reprint 2022

2. Green Technology

Learning Objectives

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

- explain green technology
- describe the green technologies for energy efficiency.

While science and technology are advancing continuously over time, the ways to use them in favour of the Earth and mankind is important. Developed countries are already taking the initiative of harnessing renewable energy sources, and are creating different tools and practices to mitigate environmental impact and climate change.

One such initiative is the adoption of green technology. Green technology is the development and application of products, equipment and practices that can support the conservation of the natural environment and resources. Green technology is useful in the following ways:

- To minimise the degradation of the environment.
- To reduce green house gas (GHG) emission.
- To conserve the use of energy and natural resources.
- To promote the use of renewable resources.

A. Technology for energy efficiency

Using energy efficiently is the best way to ensure a secure and sustainable energy supply. Energy conservation can be carried out by opting for more energy efficient technologies. Some of the energy-efficient technologies are as follows:

(i) Cogeneration or Combined Heat and Power (CHP)

Combined Heat and Power (CHP) is the sequential generation of useful thermal energy and mechanical or electrical energy from a single source. For example burning of fossil fuels can generate mechanical and thermal energy. The mechanical energy produced is used to drive a turbine for producing electricity, or rotate equipment such as motor, compressor, pump or fan for delivering various services. While, the thermal energy can be used for other purposes such as supplement space heating in winter, heating swimming pool, providing energy needed to drive the cooling process in absorption refrigerator, etc. By producing two kinds of useful energy in a single device or system, the net energy yield from the primary fuel is increased. This also helps in conservation of natural resources, reduction in emission of pollutants, energy costs, distribution and transmission losses. Figure 11.7 shows CHP power station in Denmark that burns straw as fuel. The heat generated is used in the adjacent greenhouses while the power generated is used for household activities.

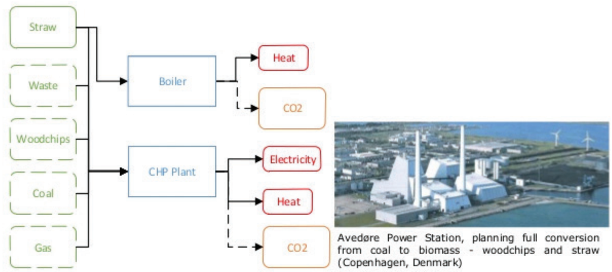


Figure 11.7. CHP power station in Denmark

(ii) *Oxy-fuel combustion*

In air fuel combustion, the fuel is burned using air where a significant amount of heat energy is used up for heating nitrogen gas present in the air. When this hot nitrogen gas leaves through the chimney, it results in loss of heat energy along with it. This heat loss can be prevented by a process called oxy-fuel combustion. In oxy-fuel combustion, the air separation plants eliminate nitrogen from the air and feeds only pure oxygen into the furnace for combusting coal. In industries, oxy-fuel combustion system decreases fuel consumption, increases the degree of combustion, and lower emissions such as CO_2 and NO_X. A simplified schematic of oxy-fuel combustion is presented in the Figure 11.8.

(iii) *Fuel efficient automobiles*

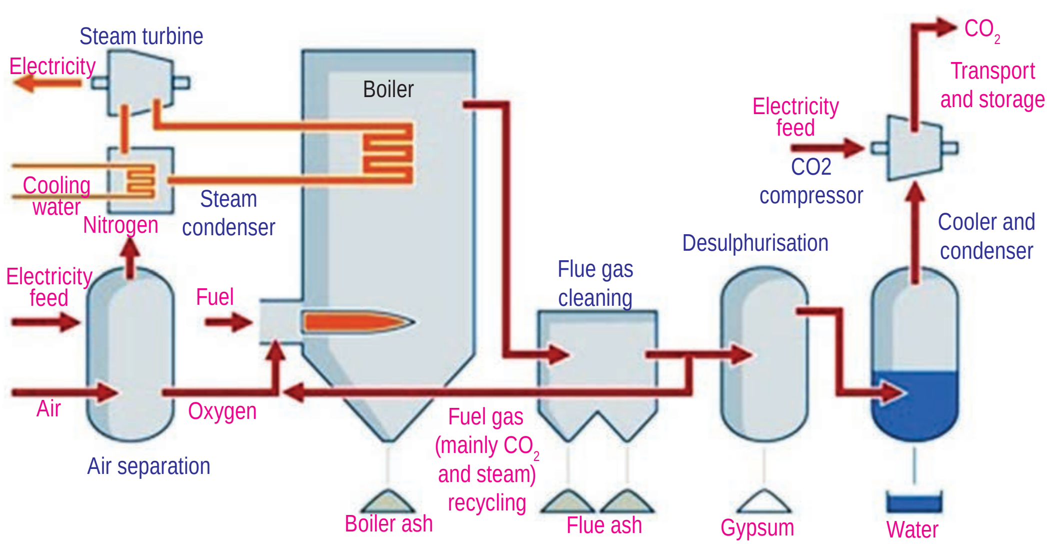


Figure 11.8. Oxy-fuel combustion

Transportation is the biggest sector that consumes a huge amount of fossil fuel. Thus, the implementation of efficient technology in transportation is necessary to reduce the consumption of fossil fuels and emission of pollutants into the environment. Efforts are made to develop fuel-efficient automobiles. Fuel cells are used in vehicles instead of a lithium-ion battery. Fuel cells are less polluting and less expensive. Hydrogen fuel cell vehicles convert stored hydrogen gas to electricity using the fuel cell to power an electric motor and battery.

In hybrid vehicles, a combination of gasoline engine and electric motor is used to power the vehicle. Hybrid vehicles use regenerative braking to generate electricity. In regular cars, the friction of braking generates heat which is dissipated. While, the hybrid vehicles capture that heat energy, converts it into electricity and store in the batteries. Such vehicles can be driven entirely on electricity, enabling the gas or diesel-power engine to operate only when necessary. The vehicle also has automatic shut off function when the vehicle comes to stop, which restarts when the accelerator is pressed. Since hybrid vehicle decreases fossil fuel dependency, it reduces emissions.

(iv) Weatherisation measures for existing construction

Weatherisation is a practice of protecting the building and its interior from the loss or gain of heat from the effects of changing weather, to increase the energy efficiency of the building. Weatherisation is achieved by implementing measures such as insulation, weather stripping and solar screens to reduce heat loss or gain from the building. Some of the weatherisation procedures that can be implemented at home are:

- sealing bypasses (cracks, gaps, and holes) especially around doors, windows and other areas through which heat may be lost.
- applying caulk around the outside edges of the window casing and door.
- installing insulation in walls, floors, and ceilings, around ducts and pipes, and near the foundation and sill.
- replacing old drafty doors with tightly sealed, foam-core doors.
- replacing older windows with low-energy, double-glazed windows.
- using heavy drapes and curtains to reduce loss or gain of heat.
- plugging the chimney hole with batt or blanket insulation when not in use.
- stopping under-door drafts by installing a rubber or vinyl sweep along the bottom.
- preventing warm air from escaping through the ceiling.

(v) Leadership in Energy and Environmental Design (LEED) certified buildings

Leadership in Energy and Environmental Design is an internationally recognised green building certification system. It provides building owners and operators with a concise framework for green building design, construction, operations and maintenance solutions. It aims at improving energy savings, water efficiency, and CO_2 emission reduction. Another advantage of LEED includes better indoor air quality and plenty of daylight.

Green building is the practice of designing and constructing buildings that conserve energy and other resources; and are environmentally responsible, healthier, safer and sustainable. Green buildings include insulated walls and roofs, coated windows oriented toward the sun.

(vi) Energy efficient devices

Energy efficient devices are those devices that consume lesser amount of energy to provide the same amount of services. Replacing old appliances with the modern energy efficient appliances like refrigerators, ovens, stoves, washing machines, etc., significantly reduces energy consumption. For instance, cloth dryers with moisture sensors cut energy use by 15%, and front-loading washers use less energy and less water than top-loading models. A compact fluorescent bulb produces as much light as a regular incandescent bulb but lasts up to 10 times longer, produces less carbon dioxide, and uses 75% less electricity. Installing motion sensor switches, at home, buildings, corridors and pathway reduces electricity consumption by eliminating the possibility of the lights accidentally left on. Light emitting plasma (LEP) has high luminary efficiency and low overall system price, hence, are better suited for roadway and high mast lighting applications than conventional high-intensity discharge (HID) and Light emitting diode (LED) systems. Such small step like changing to a motion sensor light switch and LEP lighting system will add to ongoing efforts to reduce carbon emissions, reduce the cost of electricity and conserve energy.

(a) Energy efficient appliances

(b) Motion sensor lighting

Figure 11.9. Energy efficient devices

Reprint 2022

Questions

1. What are the advantages and disadvantages of green technology?
2. How would the use of hydrogen as fuel contribute in conserving environment?

Exercise

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

   i. Energy and money in industry can be saved by using

      A. biofuel.

      B. fuel cell.

      C. photovoltaic cell.

      D. combined and heat power (CHP) system.

   ii. Which of the following accounts for the maximum use of fuel in Bhutan?

      A. Transportation

      B. Industry

      C. Home heating

      D. Electricity generation

   iii. Stack heat loss can be minimised by

      A. oxygen enrichment of combustion air.

      B. controlling the excess air.

      C. using fossil fuels.

      D. maintaining proper draft in the furnace.

   iv. The conversion of chemical energy to electrical energy in a fuel cell involves a reaction that

      A. eliminates combustion of fuel.

      B. requires high combustion of fuel.

      C. requires low combustion of fuel.

      D. requires no fuel.

v. Which of the following is a common disadvantage of renewable energy sources?

   A. Highly polluting
   B. High waste generation
   C. High running cost
   D. Unreliable

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

   i. The photovoltaic cells in solar panel, solar watch and solar water heater convert solar radiation into ________________energy.

   ii. Oxy-fuel combustion is preferred over air fuel combustion as it does not have ______________________ in the oxidant gas stream.

   iii. Hybrid vehicles have a combination of gasoline and _________________ engine to power a vehicle.

   iv. The use of fuel cells in hybrid vehicles reduces the consumption of ________________________. The by product of fuel cells are heat and _________________ which are non pollutants.

   v. Liquid hydrogen is stored at cryogenic temperature due to its low ____________________ point.

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

   i. Battery technology is not integrated into main power system due to its performance and safety issue.

   ii. Electrolyte in the hydrogen fuel cell allows both electrons and protons to move from anode to cathode.

   iii. Burning biomass is preferred over fossil fuels as it does not pollute the environment.

   iv. Weatherisation of building prevents loss or gain of heat from the building.

   v. Wind turbine is an alternative energy device that is used to generate heat.

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

   i. What are some of the ways to reduce energy use for lighting and heating in sustainable buildings?

   ii. Discuss some of the challenges that the users may face in the transition process of changing energy sources from fossil fuel to alternative energy sources.

iii. Explain some ethical issues associated with the generation and use of biofuel.

iv. Figure 11.10 shows a passive solar heating system, which absorbs and stores heat from the sun directly within the structure. How are such buildings energy efficient?

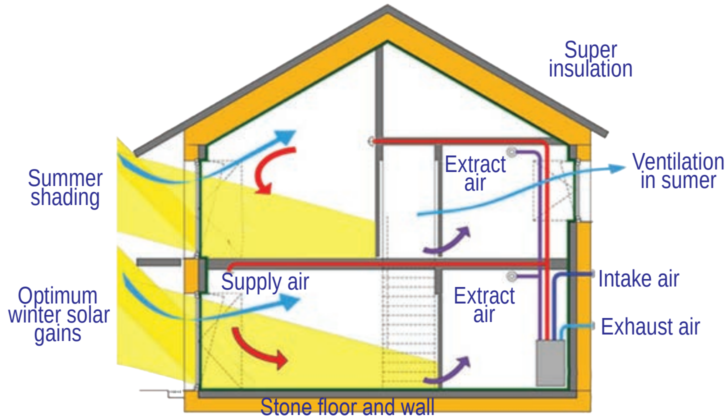


Figure 11.10.

v. Do you agree that modern technology is the best way for energy conservation? Justify.

vi. Look at Figure 11.11 and answer the following questions:

a) Name the type of green technology.

b) What is the energy source for this type of vehicle?

c) What could be some of the reasons for introducing such vehicles in Bhutan?

d) Identify some of the challenges on the use of such technologies in Bhutan.

e) If given a choice, what sort of vehicle would you buy, a gasoline car, gasoline-electric hybrid car or plug-in hybrid vehicle? Why?

Figure 11.11.

vii. If you are the principal of a school with the vision to transform your school into "Energy Efficient School", what strategies would you adopt to achieve your vision?

Reprint 2022

CHAPTER 12 ENVIRONMENTAL MANAGEMENT

In the past, while planning policies and implementing developmental activities, environmental factors were not taken into consideration. The developmental activities were based on the concept of economic efficiency. The new dimension of development emphasises on the co-relationship among environmental, social and economic development. This has led the governments around the world to integrate various environmental components into developmental policies, plans, programs and projects that ensure sound and sustainable use of ecological resources. Environmental Impact Assessment (EIA) is one of the measures implemented as a means to efficiently reduce environmental degradation and to attain sustainable development.

1. Green Economy

Learning Objectives

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

- explain green economy.
- discuss green economy practices in various sectors.
- assess consumption and production pattern depicting present and future scenario

Sustainable development has been the common goal of the global community since the Rio Conference on Environment and Development in 1992. Economic development continues to take place at the cost of our environment and poverty still remains an issue in many countries. In addition, the current economic behaviour is straining natural resources and waste assimilation capacities beyond the limits of renewability. This results in social inequity and environmental degradation. The concept of green economy has been adopted as an alternate pathway to achieve sustainable development which emphasises on cautious utilisation and appreciation of limited natural resources and their conservation.

A. Green economy

Green economy is an economy that brings about social equity, improves human well-being, and considerably reduces various risks on the environment, such as pollution, over-exploitation, and ecosystem disturbances.

The main aim of green economy is to enable economic growth as well as increasing environmental quality and promoting social inclusiveness. Improvement in the quality of the environment is achieved through sustainable use of natural resources, promoting renewable energy, preventing pollution, reducing the emission of greenhouse gases, preventing the loss of biodiversity and building natural capital. Social inclusiveness is attained by eradicating poverty, creating job opportunities, improving the health of people, and improving the living standard of people. In order to achieve economic development without compromising the quality of the environment, the developmental approach has shifted from conventional to a more sustainable and economical one.

The transition towards green economy begins with the reformation of developmental policies followed by implementation of a legal, economic and regulatory instrument to stimulate green investments. It requires specific enabling conditions to facilitate the success of public and private investment in

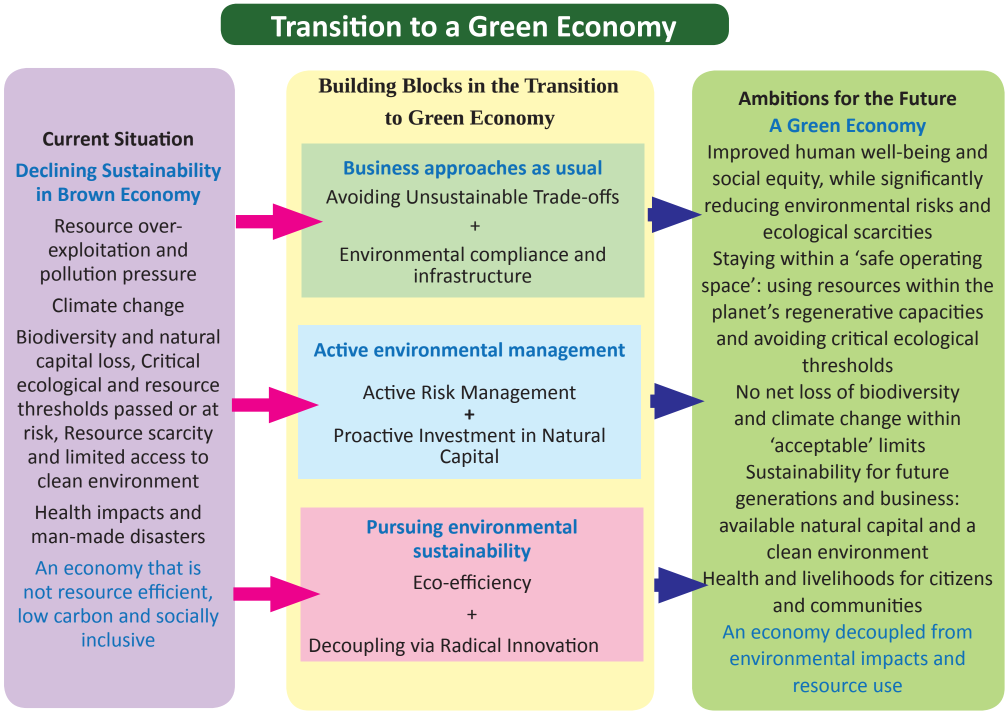


Figure 12.1. Schematic diagram of transition to green economy
(Adapted from Doreen and Patrick: What is green economy?).

green activities. The general enabling conditions include physical infrastructure in target sectors, environmental and social integration, public and private financing, sustainable trade, and innovative technology.

United Nation Environmental Program (UNEP) has identified possible sectors that could contribute to the development of green economy, which includes green buildings, sustainable agriculture and forest, water management, clean technologies, waste management, renewable energy and green transport.

(i) Green building

Buildings are responsible for a huge share of land use, energy and water consumption, utilisation of various materials, emission of carbon dioxide and waste production. Further, runoff wastewater from the buildings contaminates the river water, which has serious health implications. Unplanned construction of buildings displaces natural ecosystem. Therefore, new methods and technologies are constantly being developed to create structures that have minimum impact on the natural environment and social well-being. If the design, materials, construction, operation, maintenance, renovation, and demolition of the building are environmentally responsible and resource-efficient, it is considered a green building or sustainable building. Some of the characteristics of green building are as follows:

- Efficient use of energy, such as insulating walls, automatic shut-off switches for lights, use of light emitting diode (LED) bulb and installing proper heating, ventilation and air-conditioning systems (HVAC) to reduce the amount of energy used for heating and cooling a building.
- Efficient use of water, such as rain water harvest and wastewater treatment before releasing it into waterways.
- Use of renewable materials for construction that are environment-friendly.
- Reduce, recycle and reuse waste generated after construction or demolition.
- Protect occupant's health.
- Proper household waste management.
- Reduce pollution and environmental degradation.

(ii) Green transport

Figure 12.2. Traffic congestion

Transportation is essential for societal growth and development. However, with growing number of vehicles, cities across the world experience increasing problems with traffic congestion leading to reduced mobility, and rising CO_2 emissions. The main source of GHG emission is through the consumption of fossil fuels for transportation. More than one-half of global liquid fossil fuels extracted is utilised by transportation.

Transport-related pollution, such as nitrous oxides, particulates, noise, and vibration can cause serious threats to human health. These threats include increased risk of respiratory diseases, heart diseases, lung cancer, and low birth weight which can burden the health care system with substantial medical costs. Construction of transport infrastructure, such as roads, railways, airports, harbours is carried out at the cost of the ecosystem which causes disturbance to wildlife and loss of biodiversity.

The low carbon transportation strategy involves avoiding unnecessary transport demand, improving fuel consumption technology, and shift transport to lower carbon modes, such as cycling, walking, electric cars and public transport. Public transportation is considered a sustainable solution for cities to combat problems related to pollution and congestion. Making public transport more efficient, secure and convenient with high-quality services would attract more commuters to travel in public transport.

(iii) Green energy

Green energy is renewable energy which can be naturally replenished, such as solar, wind, hydro, tidal, biofuel, and geothermal energy.

Figure 12.3. Green Energy

A comparison of GHG emissions, based on life cycle approach, shows that all green energy technologies have lower life cycle emission than the conventional fossil-based technologies. The indicators of green energy are: high energy potential, high contribution to energy generation, low emission of greenhouse gases, low environmental impacts, sustainability of renewable energy and economic figures, such as low generation costs and low price levels.

(iv) Sustainable agriculture and forestry

Sustainable farming has the potential to transform agriculture as a GHG sink and reduce deforestation and freshwater use. Adopting resource-conserving practices, such as integrated pest management, integrated nutrient management, low-tillage farming, agro-forestry, aquaculture, water harvesting and livestock integration, increase yield and improve the livelihood of the people and contribute towards improving environmental services. Sustainable agricultural practices increase the number of attractive jobs in farming operations, supply chains, and market access infrastructures. Similarly, forests support the well-being of human and other animals by providing various environmental services. Sustainable use of forest resources, reducing deforestation and increasing reforestation can ensure healthy environment with secure resources for future generations and contribute towards poverty alleviation.

(v) Green economy in water management

Water is an essential component of a green economy. It is embedded in all aspects of development: food security, health, poverty reduction, sustaining economic growth in agriculture, industry, energy generation and maintaining a healthy ecosystem. Transitioning to a green economy in water requires Integrated Water Resources Management (IWRM) approach. IWRM is a process which involves coordinated development and management of water, land and related resources, in order to maximise equitable economic and social welfare without compromising the sustainability of ecosystems. The key tools to support the transition to green economy in water are financing of water infrastructure, dissemination of innovative technology, and improved water resources planning. Investments in water infrastructure can improve access to water services, storage, resilience to drought, wastewater treatment, water quantity and quality regulation and mitigate flood. However, infrastructure must take into account its impacts on biodiversity, energy and resource efficiency.

(vi) Green tourism

The growth of tourism is generallly accompanied by increased GHG emissions, increase water consumption, waste generation, damage to local terrestrial and aquatic biodiversity, and threats to the survival of local cultures and traditions. However, a regulated tourism create job opportunities and stimulate local business that can reduce poverty. Emphasis on ecotourism enhances the involvement of local community, thereby contributing to local economy and preservation of local culture and biodiversity.

In order to create green tourism, investment in energy efficiency, water, and waste management to reduce pollution and GHG emissions is essential. Green tourism can be achieved through private-sector orientation, destination planning, government investment policies, promoting ecotourism and local investment.

(vii) Waste management

A large amount of waste in the form of solid, liquid and gas is generated due to human activity. Inefficient management of waste can lead to economic, social, and health-related costs and liabilities. Encouraging the reduction of waste, reusing and recycling of waste could produce significant gain in decoupling waste production from economic growth. Waste materials are also valuable resources now since recycling and recovering energy from waste are profitable and also reduce pressure on the environment.

(viii) Green manufacturing

Manufacturing industries consume a large amount of resources and are responsible for the emission of a huge amount of carbon dioxide, generation of pollutants, non-degradable hazardous substances and waste. These waste and pollutants contaminate air, water and land posing great risks to organisms' health and natural environment. Greening the manufacturing sector reduces the pressure on natural resources, reduces the consumption of energy and reduces waste generations. Green manufacturing can be achieved by emphasising on redesigning the production systems and products, recycling used products and by-products and using biodegradable packing materials. It also involves treating effluents and smoke filtration before releasing it into natural environment.

Reprint 2022

Activity 12.1. *Creating green economy society*

Materials:

1. Work sheet (Sample provided below)

Table 12.1.

Green Sector: ______________________		
Green practices *(consider: design, construction, operation, maintenance, methods, policy, regulation, monitoring, materials, technology, etc.)*	**Benefits**	**Limitations**
1. Solar water heating (technology). 2. 3.	Reduce energy cost.	Expensive installation and its effectiveness differs from locations.

2. Resources (books/journals/internet etc.). Web resources available at:
   http://web.unep.org/greeneconomy/resources/green-economy-report
   https://sustainabledevelopment.un.org/topics/greeneconomy/guidebooks
   http://www.greeneconomycoalition.org/
   www.nec.gov.bt
3. Chart paper.

Instruction:

1. Work in groups.
2. Chose one sector of green economy in each group.
3. Explore and discuss on the chosen sector.
4. Write the outline of your discussion in the work sheet.
5. Present your findings to the class and justify your points.
6. Collect and put together the findings from all groups and create a Green Society.

Questions:

1. Identify the characteristics of a green society in your choosen sector.
2. Compare green practices of your chosen sector to green sector of other groups.
3. Suggest some ways to overcome the limitations of green practices of your chosen sector.
4. Why is green economy significant in today's context?
5. How can you incorporate green building concepts into your home or school?

B. Green Economy Initiatives (GEI)

Green Economy Initiative (GEI) is intended to support governments in transitioning to a green economy through policy support and investment in a range of sectors, such as clean technologies, renewable energies, water services, green transportation, waste management, green buildings and sustainable agriculture and forests.

a. United Nation Environmental Programme's (UNEP) Green Economy Initiative

UNEP's Green Economy Initiative (GEI), launched in 2008, aids governments in reshaping and refocusing policies, plans and investments towards a range of sectors, such as green transportation, clean technologies, efficient water management, renewable energies, waste management, green buildings and sustainable agriculture and forest use. The initiative also assesses how these sectors can contribute to economic growth, create decent jobs, bring social equity and reduce poverty while addressing climate risk and other ecological challenges. The green economy initiative includes the following components:

(i) Green Economy Report (GER)

GER provides information on the analysis of the economic, social, employment and environmental gains that result from investments in greening various sectors. The report also guides governments to formulate policies and create enabling conditions that can facilitate transition to a green economy.

(ii) Providing advisory services

UNEP's Green Economy Advisory Services provide technical assistance and capacity building services, shares international experiences and best practices to build analytical capabilities in planning that helps in transitioning to a greener economy.

(iii) Working in partnership

The UNEP works with various partners to develop research products, harmonise green economy policies, and identify financial and human resources for undertaking green economy activities at both regional and national level.

b. Green Economy Initiatives in Bhutan

Bhutan's economic development policy is guided by the philosophy of Gross National Happiness (GNH). GNH Commission ensures incorporation of the principles of GNH in the policies and implementation of plans and programs.

Reprint 2022

Unlike in many countries, where the environment has remained a low priority for public investment and policy development, Bhutan has placed environmental conservation at the core of its developmental strategy. All major development initiatives are evaluated thoroughly in terms of their environmental impact.

To facilitate green initiatives in the country, the government creates enabling conditions in terms of fiscal policy, reformation of environmental subsidies, greening public procurement, and improving environmental rules and regulations. Some of the major green economy initiatives taken by Bhutan across various sectors are:

(i) Green policies

Bhutan emphasises on the conservation of natural resources, biodiversity conservation, and prevention of environmental degradation while promoting justifiable socio-economic development. For instance, Waste Prevention and Management Act of Bhutan (2009)includes policies that aim to protect and sustain human health through effective reduction and management of all forms of waste. Biodiversity Act and Water Act of Bhutan also contributes to the protection of the environment and sustainable use of resources.

(ii) Green Public Procurement (GPP)

The project on GPP in Bhutan is a strategic approach to enhance public demand for environmentally and socially preferable goods, services and infrastructure. Through GPP, government authorities can choose to procure products that are durable, can be recycled or reused, and are biodegradable and less toxic. GPP promotes local entrepreneurship and provides an incentive for the sustainable production of goods and services.

(iii) Other initiatives

Other green initiatives include promoting sustainable hydro and wind generated electricity, high-end low-impact tourism, promotion of organic agricultural products promotion of environmentally friendly businesses and foreign direct investment. These initiatives are achieved through green incentives, such as rebates in taxes and customs duties, support for services in the areas of health, education, financial services and tourism.

c. Challenges in transition to green economy

The most prominent challenge especially for developing countries to initiate green growth is the financial constraints. The green project requires more investment than the conventional projects. Public institutions face difficulties in aligning and integrating work across the social, environmental, and economic dimensions of sustainable development. Further, small domestic market, narrow export product base and markets, inadequate infrastructure, high transportation cost, lack of management and technical skills and a shortage of professionals pose considerable hindrance in transitioning to a green economy. Consumption and production pattern are also a determining factor that facilitates that transition into green economy.

Sustainable consumption patterns are consumption practices that satisfy basic needs at present and future without impacting the quality of the environment. Consumption patterns are unsustainable if the resources consumed exceed the basic needs and cause environmental damage, or if consumption pattern does not meet basic needs. The consumer's activities and behaviour determine the type of goods and services they purchase. This in turn, influence production since the purpose of production is consumption. Sustainable consumption leads to sustainable production. The creation of goods and services using the processes and systems that are non-polluting, economically viable, safe, healthy and efficient is considered as sustainable production. Therefore, considering the environmental and social impacts, sustainable consumption plays a critical role in the transition towards a green economy.

Activity 12.2. *Examining global energy production and consumption*

Instruction:

In groups, study the graph given in Figure 12.4 and answer the questions that follow:

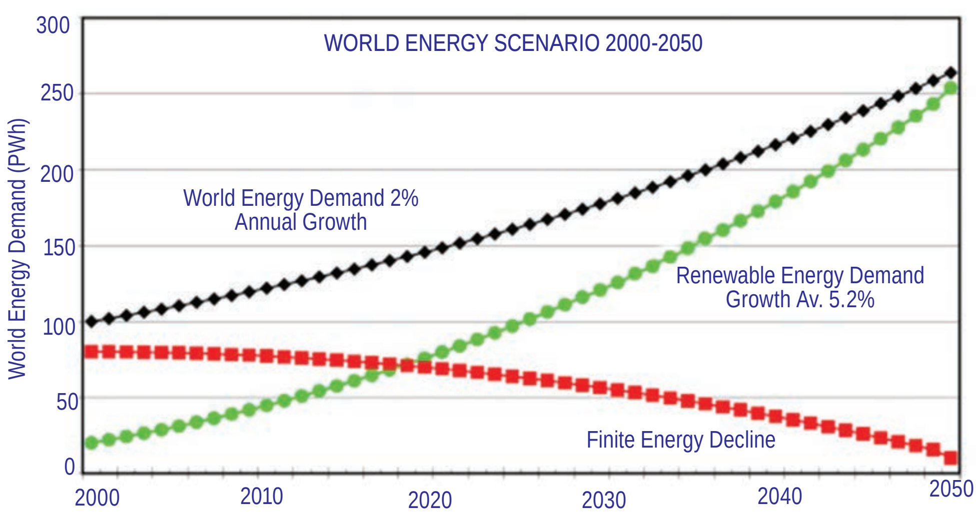


Figure 12.4.

Questions:

1. Compare the curves of renewable energy and non-renewable energy from 2000 to 2050. Explain the reasons for the changes.
2. What could be the possible reasons for the rise in energy demand and rise in demand for renewable energy?
3. Do you think the trend in the energy demand will occur as represented in the graph by 2050? Support your statement with justification.
4. If the number of fossil-fuel-run cars in Bhutan doubles by next ten years, how would energy demand change? Plot a graph to show the change.

Questions

1. How is green economy different from sustainable development?
2. What enabling conditions should our government create to facilitate greening in the following sectors?
   a) Transportation sector
   b) Agriculture
   c) Tourism
   d) Industries
3. What green initiative can we take up at an individual or household level to contribute towards a sustainable consumption of goods and services?

2. Relationship - Development and Environment

Learning Objectives

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

- explain environmental management systems in the context of sustainable development.
- identify tools for sustainable environmental management.

Developmental activities, such as infrastructure construction, industrial expansion, urbanisation, technological innovations and change in consumption pattern have increased pressure on natural resources. These activities pollute the environment, degrade biodiversity, increase deforestation, change land use pattern and generate waste. Therefore, it is widely recognised that environment has to be managed wisely and equitably.

A. Environmental Management Systems model

An Environmental Management System (EMS) is a systematic approach for managing an organisation's significant environmental impacts. Adopting an EMS can help an organisation to:

- manage and increase resource efficiency (e.g. cutting waste and energy use).
- comply with environmental laws and regulations.
- cut down the cost of production and improve financial savings through the well-managed use of resources.

An EMS is built on the Plan-Do-Check-Act (PDCA) model to ensure that environmental issues are systematically identified, controlled and monitored. The key cyclic elements of the EMS are:

1. ***Plan:*** what to do,
2. ***Do:*** carry out what is planned,
3. ***Check:*** ensure that it is carried out as planned, and
4. ***Act:*** review and make improvements.

Through this cycle, all EMSs set a framework through which the organisation can bring about continuous improvement in terms of environmental performance.

Reprint 2022

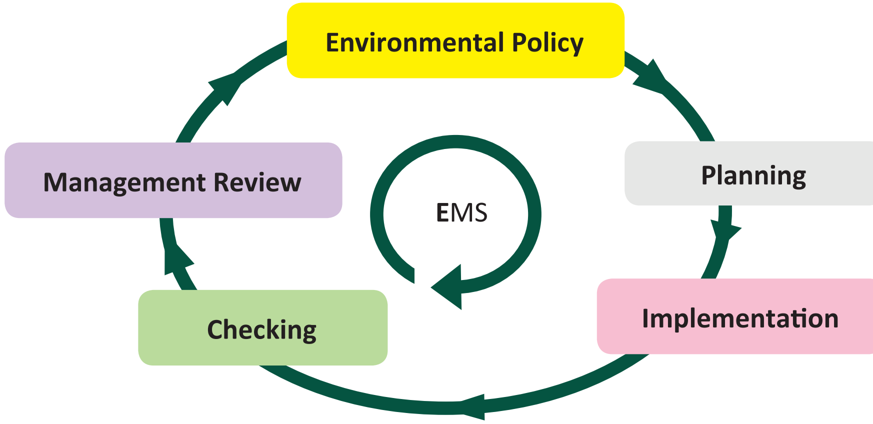


Figure 12.5. Key elements of EMS

There are five phases of EMS based on Plan-Do-Check-Act which is described below:

(i) Environmental policy

An EMS starts with establishing an environmental policy that is tied to the organisation's mission. The environmental policy commits the organisation's compliance with relevant environmental legislation, pollution prevention and continual improvement in environmental performance. The policy developed should be appropriate to the nature, scale and impacts of the organisation's activities, products, and services. The policy needs to be communicated to all employees and the public. An example of an environmental policy is shown in Box 12.1.

The hotel commits towards continually improving environment management by:

- efficient use of electricity, fuel and water.
- reduce use of non-biodegradable materials.
- creating awareness on environmental objectives amongst employees and guest.
- ensuring proper management of all kinds of waste.
- complying with environmental policies.

Box 12.1. Environmental Policy of a hotel industry

(ii) Planning

The planning step begins with the identification of process, resources, products, and associated impacts. The serious impacts are listed and serve as the focus of EMS to develop objectives and targets. For each objective, a management plan and programme is developed outlining the means and the time frame within which the target is to be achieved for improving environmental performance. An example of objective and target in a hotel industry is given in Box 12.2.

Box 12.2. Objective and target in hotel industry

Objective1: Reduction in LPG consumption.
Target: Substantially reduce LPG consumption in the next five years.

Objective 2: Reduction in electricity consumption.
Target: Reduce electricity consumption by using energy efficient devices.

(iii) Implementation and operation

The implementation step consists of defining the structure, responsibilities, and programs to achieve its environmental policy commitments. The awareness level and competencies among the employees are improved with implementing of appropriate training and awareness programme to tackle the environmental impacts. Promotion of proper communication within the organisation as well as with external agencies ensures successful implementation and operation of EMS. Development and implementation of emergency preparedness plan and response procedures enhance the effectiveness of EMS. An example for developing an environmental management program is given in Table 12.2.

Table 12.2. Implementation and operation

Objectives	Target	Target period	Responsibilities	Implementation Programme	Date line
Reduction in LPG consumption	10 % reduction in LPG consumption	August	Kitchen steward to implement the programme	1. Collection of baseline data about LPG consumption.	January
				2. Gather information about energy conservation techniques and work out feasibility plan.	Febru-ary
				3. Research on FLUX Gas-O-MaxTM technology.	March
				4. Obtaining quotation for FLUX Gas-O-MaxTM.	April to May
				5. Planning, including cost computation, installation schedule and issue purchase requisition for management approval.	June to July
				6. Installation of FLUX Gas-O-MaxTM.	August

(iv) Checking and correction

The checking and corrective action step includes monitoring and measuring problem related to environmental performance that progress and aid in identification, correction or prevention, ensuring that the system is effective and conforming to its requirements.

(v) Management review

Management review is a periodic basis of assessment to address the possible need for any changes in the policy, objectives and other elements of the EMS. The management review ensures an organisation's continual improvement of EMS, taking into account the results of checking and corrective actions undertaken.

Activity 12.3. *Studying of Environmental Management System*

Instruction:

1. Work in groups.
2. Visit an organisation in your locality to investigate the adoption and implementation of environmental management system.
3. You may focus on the following four objectives for your study:
   i. to determine the organisation's awareness of EMS.
   ii. to identify sustainable programmes that have been implemented in the organisation.
   iii. to explore the organisation's understanding of the benefits associated with the adoption and implementation of EMS.
   iv. to understand possible challenges associated with the adoption and implementation of EMS.
4. Discuss in groups and frame questions to gather information on the above objectives. You may use the following fields as a guide to frame questions:
   a. Decrease in resource consumption.
   b. Decrease in solid waste generation.
   c. Overall improvement in property management.
   d. Increase in staff meeting.
   e. Implementation of environmental policy.
   f. Challenges in implementing EMS.

Questions

1. Write a report of the environmental management system of the organisation under study following the five phases of EMS.
2. Share the report with the class and compare EMS of different organisations.

B. Environmental management tools

In order to address escalating environmental problems, most of the countries including Bhutan have initiated various types of environmental protection programmes. These programmes implement environmental protection policies, laws, regulations, standards and also lays provisions for the establishment of environment related governmental and non-governmental organisations. A number of environmental assessment tools are formulated to protect and manage the environment. These tools connect environmental science and policy to ensure that the activities of a project are managed in an environmentally sound manner, and to achieve sustainable development. Some of the best known environmental management and environmental performance improvement tools are:

(i) Environmental Impact Assessment (EIA)

EIA refers to a systematic process of identification, prediction, and evaluation of environmental, social and economic impacts of proposed developmental projects. EIA is carried out to find ways to reduce adverse impacts at an early stage and shape projects to suit local environment.

Figure 12.6 shows the general steps in EIA.

Step 1 Screening	▶ Categorise the projects. ▶ Determine whether an EIA is required for a project.
Step 2 Scoping	▶ Identify potentially significant environmental impacts. ▶ Identify alternative solutions that avoid, mitigate or compensate adverse impacts.
Step 3 Data Generation	▶ Provide detailed description of existing status of various environmental and social components in the study area.
Step 4 Impact Assessment	▶ Identify, evaluate and predict potential environmental impacts using data information. ▶ Determine the intensity and importance of all predicted impacts using variety of methodologies and models.
Step 5 Mitigation	▶ Design and recommend system and processes to avoid, reduce and minimise adverse impacts and to enhance beneficial outcomes.
Step 6 Management	▶ Translate the recommended mitigation and monitoring measures into specific actions.

12.6. Procedural steps followed in the implementation of EIA.

Reprint 2022

The main purpose of EIA is to:

- provide information for decision-makers on environmental consequences of the proposed project,
- promote environmentally sound and sustainable development through the application of mitigation measures to reduce environmental impact, and
- understand potential health and environmental impacts and achieve a balance between development, social well-being, and environmental concerns.

(ii) Strategic Environmental Assessment (SEA)

SEA is a systematic approach that involves reviewing of policies, plans and programmes to ensure that the environmental effects are considered at early stage of decision-making.

Unlike EIA, SEA covers a wider range of activities and a longer time span. SEA fosters and provides critical systematic considerations at the sectoral, regional and national levels to promote environmental sustainability, smart growth, and pollution prevention. SEA allows problems of environmental deterioration to be addressed during policy and planning process, rather than mitigating their symptoms or project level impacts.

EIA and SEA approval procedures vary from country to country and are based primarily on the prevailing environmental legislation and regulations. In Bhutan, every individual has to ensure that environmental concerns are incorporated when formulating, renewing, modifying or implementing any policy, plan, program or a project. Environmental Protection Act of Bhutan and other related regulations like Regulation on the Environmental Clearance of Projects establish procedures for the assessment of potential effects of projects on the environment and its measures to reduce potential adverse effects and promote environmental benefits. The environmental clearance is a prerequisite for commencing any activity.

Activity 12.4. *Assessing impact of a developmental activity*

Instruction:

1. Work in groups.
2. Visit any developmental activity sites like construction of farm road, house, an irrigation channel, river retention walls or industrial area.
3. Observe the chosen site and complete the checklist given in Table 12.3.

Table 12.3. Checklist for impact assessment

Potential impact areas	Construction phase (period where construction activities takes place)			Operation phase (period where construction is completed and facilities are being utilised)		
	Adverse effect	No effect	Beneficial effect	Adverse effect	No effect	Beneficial effect
A. Land transformation and construction						
1. Erosion						
2. Deposition (sedimentation, precipitation)						
3. Stability (landslides)						
4. Floods						
5. Waste control						
B. Land Use						
1. Open space						
2. Recreational						
3. Agricultural						
4. Residential						
5. Commercial						
6. Industry						
C. Water resources						
1. Odour						
2. Particulate matter						
3. Chemicals						
D. Public Service Systems						
1. Schools						
2. Police station						
3. Fire protection						
4. Water and power						
5. Sewerage						
6. Solid waste disposal						
E. Biological conditions						
1. Wildlife						
2. Trees and shrubs						
3. Grasses						
F. Transportation						
1. Automobile						
2. Safety						
3. Movement						
G. Aesthetics						
1. Scenery						
2. Structures						

Reprint 2022

H. Community structure						
1. Relocation						
2. Recreation						
3. Employment						
4. Housing						

Questions

1. Which step of EIA is being focussed in the above finding? Give reasons to support your answer.
2. Which step of EIA is not followed in the above study? Give reasons.
3. Suggest recommendations to make the developmental activity environment -friendly and sustainable. You may use the following areas to give recommendations:
   a. Physical environment.
   b. Biological environment.
   c. Socio-economic conditions.
   d. Land use patterns.

(iii) Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a tool for identifying and evaluating the potential environmental impacts associated with a product taking into account the complete life cycle. The LCA method considers the energy used and the waste (solid, liquid and gas) generated during extraction of raw material, production, transportation, disposal of the used product and health and environmental impacts associated with the product.

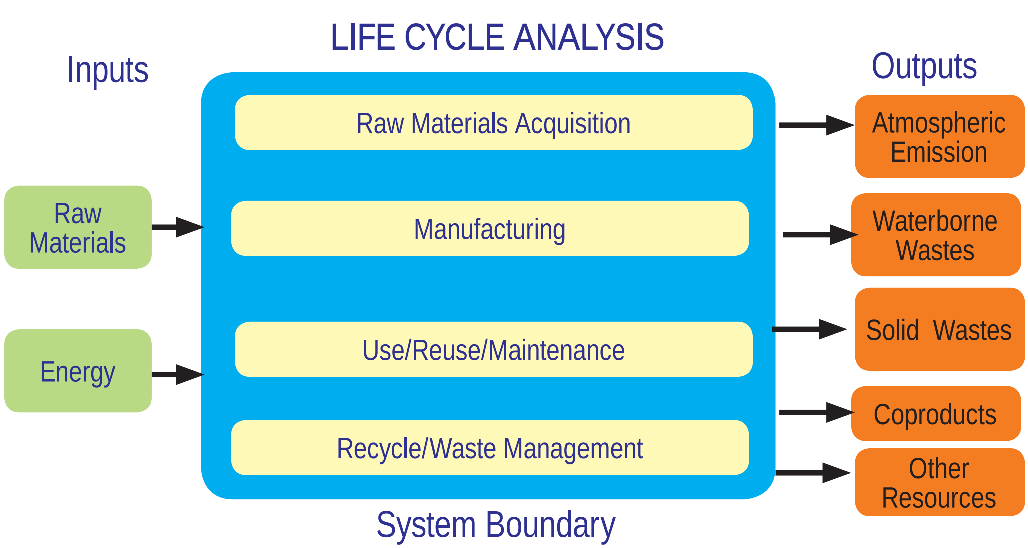


Figure 12.7. Life Cycle Assessment pattern

LCA is concerned with reducing environmental impacts at all the stages and considers the total picture rather than just one stage of the production process.

For example, jeans are made of cotton dyed with indigo that has notable contributions related to climate change impact, water use and non-renewable energy consumption. The entire life cycle of a pair of jean equates to:

The entire life cycle of one pair of jean equates to:

Climate Change:
33.4 kg CO_2 -e...

Water Consumed:
3,781 litres...

Eutrophication:
48.9 g PO_4 -e...

Land Occupation:
12 m^2/year...

- 69 miles driven by the average US car
- 246 hours of TV on a plasma big-screen

- 3 days worth of one US household's total water needs

- The total amount of phosphorous found in 1,7000 tomatoes

- Seven people standing with arms outstretched, fingertips touching, would form one side of a square this size

Figure 12.8. Life cycle assessment of jeans (levistrauss.com)

Life-cycle assessments of a pair of jeans provide data from every stage of a product's life, from raw material extraction through cultivation, manufacturing, distribution, use, repair and maintenance, and disposal or recycling. These data can be considered one of the first ways to reduce environmental impacts.

(iv) Environmental Audit

An environmental audit is a tool that is used to check whether an organisation is doing what it should be doing. The key objectives of an environmental audit include verifying compliance with the environmental laws and regulations, evaluating the effectiveness of environmental management systems, providing a database for corrective actions and developing an organisation's environmental strategy. An environmental audit is an essential component of EMS. Through environmental auditing, EMS can ascertain the instances of non-compliance with environmental legislations and correct the organisation.

(v) International Organisation for Standardisation (ISO) Certification

ISO is the International Organisation for Standardisation that has published more than 18000 standards. These standards provide practical tools for all three dimensions of sustainable development: economic, environmental and societal. The ISO standards represent an international consensus on the state of the technology or good practice concerned.

The ISO certification helps in reducing environmental pollutions and conserving natural resources, for achieving global goal of sustainable development. The ISO 14000 family of standards is primarily concerned with the environmental management. For example, the ISO 14064 is greenhouse gas accounting and verification standard that provides a set of clear and verifiable requirements to support organisation's greenhouse gas emission reduction. To obtain a certificate of ISO 14001, an organisation has to minimise harmful effects on the environment caused by its activities and achieve continual improvement of its environmental performance. The use of ISO 14000 families provides significant benefits such as:

- reduce raw materials or resource use.
- reduce energy consumption.
- improve process efficiency.
- reduce waste generation and disposal costs.
- utilise recoverable resources.

Questions

1. Why is it important for an organisation to have EMS? Design EMS for your house.
2. Why is environmental audit carried out?
3. The school has implemented rules to safeguard environment by reducing the paper use encouraging re-use, double-sided copies, print drafts on used paper, reduce the number of copies, making signs and posters, etc. Develop an environmental audit tool to verify the compliance of the rules.

Exercise

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

   i. The purpose of screening step in Environmental Impact Assessment (EIA) is to

      A. assess the quality of the project design.

      B. determine the requirement of EIA.

      C. develop terms of reference for the environment.

      D. mitigate the adverse impacts on the environment.

   ii. Which of the following are the characteristics of a green economy?

      I. efficient resource usage.
      II. Achieving high economic growth.
      III. Technologies replacing human labour.
      IV. Reducing carbon emission.

      A. I, II and III

      B. I, III and IV

      C. II,III and IV

      D. III, IV and I

   iii. A factory, in order to manage and increase it resource efficiency and to minimise its environmental impact, it first must

      A. set environmental objectives and targets.

      B. assign environmental responsibilities.

      C. establish environmental policy.

      D. review environmental impacts.

   iv. Walking, cycling, use of public transport and electric cars are some examples of

      A. sustainable agriculture.

      B. green building.

      C. green transport.

      D. green tourism.

Reprint 2022

v. Life cycle assessment is

A. evaluation of the difference in the amount of environmental impacts caused by individuals from different parts of the world.

B. evaluation of all the environmental impacts of a product from the time the raw materials are gathered to their ultimate disposal.

C. the amount of environmental degradation that the average person creates within their lifetime, expressed in monetary terms.

D. the area of biosphere required to sustain an individual, company/ organisation or country.

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

i. The environmental clearance application for any project in our country is accessed from_____.

ii. International Organisation for Standardisation (ISO) ______ families of standards are concerned with the environmental management.

iii. UNEP's green economy initiatives include _________________ which is an analysis of the economic, social and environmental gains from investing in greening various sectors.

iv. Tool for verifying compliance with the environmental laws and regulations and evaluating the effectiveness of EMS is ___________.

v. Transitioning to a green economy in water requires ___________ approach.

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

i. Impact assessment is done for the planned project and the identified alternatives.

ii. UNEP's green economy initiatives provide financial support to all nations in transitioning to green economy.

iii. Economy and environment dimensions are the core components of the green economy concept while the social dimension is not given much consideration.

iv. The term "green economy" is also referred to as sustainable development.

v. Strategic Environmental Assessment (SEA) is carried out in short time span for a particular project.

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

i. What are the roles of the general public in EIA procedures?

ii. Explain the term Life Cycle Assessment?

iii. What is the importance of mandating firms to obtain environmental clearance for any developmental project?

iv. Explain the roles of GPP in Bhutan's endeavour to achieve a green economy.

v. "One of the key objectives of green economy is to alleviate poverty." How can this objective be achieved if your localities adopt green economy?

vi. "Green washing" is a term used to describe a claim made by companies stating their product and practices to be "green" even though their products and services may not be necessarily be environmentally friendly. This is generally done through advertisement and marketing in order to create an image and attract business. Should the regulatory authority ignore, restrict or encourage such practices? Comment.

vii. Observe the life cycle assessment illustration of plastic bottle shown in Figure 12.9 and answer the questions.

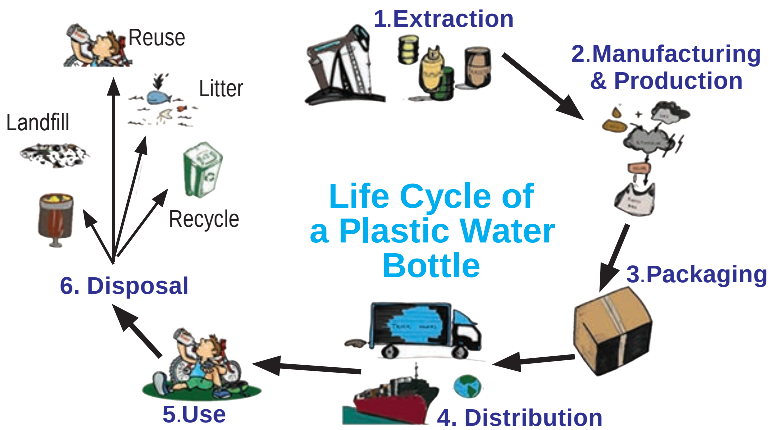


Figure 12.9. Life cycle of a plastic bottle

a) Write a life cycle assessment report on plastic bottles.

b) Explain two social and environmental impacts of plastic bottles.

c) Suggest suitable measures to mitigate the impacts.

d) Recycling plastic bottles have enormous environmental and economic benefit over production of new plastic bottles. Support the statement.

13 CHAPTER SUSTAINABLE DEVELOPMENT

The world is facing challenges in all the three dimensions of sustainable development, economic, social and environmental. Unsustainable consumption and production patterns have resulted in huge economic and social costs that endanger life on the planet. Achieving sustainable development requires global actions on delivering legitimate strategies for economic and social progress, and at the same time strengthen environmental protection.

Bhutan's economic development policy continues to be guided by the overarching philosophy of Gross National Happiness (GNH). The philosophy of GNH has several dimensions correlating to global sustainable development goals, with a focus on creating harmonious and happy society.

Reprint 2022

1. Sustainable Development Goals and Indicators

Learning Objectives

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

- identify sustainable development goals.
- discuss sustainable development goals and their challenges.
- formulate indicators to measure sustainable development.

Before the SDGs, the global development was guided by Millennium Development Goals (MDGs). Although MDGs has provided an important framework for development and significant progress has been made in some areas, the progress has been uneven in many countries. Some of the MDGs remain off-track, in particular, those related to maternal, newborn and child health, and reproductive health. To ensure the optimum realisation of the MDGs and to reach the most vulnerable, sustainable development goals have been developed towards providing focused and scaled-up assistance to least developed countries and other countries in special situations.

A. The sustainable development goals

Sustainable Development Goals (SDGs) are also called Global Goals. These goals were adopted by countries on September 25, 2015, to end poverty, protect the planet and ensure prosperity for all. Each goal has specific targets to be achieved over the next 15 years. It is proclaimed that these goals work in the spirit of partnership and pragmatism to make the right choices to improve the lives of present and future generations in a sustainable way. A country adopts the goals based on its developmental priorities and the environmental challenges that the world face at large.

Activity 13.1. *Analysing SDGs*

Instruction:

1. In groups, analyse each SDG as in Figure 13.1 based on the following aspects:
   a) *Global Scope and Challenges*
   b) *Relevancy for Bhutan*
   c) *Limitations for Bhutan*
2. Present and discuss your findings to the class.

Reprint 2022

Figure 13.1. Sustainable Development Goals

Questions:

1. Justify the scope of SDGs for global peace and prosperity.
2. List the SDGs that you think Bhutan should prioritise for the conservation of biodiversity. Justify your choices.

B. Targets and indicators of sustainable development goals

a. Targets

A target is the explicit statement of desired results to be achieved over a specified period. It guides and keeps track of the activities and the status of goal

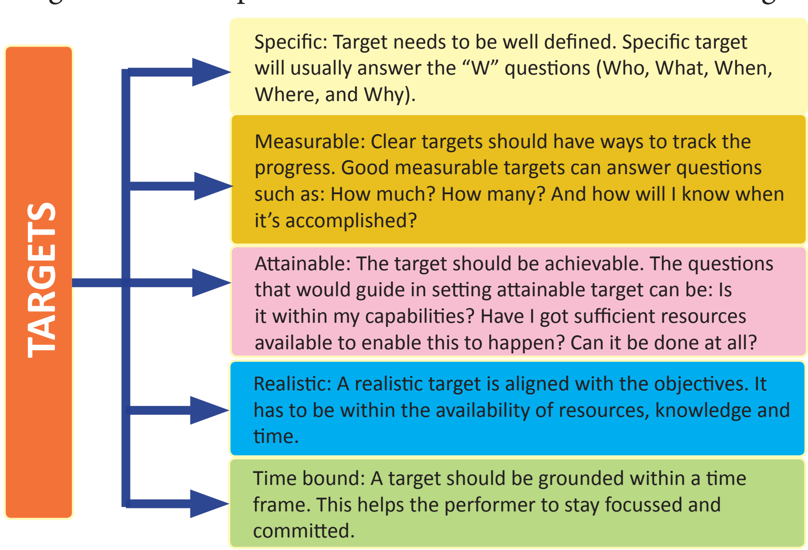


Figure 13.2. Description of SMART

achievement. It should be 'SMART', i.e., specific, measurable, attainable, relevant, and time-bound as described in Figure 13.2.

Other criteria for setting the targets may include the following:

- consistent with the SDG target,
- universal but adaptable to local context, and
- clear on their definition of zero deprivation.

For the development to be driven in the right direction, the targets are prioritised to achieve the goals successfully. Prioritising the targets helps a nation or an organisation to achieve the goals within the specified length of time with the right use of resources.

Table 13.1 shows the target and indicators for the fifteenth SDG – Life on land. The target is well defined, specific and operational.

Table 13.1. Target and indicators of SDG – Life on land

Goal	Targets	Indicators
Life on land	By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development.	Coverage by protected areas of important sites for mountain biodiversity. Mountain Green Cover Index.

b. Indicators

Achievement of goals substantially relies on the fulfillment of targets. The achievement of the target is measured by the indicators. An indicator is a management tool as well as a report card to help countries develop and measure the implementation and progress in achieving the targets. It monitors and ensures the accountability of government and other stakeholders in achieving the targets. An indicator should be universally accepted, explicit and unambiguous. Too many indicators would be difficult to achieve. Therefore, a required number of good indicators should be identified in measuring the achievement of target. The characteristics of the robust indicator are shown in Figure 13.3.

Reprint 2022

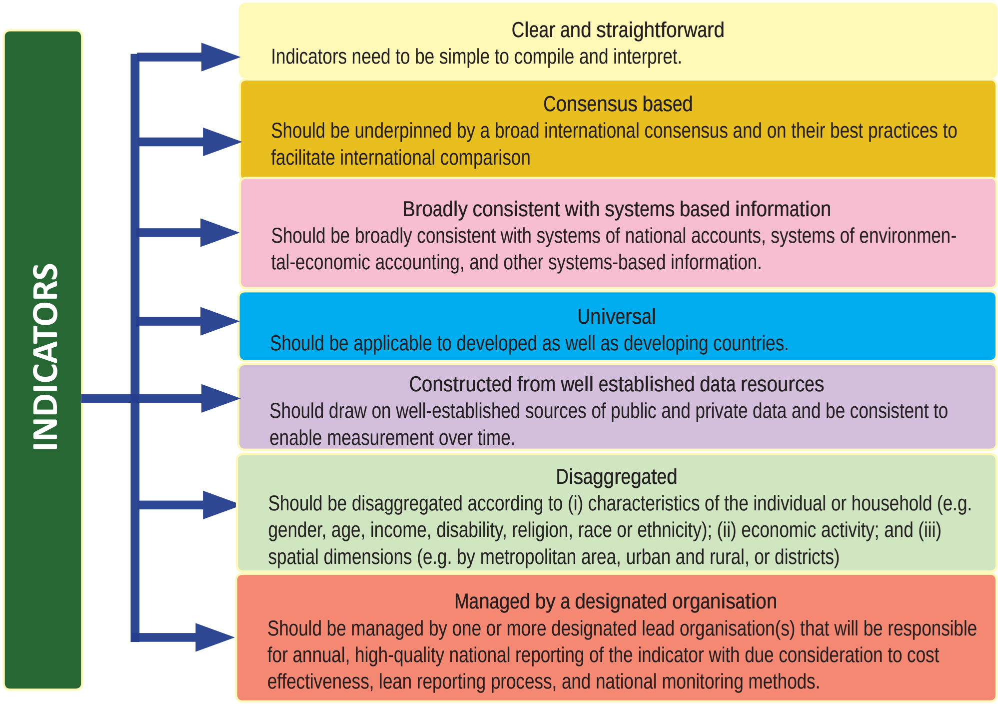


Figure 13.3. Characteristics of good indicator

Activity 13.2. *Formulating sustainable goals, targets and indicators*

Instruction:

1. In groups, refer the documents on vision and mission of Ministry of education or your school.
2. Design sustainable goals to fulfil vision and mission.
3. Formulate SMART targets to achieve these goals within five years.
4. Formulate indicators to achieve the targets.
5. Present your goals, targets and indicators to the members of other group.
6. Discuss and prioritise the goals and targets, and tabulate them as a common goal for the Ministry of Education or your school.

Questions:

1. What activities should be in place to achieve each of the targets?
2. What will be some of the possible challenges in achieving the goals? Propose possible solutions to overcome challenges.

B. Bhutan's five year plan and SDGs

Bhutan's five-year plan continues to be guided by holistic and inclusive development philosophy of GNH. Bhutan's long-held conviction to GNH accords well with the holistic and integrated approach that underpins the SDGs.

Bhutan's Five Year Plans are a series of national economic development plans implemented since 1961. The plans set out an ambitious development agenda to achieve the goals and target. Similarly, Bhutan has also adopted the Sustainable Development Goals, which will be achieved by 2030 through the Five-Year Plans.

Activity 13.3. ***Identifying SDGs in Bhutan's Five Year Plan***

Instruction:

1. In groups, read the current five-year plan document of Bhutan and identify core areas of development and list them under the column 'Central areas of development' in Table 13.2. (You can access the five-year plan document from the website http://www.gnhc.gov.bt)
2. Identify the corresponding SDGs and list them in the column 'SDGs' in the table.

Table 13.2.

Central areas of development	SDGs
Eg. Education	*SDG4: Quality Education*

Questions:

1. Which SDGs are prioritised in the current five-year plan?
2. How much of these SDGs will be achieved by the end of the current five-year plan? Justify.
3. Suggest SDGs that could be prioritised for the next five-year plan? Give reasons.

Questions

1. "How do we achieve a measure of self-reliance that will make our growth sustainable? How do we overcome our dependence on import, for example?"- His Majesty the King's address to the nation during the National Day on December 17, 2011. Which SDG is envisioned in the Royal Address above? Frame targets and indicators to achieve this SDG?
2. How can we put science, technology and innovation in the service of the poor and hungry?

2. Future Policies and Alternatives

Learning Objectives

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

- identify challenges for Bhutan in achieving SDGs.
- analyse policies, agreements and laws on SDGs.
- design alternative model of development.

Countries implement SDGs according to their priority and challenges. They align the SDGs with their national development plans. For example, Bhutan aligns its Five Year Plans for development with the philosophy of GNH and the SDGs. Thus, targets of prioritised SDGs are fully or partially achieved in every five-year term.

A. Challenges on SDGs

The United Nations Development Group (UNDG), comprised of over 30 UN agencies, helps countries to implement the SDGs through a common approach called 'MAPS', which stands for Mainstreaming, Acceleration and Policy Support.

Mainstreaming refers to landing the 2030 agenda for sustainable development at the national and local levels, and integrating into national, sub-national, and local plans for development; and subsequently, into budget allocations.

Acceleration refers to targeting national and UN resources at priority areas identified in the mainstreaming process, paying special attention to synergies and trade-offs across sectors, bottlenecks, financing and partnerships, and measurement.

Policy Support is about making sure that the skills and expertise held in the UN development system are made available on time and at the lowest cost possible.

Despite several approaches in place, challenges persist and hinder acceleration of sustainable development in various regions of the world. For example, some challenges faced by South Asian countries are:

- No coherence between pillars of sustainable development and policies, and dynamics of social, economic and environmental pillars.
- Imbalance between economic growth and environmental protection.
- Weak mainstreaming of SDGs in the developmental framework at the

institutional level within the country.

- Inability to foster involvement of local and regional governance along with stakeholder's participation in the development of strategies and plans.
- Challenges in integrating concepts of SDGs to local services at national, regional and sub-regional levels, and maintaining regional and subregional cooperation.
- Difficulty in strategy formulation and capacity development at a regional and sub-regional level for a green economy; inter-cooperation for developing integrated mechanisms to integrate trans-boundary environmental, social, and trade issues; looking beyond political conflicts; and establishing decentralised frameworks to integrate development planning at all levels.

Some of the challenges for Bhutan in achieving SDGs include its dependency on foreign aid to achieve development targets, high inflation due to the import of food products and fuel, and low level of agricultural productivity. Limited access to markets, road infrastructure and the impact of rural-urban migration also attribute to challenges in achieving SDGs. Further, it should be understood that disasters can put development at risk, making it unsustainable. Hence, effective disaster risk reduction contributes to sustainable development. The current scenario of youth unemployment issues, gender inequality in literacy, and a low percentage of women in decision-making positions are also possible factors that may delay the achievements of SDGs.

B. Policies, agreements and laws on SDGs

Sustainable development goals are guided by the purpose and principles of the charter of the United Nations, respecting all the international laws. It is grounded on the Universal Declaration of Human Rights; international human rights treaties; Millennium Declaration; and the 2005 World Summit Outcome. It is also informed by other instruments such as the Declaration on Right to Development.

Implementation of SDGs globally would rely on countries, taking into account different national realities, capacities and levels of development and respecting national policies and priorities.

Reprint 2022

Activity 13.4. *Analysis of Bhutan's Economic Development policy*

Instruction:

Study the extract in Box 13.1 and answer the questions that follow:

Box 13.1. Economic Development Policy of the Kingdom of Bhutan, 2010

"Economic Development Policy of the Kingdom of Bhutan, 2010"

Vision

To promote a green and self reliant economy sustained by an IT enabled knowledge society guided by the philosophy of GNH.

Purpose

The Economic Development Policy shall be the apex policy for economic development of the country and shall be the guiding document for all ministries and agencies to stimulate the economy growth and more importantly, to ensure that growth takes place in consonance with the principles of GNH. This Policy provides the basis for government intervention to enhance productivity of the economy as a whole. Wherever necessary, policies, laws, rules and regulations shall be harmonised or amended in line with the provisions of the Economic Development Policy.

The time line to achieve the goals of this Policy shall be 2020 and will be subject to periodic review.

Objectives

- Achieve economic self-reliance by the year 2020.
- Full employment (97.5%).

Strategies:

3. Diversify the economic base with minimal ecological footprint.
4. Harness and add value to natural resources in a sustainable manner.
5. Increase and diversify exports.
6. Promote Bhutan as an organic brand.
7. Promote industries that build the Brand Bhutan image.
8. Reduce dependency on fossil fuel especially in respect to transportation.

The economic development process shall take into account environment mainstreaming in a phased manner that allows for industries to grow as well as engage in cleaner production. The Royal Government shall also provide incentives for the promotion of green technology, micro-hydro projects, solar, wind, biomass and energy efficiency and conservation programmes. The success of the country's environment conservation efforts shall be one of the main drivers for developing the "Brand Bhutan" theme. Protection of biodiversity, genetic resources and promotion of indigenous knowledge shall be pursued.

Economic Opportunities

A broad range of economic opportunities have been identified and these will be based on developing the "Brand Bhutan" in natural resources, tourism, culture, handicrafts, textiles and agro produce. The other opportunities lie in building on the existing comparative advantages of location, natural resource endowment and availability of clean energy. The promotion of "Brand Bhutan" will be based on its unique selling point (USP).

(Source: http://www.gnhc.gov.bt/en/wp-content/uploads/2017/05/EDP.pdf)

Questions:

1. How do Bhutan's economic developmental policies favour environmental conservation?
2. Identify the developmental goal of Bhutan from the text.
3. Elaborate how Bhutan's economic development objectives are aligned with the SDGs.
4. Explain the economic opportunities offered by the policy.

I. Future model of development

Bhutan is recognised as one of the fast growing countries in south Asia in terms of economy. Current development strategies are guided by holistic approach of GNH and implemented through the five-year plans. However, Bhutan needs to push its developmental activities and become more sustainable by minimising its dependence on foreign aid. To achieve this, the country's GDP should increase substantially. Therefore, development activities should be driven towards surpassing imports by exports.

Activity 13.5. ***Designing future development plan of your gewog***

Instruction:

1. In groups, carry out a survey of any gewog nearby your school.
2. Identify and list all the resources and services that exist in the gewog.
3. Based on your survey report, identify the developmental priorities for the gewog.
4. Design a sustainable development framework for the gewog based on your findings.
5. Share your plan with other groups in the class.

Questions

1. What is the use of identifying the potential resources and services for planning?
2. What is the significance of designing developmental framework at the grassroot level?
3. List the criteria that you have used to frame the developmental framework for the gewog.
4. Why should you align the gewog developmental framework with the SDGs?

Exercise

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

   i. All of the following is the part of sustainable development goals EXCEPT

   A. Access to sustainable energy for all.

   B. Availability of water and sanitation for all.

   C. Provision of internet services for all.

   D. Promotion of decent job for all.

   ii. Which of the following are the relevant indicators for the achievement of the target, "End extreme poverty, including absolute income poverty ($ 1.25 or less per day)"?

   I. Percentage of population below $ 1.25 per day.

   II. Percentage of population in extreme multi-dimensional poverty.

   III. Percentage of population living below national poverty line.

   IV. Percentage of gender equality ratio.

   A. I, II and III

   B. I, II and IV

   C. I, III and IV

   D. II, III and IV

   iii. Which of the following suits the social dimension of SDG?

   A. Stewardship of resources managing and conserving the environment.

   B. Sharing benefits fairly and equitably and respecting the quality of life of communities and human rights.

   C. The concept of the enterprise supporting jobs and delivering income to communities in the long term.

   D. The concept of the enterprise supporting jobs and delivering income to communities in the short term.

(The statement below is to be used with question iv)

"The sustainable development goals can be adopted by the countries of the world by making it relevant to its situational needs and adaptation."

iv. Which one of the following components of the target prioritisation is addressed by the above statement?

A. Supports multiple dimensions of sustainable development.

B. Reflects existing commitments.

C. Results-oriented.

D. Transformational.

v. Which of the following are the reasons behind the adoption of SDGs?

I. Creating equal distribution of wealth around the world.

II. To end poverty and hunger in all forms and dimensions.

III. Extracting resources to boost the economic development.

IV. Protect the mother earth through sustainable consumption and production.

A. I, II and IV

B. I, II and III

C. I, III and IV

D. II, III and IV

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. Global developmental goals	a. Millennium Development Goals.
2. Dimensions of the development	b. Common implementation strategy of SDGs.
3. SDG goal 15	c. Sustainable Development Goals.
4. MAPs	d. Social, economic and environmental.
5. GNH	e. Life on land.
	f. Developmental philosophy.

Reprint 2022

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

   i. Each Sustainable Development Goal is supported by a set of objectives that are generally termed as__________.

   ii. A community having a series of health problems for the last decade needs immediate support. To mitigate this health issue, the relevant SDG is ________.

   iii. SDGs are developed to ensure optimum realisation of __________.

   iv. Under the Royal patronage of His Majesty the King, rural rehabilitation program has helped many homeless and farmless citizen of the country, which contributes to the achievement of __________________ pillar of GNH.

   v. The process of targeting national and UN resources at priority areas identified in the mainstreaming process to enable the achievement of SDGs is______________________.

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

   i. The achievement of the target is measured by the goals.

   ii. Disparities in income and social outcomes are of growing concern in Bhutan.

   iii. Lack of adequate preparation for the inevitable trend of rapid urbanisation leads to new social, economic and infrastructure challenge.

   iv. Private sectors play a minimum role in socio-economic development of the country.

   v. Balancing development and environmental conservation leads to the creation of happy society.

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

   i. How are the following components of MAPS being carried out by Rural Economy Advancement Program (REAP) in Bhutan?

      a) Mainstreaming

      b) Acceleration

      c) Policy Support

   ii. Why do you think SDGs would help Bhutan to solve the economic disparity?

iii. The excerpt, "Based on the Non-Wood Forests Products (NWFP) inventory, 284 acres of community forest has been handed over to the community," is geared towards achieving SDG 12 – Responsible Consumption and Production. Justify.

iv. Make a diagrammatic representation of how SDGs can contribute to environmental conservation.

v. The data on the status of MDGs in Bhutan is given in the Table 13.3. In reference to the information in the table, answer the following questions:

Table 13.3.

Indicators	1990	2000	2012
% of population below the national poverty line	-	36.30%	12%
Net primary enrollment ratio	-	62%	96%
Ratio of girls and boys in primary education	69%	82%	99%
Proportion of population without sustainable access to an improved water source	55%	22%	10%
Proportion of population without access to improved sanitation	33%	12%	17.5%

a) Identify the indicator in which Bhutan made the maximum achievement by 2012.

b) In which indicator, Bhutan did not perform well in 2012? Give possible reasons.

c) What is your reaction on the achievement of the indicator "Proportion of population without access to improved sanitation–2012"?

d) What conclusion can you draw from the data in the table?

Reprint 2022

SAMPLE QUESTION

Environmental Science

Class: XII **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. When a habitat is fragmented, the edge effect

A. cannot be predicted.

B. decreases.

C. increases.

D. remains constant.

ii. A farmer stops cultivating a large area of farmland and abandons it. The natural changes taking place soon afterwards, such as the growth of wild grasses and weeds are considered as secondary succession because

A. a new ecosystem develops.

B. an identical ecosystem develops.

C. the land is not controlled by humans.

D. wild grasses and weeds make soil from rocks.

iii. Identify the statement that describes a rural area.

A. Poor communication facilities

B. More job opportunities

C. Better healthcare facilities

D. More recreational activities

iv. Maximum percentage of freshwater on the Earth is in the form of

A. snow.

B. glaciers and ice caps.

C. groundwater.

D. streams and rivers.

v. Read the statements P and Q given below and choose the correct answer:

(P) increase chances of heart disease is due to air pollutant PM 2.5
(Q) PM 2.5 can enter into lungs and blood.

A. P is correct, but Q is wrong.

B. P is wrong, but Q is correct.

C. Both are correct, Q explains P.

D. Both are wrong.

vi. If you are gathering the evidence in phenology study through 'observation studies' method, which one of the following activity will you be engaging in most?

A. Analysing the data already maintained by different organisations.

B. Carrying out experimental studies looking for the effect of variables.

C. Referring to the earlier researched articles and journals.

D. Visiting regularly the selected species and recording data.

vii. Mock drills conducted in schools

A. eliminate the need for centralised disaster management.

B. increase the likelihood of survival.

C. prepare people to participate in a mock drill at the national level.

D. strengthen disaster mitigation strategies.

viii. Why is genetic diversity within a population important?

I. It contributes to evolution of species..

II. It brings an immediate change in the food chain.

III. It contributes to species richness.

IV. It increases the survival rate of the individuals.

A. I and II

B. II and IV

C. I and III

D. I and IV

ix. Karma uses a perforated earthen pot and buries it to the neck in the soil to irrigate the field. This method of conservation of water in agriculture is known as

A. drip irrigation.

B. pitcher irrigation.

C. sprinkler irrigation.

D. surface irrigation.

x. Higher efficiency in the combustion of fuel can be achieved by

A. supplying excess of air.

B. keeping the flue gas exhaust temperature very high.

C. removing flue gas immediately.

D. supplying pure oxygen.

xi. A cement manufacturing industry has developed an Environmental Management System (EMS). The key aspect of this EMS would include the

A. consideration of the costs involved in developing an environmental policy.

B. development of an overall environmental policy.

C. focus on an increased investment by shareholders in environmental policy.

D. limited audit of some areas of the manufacturing plant's safety procedures.

xii. Social, economic and ecological equity are necessary conditions for achieving

A. ecological development.

B. economic development.

C. social development.

D. sustainable development.

xiii. The most valuable information required during a disaster is

A. addresses of all hospitals and BHUs throughout the country.

B. first aid manuals, maps and emergency operation manuals.

C. location of safe areas.

D. phone numbers of local, national and international emergency units.

xiv. On testing the water quality of a river, it was found that there was a presence of a large number of *E.coli* bacterium in the river. The high level of *E. coli* indicates

A. contamination of water by human excreta.

B. contamination of water by insect vectors.

C. high salt level, making it unfit for drinking.

D. presence of a chloride residue.

xv. Which one of the following is the best biodiversity management practice?

A. Regulating the number of species.

B. Increasing the size of arable land.

C. Reducing the emission of greenhouse gases.

D. Installing electric fencing.

2. Fill in the blanks. **[½ x 10=5 marks]**

i. One way to address human-wildlife conflict is by moving the local communities to areas with better resources and opportunities by ________________.

ii. Removal of ________________ species decreases the overall species diversity in a community.

iii. The time frame in ecological time scale is ____________ than that of geological time scale.

iv. The ability of a biologically productive area to generate an ongoing supply of renewable resources and to absorb its wastes is known as ________________.

v. Punatshangchhu project provides financial support for plantation programme in barren areas to increase carbon dioxide absorption. This is an example of carbon ________________.

vi. If the community can resist, adapt and quickly recover from the effects of hazards, then the community is said to be __________________.

vii. GMOs have the potential to become highly ______________ because of its superior traits.

viii. High electrical conductivity in soil indicates salinity. Hence, soil with high electrical conductivity reduces the growth of crop and ____________ activity.

ix. Pema usually rides a bicycle to office in order to contribute to the ________________ economy.

x. Importing packaged food, live plants and animals will increase the risk of ________________ hazards..

3. Match the items of Column A with the most appropriate items of Column B. Rewrite the correct matching pairs. [½ x 10=5 marks]

Column A	Column B
i. Countries implementing SDGs through MAPS.	a) Phenology.
ii. Program intended to promote low emission of carbon.	b) ICDPs.
iii. Formulate policies and measures for the safety of citizens and environment.	c) Autogenic succession.
iv. Filtration of wastewater by wetlands.	d) Industrialisation.
v. Change in animal behaviour in relation to change in environment.	e) CCS.

vi. Ensure conservation and sustainable utilisation of biological resources.	f) Allogenic succession.
vii. Organisms modify the environment and lead to the replacement of the old community.	g) NBF.
viii. Capturing carbon dioxide and storing under ground.	h) UNDG.
ix. Project to achieve both socio-economic and ecological goals.	i) LECB.
x. Time-space compression.	j) Regulating service.
	k) Biodiversity Act of Bhutan.

4. Write TRUE or FALSE against the following statements. Rewrite the false statements in the correct forms. [1 x 5 = 5 marks]

i. Installing warning devices is one of the activities carried out during mitigation phase of disaster management cycle.

ii. Different species can share the same habitat, but competition among them is reduced if they occupy different niches.

iii. The main objective of sustainable development is to focus only on the natural environment.

iv. Trees are usually found in a pioneer community.

v. An organism at the consumer level has more ecological footprint than organism at the producer level.

5. Answer the following questions briefly. (1 x 10=10 marks)

i. Which attributes of biodiversity are important for poverty alleviation? Why? [2]

ii. What is a photochemical smog? [1]

iii. Climate change mitigation and adaptation are interlinked with sustainable development. Justify. [2]

iv. If you are farming on a steep slope, which irrigation method would you use? Why? [2]

v. What are some of the issues associated with the use of hydrogen as an energy source? [1]

vi. Compare fundamental niche and realised niche. [1]

vii. How do the total number of organisms and biomass change during an ecological succession? . [1]

Section B (60 marks)

Answer any **SIX** *questions.*

Question 1

i. How does a community help establish the next community in the process of primary succession? [3]

ii. What is a fuel cell? Why is it considered as potential alternative energy device? [2]

iii. Deki conducted an experiment to determine the chemical oxygen demand of Phuntsholing Thromde water source and tabulated the following observation:

Table 1.1

Sl No	Sample	Volume of sample (mL)	Burette reading (mL)		Volume of 0.1 N FAS (mL)
			Initial	*Final*	
1	*Blank*	*2.5*	*0*	*14.1*	*14.1*
2	*Sample 1*	*2.5*	*0*	*13.2*	*13.2*
3	*Sample 2*	*2.5*	*0*	*13.2*	*13.2*

a) Calculate the COD of the water sample. [2]

b) Is the water potable? Give reason. [1]

iv. Explain two challenges that Bhutan is facing in achieving sustainable development goals. [2]

Question 2

i. On a hazy day in Pasakha, the level of carbon monoxide was recorded as 12 ppm. The standard amount of carbon monoxide is 9 ppm.

a) What is the air quality index (AQI) of Pasakha? [1]

b) What would be the implications of this air quality on the local community? [1]

c) Which group of people are likely to be affected more by this air quality? [1]

ii. How does Green Economy help in addressing the climate change issues? [2]

iii. How does biodiversity help to reduce the impact of natural disasters? Give two examples. [2]

iv. Read the given situation to answer the questions that follow:

Sonam wants to buy a house in Thimphu. He has two options from which he needs to make a choice. The first house is located in the city while the second one is located in the suburb of Thimphu. The second house has a beautiful surrounding, continuous water supply and no noise pollution. Sonam approaches you to help him make a choice.

a) Which ecosystem service valuation (ESV) method would you use to help Sonam make a choice? [1]

b) What is the presumed outcome obtained from the method chosen? [1]

c) How does ecological service influence the pricing of the house in this method? [1]

Question 3

i. The National Forest Policy of Bhutan, 1991, aims to protect the land and its soil against degradation, and the improvement of all degraded forest land areas through proper management systems and practices. In line with the statement, answer the following questions:

a) What is the significance of this policy? [1]

b) Mention some of the management system and practices for land conservation. [2]

ii. What are the impacts of climate change on the socio-economic development of a nation? [2]

iii. Describe some of the best practices in Bhutan for managing a protected area. [2]

iv. Explain three causes of desertification. [3]

Reprint 2022

Question 4

i. Figure 1 represents the summary of disaster statistics for Bhutan from the year 2000-2015. Study the figure and answer the questions that follow:

a) It is evident from the figure that Bhutan has experienced the highest frequency of earthquake within fifteen years. What makes Bhutan

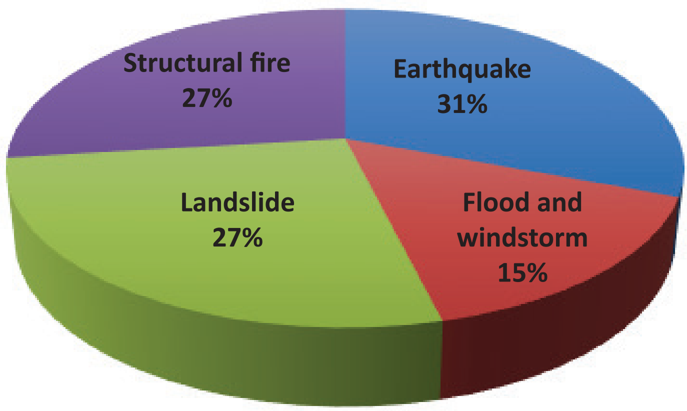


Figure 1

vulnerable to the earthquake? [1]

b) The frequency of occurrence of landslide is 27%, which is next to earthquake. Mention some of the causes that led to increased frequency of landslide. [2]

c) State two mitigation measures for fire outbreak implemented by the Department of Disaster Management. [1]

ii. Hundred years from now, fossil fuels are likely to be exhausted. Given the sources of energy available today, what would be the potential fuel for transportation and why? [2]

iii. What are some of the challenges involved in achieving food security for the growing population? [2]

iv. List down possible health hazards associated with the following pollutants: [2]

a) Oxides of nitrogen

b) Ground level ozone

Question 5

i. Figure 2(a) to (d) show different stages in ecological succession. Study the figure and answer the questions that follow:

Figure 2

a) Which picture represents the climax stage of succession? Why? [2]

b) Arrange the pictures in order of their ecological succession. Do not copy the figure, use the numbers instead. [1]

ii. 'Climate change will hinder the conservation effort of environment in Bhutan.' Support this statement with an example. [2]

iii. Strategic environmental assessment is a better environmental management tool than environmental impact assessment. Do you agree? Justify. [2]

iv. Describe three causes of human-wildlife conflict in Bhutan. [3]

Question 6

i. A group of environmentalists studying emissions from a coal-burning power station recorded that a high concentration of sulphur dioxide emissions affected the city that is 10 km away from the power station. Based on the scenario answer the following questions:

a) What possible impact will the high concentration of sulphur dioxide have on human health? [1]

b) Health workers are concerned about the residents' exposure and dosage of sulphur dioxide. Explain the differences between the terms 'exposure' and 'dosage'. [2]

ii. Describe the value of bee as a pollinator to a farmer. [2]

iii. Explain the impacts of increased agricultural production on the soil quality. [2]

iv. How can genetic engineering bring about food security? [3]

Question 7

i. 6019 metric tonnes of carbon dioxide is produced by an individual annually. The national average absorption of carbon dioxide is 0.21 metric tonnes per hectare. If the yield factor for carbon dioxide emission of a country is 0.83 and the equivalence factor is 2.51, calculate the Carbon Footprint. [3]

ii. Why is sustainable development often associated with protection of environment? [2]

iii. Biofuels address all concerns regarding energy security. Justify the statement. [2]

iv. Observe the life cycle assessment illustration of plastic bottles shown in Figure 3 and answer the questions that follow:

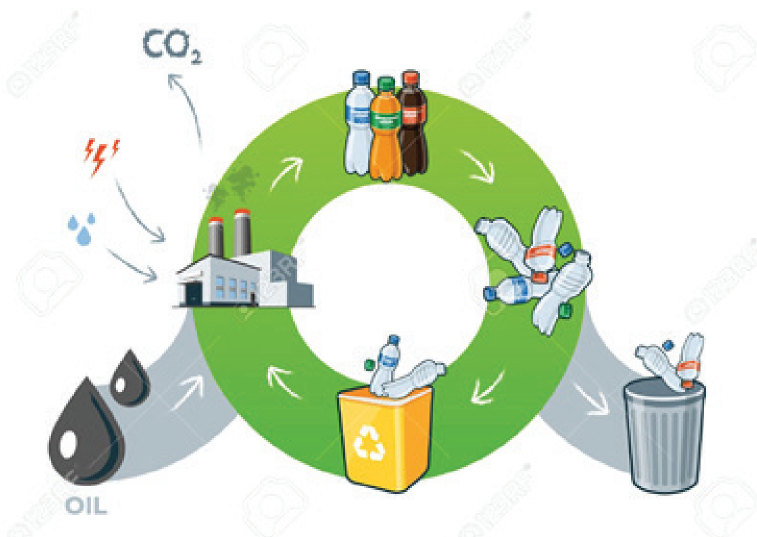


Figure 3

a) Write the environmental impact of plastic bottles. [1]

a) What are some other ways of minimising impact of plastic-bottle waste on the environment besides recycling?
[2]

Annexure

Procedure for preparation of standard solution for COD test

Materials required

Apparatus: Beakers, measuring cylinder, and funnel

Chemicals: Potassium dichromate ($K_2Cr_2O_7$), concentrated sulphuric acid (H_2SO_4), ferrous ammonium sulphate ($Fe(NH_4)_2(SO_4)_2$), ferroin indicator ($C_{36}H_{24}FeN_6O_4S$), mercury sulphate crystals ($HgSO_4$), silver sulphate crystal (Ag_2SO_4) and distilled water.

Instructions

1. Standard potassium dichromate reagent:
   i. Weigh accurately 4.913 g of potassium dichromate, previously dried at 103^0C for 2-4 hours and transfer it to a beaker.
   ii. Weigh exactly 33.3 g of mercuric sulphate and add to the same beaker. Measure accurately 167 mL of concentrated sulphuric acid using clean dry measuring cylinder and transfer it to the beaker. Dissolve the content and cool it to room temperature. (If not dissolved keep it overnight).
   iii. Take 1000 mL standard measuring flask and place a funnel over it.
   iv. Carefully transfer the contents to the 1000 mL standard flask and make up to 1000 mL using distilled water.
   v. This is the standard potassium dichromate solution to be used for digestion.
2. Sulphuric Acid Reagent-Catalyst Solution:
   i. In 1000 mL dry clean beaker, weigh accurately 5.5 g of silver sulphate crystals.
   ii. Add about 500 mL of concentrated sulphuric acid and allow standing for 24 hours, so that the silver sulphate crystals dissolve completely.
3. Standard Ferrous Ammonium Sulphate Solution:
   i. Weigh accurately 39.2 g of ferrous ammonium sulphate crystals and dissolve it in distilled water.
   ii. Take 1000 mL standard measuring flask and place a funnel over it.
   iii. Carefully transfer the contents to the 1000 mL standard flask and make up to 1000 mL mark using distilled water.

Reprint 2022

Calculation of normality of FAS

$$\text{Normality of FAS} = \frac{W}{(TV \times 0.04904 \times 10)}$$

where: TV = (F-I) is volume of ferrous ammonium sulphate solution consumed in titration

W = weight of potassium dichromate taken.