CONTENTS

Introduction

The critical importance of environmental studies cannot be disputed. As a student of environmental management, you are certainly aware of environmental issues such as climate change, the loss of biodiversity, pollution, solid waste disposal, soil erosion and deforestation. The environment is indeed one of the major problem complexes humankind faces in the 21st century. Global environmental threats are so serious that, in 1989 already, the General Assembly of the United Nations called for the formation of a global partnership to address the environmental problems arising from imbalanced development (Agenda 21 1998). This resulted in the largest international summits ever held, namely the Earth Summit in Rio de Janeiro in 1992, the Kyoto Conference in Japan in 1997 and the World Summit on Sustainable Development in Johannesburg in 2002. At these summits, the leaders of more than 160 nations gathered to debate many important, long-term environmental issues. No citizen of the Earth can afford to be ignorant of environmental problems since no-one is unaffected by them.

Our planet has existed for more than four billion years, but never before has one species dominated the Earth and all other species so completely (McKinney & Schoch 2003). Because of humankind's technological capabilities and the amount of energy it can harness, the natural environment has been significantly impacted and changed. This is true for all parts of the globe (Seager 1995), including South Africa. Over the past century, the environmental face of South Africa has changed dramatically (Moosa 1999). Agriculture and forestry have replaced large areas of South Africa's natural vegetation, while mining has changed entire landscapes; significant portions of the country are now covered by rapidly growing urban conglomerations.

The environmental changes that result from human actions are accelerating and extending to previously untouched regions. Paul Ehrling, Professor of Population Studies at Stanford University in California, said: ''We're waging a war on the environment, a very successful one'' (in Engel 2004:30). In the future, the Earth could be a very different place indeed. In all likelihood, the next few decades will mean drastic changes on the Earth for its inhabitants (McKinney & Schoch 2003). Humankind now stands at a unique crossroads and critical choices have to be made (Lean et al 1990). It is up to us – as individuals – to try to influence decisions and the outcomes of these changes sustainably so that the welfare of both humankind and the environment is best served. This brings us to the central theme of this module: sustainability. Sustainability can be described as the ability of the Earth's various natural systems and human cultural systems and economies to survive and adapt to changing environmental conditions indefinitely (Miller & Spoolman 2011).

The aim of this module

This module (Our living Earth) was specifically developed for the BA degree in Environmental Management and is aimed at strengthening the scientific base of this learning programme. In this module, you will learn how nature works, how things in nature are interconnected, how to deal with environmental problems and how to live

more sustainably. All natural processes are driven by energy and governed by physical or natural laws, and all life on Earth depends on certain chemical compounds. In order to understand the environmental issues of our time and the effect of human actions on our natural environment, you have to have some knowledge of the energy, the scientific laws and the life-sustaining chemical compounds that govern our environment. These basic, scientific fundamentals usually form part of most courses in the natural and life sciences, but not of courses in the human and social sciences. This module (GGH1503) was developed to fill this gap.

This module is like the third member of non-identical triplets. The other two modules of these triplets are GGH1501 and GGH1502. Some of the topics and issues that are dealt with in the other two modules are also addressed in this module, but there are some marked and important differences between the approaches of the three modules. In modules GGH1501 and GGH1502, spatiality and anthropocentrism (human-centeredness) are paramount; in module GGH1503, basic science and nature are paramount. For example, module GGH1501 focuses on the spatial distribution of wealth in the world and the inequality of global economic development. These issues are also relevant in module GGH1503, but in this module the focus is on the environmental effects of unequal and imbalanced development. In both modules GGH1502 and GGH1503, air pollution is important; however, in the latter module the focus is on the chemistry involved and how it can affect life on Earth.

Students in the human and social sciences often get a fright when chemistry, physics and biology are mentioned. They regard these areas as ''difficult'' or ''hard''. Rest assured that there is nothing difficult or hard about this module. The chemistry, physics and biology that we teach in this module are very elementary and are taught within the context of the natural environment and life processes. You will not even know that you are learning chemistry, physics or biology. The scientific knowledge that you acquire in this module will deepen your understanding of the environmental issues which are the main concern of environmental scientists and managers.

As in modules GGH1501 and GGH1502, we deliberately adopt a global perspective in this module. The entire living Earth is the focus not only a specific part of it of this module. However, in your prescribed book, the focus is firmly placed on the United States. This is not really a drawback since the United States not only has the biggest economy in the world, but is also the biggest consumer of fossil fuel energy, the biggest producer of greenhouse gases, the biggest producer of solid waste, and a major player in the global economy and international politics. When you have studied all the study units, you will know that the global environment is to a large degree at the mercy of the United States and increasingly China.

The learning outcomes of this module

At the end of this module, you should be able to

- explain what our most serious environmental problems are, how they were caused and how they might be solved
- define sustainability and discuss its importance in terms of addressing environmental problems
- explain what science is and what scientists do

- explain the importance of systems and scientific laws
- explain what ecosystems are, how they function and why life on Earth is so diverse
- distinguish between life on land and life in the water, and explain how both can be conserved
- explain the ecology of biological communities
- explain why the production of food for the world's population is a serious environmental problem
- explain why clean fresh water is the Earth's most precious resource
- distinguish between renewable and non-renewable energy resources, and describe the environmental impacts of energy use
- discuss the different types of air pollution and explain how air pollution can be reduced and prevented
- explain the effects of chemicals and pathogens on life
- discuss the problem of solid waste
- explain the extinction crisis
- collect, process, represent and interpret data on the environment and environmental issues

The study package

The study material for this module consists of the following:

- The prescribed book: Miller, GT & Spoolman, S. 2011. *Our living Earth*. Custom edition. Belmont, CA: Brooks/Cole.
  This prescribed book contains the material that you have to study. You have to obtain your own copy of the book because you will work from it the entire academic semester. Do not even consider relying on a copy from Unisa's library.
- Although this study guide will guide you through the prescribed book, it contains very little of the material you have to study.
- A thick A4 notepad, scribbler or exercise book, which you can buy from a stationer. You have to use this to make notes and write down the answers to questions.
- Tutorial letters, which you will receive from Unisa during the academic year.

The structure of this study guide

This study guide contains 12 study units. Each study unit deals with a specific topic and refers to a specific part of the study material. The study material as such appears in your prescribed book. The topics are organised more or less in accordance with your prescribed book. This makes it easier for you because you will start at the beginning of the prescribed book and, by and large, work your way to the back. Hopping about in the book is therefore minimised. Do not skip a study unit because it will disrupt the logic flow according to which the topics are organised. Study the units in sequence and complete each study unit before you start on the next one.

The content and structure of the study units

The study units contain a minimum of study material but refer you to the relevant chapter(s) or sections that you should study in the prescribed book. Each study unit has a number of sections.

1. Introduction

Here, the topic is briefly introduced and gives you an idea of what the study unit covers.

2. Sources to consult

Under this heading, we indicate the chapter(s) or sections that you should study in the prescribed book. Please pay close attention to these directions so that you do not omit important study material by mistake.

3. Additional resources

We give links to additional resources on the internet in this section with the aim of improving your learning experience. The *my*Unisa learning management system (http://my.unisa.ac.za) is Unisa's online campus that will help you to communicate with your lecturers, with other students and with the University's administrative departments all by means of the internet. This website also contains numerous resources (for example PowerPoint lecture(s)) that can facilitate improved learning.

In addition, you can view short video clips about current news stories on environmental issues from around the world on the CengageNow website (www.ilrn.com/ilrn/). You can also download audio study tools, which contain valuable information such as reviews of important concepts, key terms, questions, clarification of common misconceptions and study tips. It is important to note that registration on this website is at your own expense.

4. Learning outcomes

We indicate the learning outcomes for each study unit. In order to achieve these learning outcomes, you will have to work through the study material carefully and methodically. Once you have reached these learning outcomes, you will have mastered the material in the study unit. The learning outcomes give you an overview of the topics in the study unit and serve as a guide on what topics you could be asked in the examination.

The learning outcomes that are set for each study unit give you an idea of the knowledge you should have mastered (in other words, what you have to be able to) when you have finished studying the study unit. The words that tell you what you should be able to do are called ''action words''. Action words are verbs. If you are able to recognise the ''action words'' in the learning outcomes, you will know what you should be able to do when you have studied the material in the relevant study unit.

The following are some of the action words that you will get in the learning outcomes:

analyse – Break the material up into parts and discuss the parts in relation to the whole.

compare – Indicate the similarities and differences between two or more phenomena, approaches, patterns or processes.

contrast – Indicate the differences between two phenomena, approaches, patterns or processes.

criticise – Describe the advantages and disadvantages, good and bad characteristics, or possibilities and limitations, with the necessary support (substantiation) for your point of view.

define – Give a short description of the meaning of a term by using other terms or words than the one that has to be defined.

describe – Name the characteristics of something. Explain something fully without expressing your own opinion about it.

discuss – Describe, interpret, argue, debate and come to a conclusion where appropriate.

distinguish – Name the differences that are characteristic of two or more things or phenomena, and show what makes them different from each other.

draw – Outline, trace, sketch or formulate in graphical form (for example a map, graph or diagram).

evaluate – Give an opinion about a phenomenon, which is supported by facts and arguments, and determine the value of the phenomenon by using certain standards or criteria.

explain – Make something more clear by using illustrations, descriptions, examples and/or comparisons.

give – Write down names, facts, items and so on. Do not discuss.

identify – Look for and give the main characteristics.

illustrate – Give or describe an example.

indicate – Describe by using a logical framework.

interpret – Try to verify an explanation by reasoning about it. Come to a conclusion.

list – Write down names, places, characteristics, items or facts in a specific order.

name – Write down names, places, characteristics, items or facts.

summarise – Write down the key aspects of a given topic.

5. Reading activity

The chapter(s) and section(s) that you have to study are indicated under this heading.

6. Content summary

The content summary is provided to help you go over the material in the different sections of the prescribed book. The purpose is to highlight the essence of each section. The length of the discussions depends on the depth in which the topic is discussed in the prescribed book and the difficulty of the material.

7. Learning activities

At the end of each study unit, we give you activities on a specific section in the prescribed book. Ensure that you do each activity before you move on to the next study unit. These activities cover the study material in the study unit and will give you an idea of the type of questions you will probably get in the examination. The test yourself questions are similar to and on the same level as the examination questions. You can try to answer these questions and actually write out the answers. If you can answer them successfully, you will know that you have mastered the study material and have achieved the learning outcomes of the study unit.

How to use this study guide

Begin each study unit by reading the introduction. Then skim or quickly read through the study material that is prescribed for the study unit to get some idea of its scope and content. Next, carefully read the learning outcomes so that you know what you have to be able to do after you have studied the material. Then systematically study all the relevant, prescribed study material.

The study units differ in length and some will take more time to master than others. You should aim at completing a study unit in one week. Remember that the academic semester is shorter than you think and you should allow for ample time to revise and do examination preparation.

Once you have worked through all the material in a study unit and are sure that you understand it, you should answer the questions in the learning activities. Write out the answers to the questions. Keep your written answers and read, revise and improve them when you do your examination preparation. If you cannot answer a question, immediately revise the relevant section(s) in the prescribed book. If you are still unable to answer a question, contact your lecturer for help.

References

Agenda 21: an agenda for sustainable development into the 21st century. 1998. Pretoria: Department of Environmental Affairs and Tourism.

Engel, M. 2004. The war on terra firma. *Earthyear* 1/2004:28–35.

Lean, G, Hinrichsen, D & Markham, A. 1990. *Atlas of the environment.* London: Arrow.

McKinney, ML & Schoch, RM. 2003. *Environmental science: systems and solutions.* London: Jones & Bartlett.

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Moosa, V. 1999. Foreword, in *State of the environment in South Africa – an overview,* edited by A Weaver, W Le Roux & R Pretorius. Pretoria: Department of Environmental Affairs and Tourism.
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Study unit 1

Environmental problems and their causes, and sustainability

Introduction

One thing that scientists from many disciplines, environmentalists, informed citizens and even politicians agree on is that humankind is facing an array of troubling environmental problems. In June 2003, Michael Meacher (British Minister of Environment) listed (1) the lack of fresh water, (2) the destruction of forest and crop land, (3) global warming, (4) the overuse of natural resources and (5) the continuing rise in the human population as the five most important environmental issues (Engel 2004). Although no scientist will disagree that all of these are important, many will add increasing waste production, pollution and the loss of biodiversity to Meacher's list.

Look closely at the abovementioned issues. You will notice that they are related and that the continuing increase in the human population can be seen as the root cause of all the others. What we are facing is in fact a complex, interwoven network of issues or ''problems'' where each ''problem'' directly or indirectly causes a number of others. All of these environmental problems are of humankind's own making, but they were neither caused deliberately nor created overnight. They developed over the centuries as a result of population growth, the use of natural resources and the production of waste products. Although this is factually true, it is an oversimplification. The origin of our current environmental problems lies in two things: (1) humankind's ability to survive, to procreate (produce offspring), to better the quality of human life, to use the available natural resources, to change the environment, to develop various technologies and to dominate the Earth; and (2) a human-centred (consumerist) worldview. The unravelling of this network of causality is tricky, but necessary, if one is to understand the environmental issues of our time.

It is generally acknowledged that environmental problems are one of the major concerns of the 21st century, but there is some disagreement about the seriousness of the different problems and whether we really are facing an environmental ''crisis''. The abovementioned Minister of Environment believes the situation is so serious that the very survival of the planet is at stake. He words his concern as follows: ''There is a lot wrong with our world. But it is not as bad as people think. It is actually worse'' (Engel 2004:29). This is scary. Some scientists and environmentalists take a different, more optimistic view. They believe that the existing problems can be addressed and that the same ingenuity which got us into this pickle can also get us out of it (Miller & Spoolman 2011).

In this study unit, you will learn what our most pressing environmental problems are, how they were caused and how they might be solved. You will learn how cultural

changes and technological advances have created and/or contributed to environmental problems. You will see that the environmental concerns of the wealthy (developed) nations differ from those of the poor (developing) nations; but since we all share the same planet, we have to work together to solve our environmental problems. The prescribed study material will give you an overview of the problems, causes and solutions. However, you will not understand any of it unless you know the ''environmental language'' scientists use. We therefore first define a lot of the essential terms and explain some key concepts.

Sources to consult

Prescribed book: Chapter 1 ''Environmental Problems, Their Causes and Sustainability'' and chapter 25 ''Environmental Worldviews, Ethics and Sustainability''.

Additional resources

***my*Unisa**

https://my.unisa.ac.za/portal/

- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 1''.
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 1''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 1.

Learning outcomes

When you have completed this study unit, you should be able to

- describe and interpret the characteristics of an environmentally sustainable society
- analyse how environmentally sustainable societies can grow economically
- explain how our ecological footprints are affecting the Earth
- analyse the different types of pollution, their impact on the environment and how we can overcome pollution
- explain why we have environmental problems
- describe the four scientific principles of sustainability
- explain and distinguish the major environmental worldviews of sustainability
- explain the role of education in living more sustainably and discuss how we can live more sustainably

Section A

What is an environmentally sustainable society?

Reading activity

Study the section ''What is an environmentally sustainable society?'' in chapter 1 of the prescribed book.

Content summary

- Environmental scientists study how the Earth works, our interaction with the Earth, and the methods/procedures we use to deal with environmental problems.
- Environmental science concerns everything that affects a living organism.
- Ecologists study relationships between living organisms and their environment.
- Environmentalism is a social movement that is dedicated to protecting life support systems for all species.
- The path toward sustainability includes five subthemes:

  (1) natural capital – natural resources and services that keep us and other species alive
  (2) natural capital degradation – when human activities use renewable resources unsustainably
  (3) solutions – are sought to the degradation of natural resources
  (4) trade-offs – or compromises are made to resolve conflicts
  (5) individuals matter – to search for solutions to environmental problems

- Life and economies depend on solar capital (energy from the sun) and natural capital.

How can environmentally sustainable societies grow economically?

Reading activity

Study the section ''How can environmentally sustainable societies grow economically?'' in chapter 1 of the prescribed book.

Content summary

- Economic growth provides people with the goods and services they need.
  - Gross domestic product (GDP) is the market value for goods and services that are produced within a country.
  - Standard of living is the GDP divided by total population at midyear.
- Economic development is improving living standards through growth. Most developed countries have high industrialisation and high per capita income. Developing countries have moderate to low income.
  - Economic developments reflect good and bad economic news.
    - Poverty produces harmful environmental effects.
  - People in developed countries enjoy a higher standard of living.
    - They have a longer life expectancy.
    - There is a decrease in infant mortality.
  - Environmentally sustainable development rewards sustainable activities and discourages harmful activities.

How are our ecological footprints affecting the Earth?

Reading activity

Study the section ''How are our ecological footprints affecting the earth?'' in chapter 1 of the prescribed book.

Content summary

- Natural capital/resources are resources in the environment or those that are obtained from the environment: food, water, air, shelter, petroleum and so on.
- Material resources we get from the environment are classified as perpetual, renewable or non-renewable.
  - A perpetual resource is renewed continuously, such as solar energy.
  - A sustainable yield is the highest rate of use on an indefinite scale without degradation or depletion.
  - Environmental degradation occurs when the use of resources exceeds the rate of replacement.

- ''Tragedy of the commons'' describes the overuse or degradation of freely available resources such as ocean pollution, abuse of national parks and air pollution. Not one individual owns these free-access resources.
- What is our ecological footprint/impact on the environment?
  - The per capita ecological footprint is the biologically productive land and water that are needed to supply renewable resources and absorb waste for each individual.
  - Humanity's ecological footprint exceeds by about 39% the Earth's ecological capacity (or biocapacity) to replenish its renewable resources and absorb the resulting waste products and pollution.

- What are non-renewable resources?
  - Non-renewable resources are resources that exist in a fixed quantity in the Earth's crust. A non-renewable resource is economically depleted when it costs too much to obtain what is left.
  - These resources include energy resources (for example oil, coal and natural gas), metallic mineral resources (for example copper, iron and aluminium) and non-metallic minerals (like salt, clay, sand and phosphates).
  - There are solutions to an economically depleted resource.
    - Try to find more of the resource.
    - Recycle the resource.
    - Waste and use less.
    - Try to develop a substitute for the resource.

Read the case study: The number of affluent consumers will soon double as people in underdeveloped countries attain a middle-class lifestyle. China is already a leading consumer of many resources, and its economy and population are continuing to grow at a rapid rate. Therefore, its ecological footprint and overall level of resource consumption are expected to continue to grow.

What is pollution and what can we do about it?

Reading activity

Study the section ''What is pollution and what can we do about it?'' in chapter 1 of the prescribed book.

Content summary

- Pollutants are chemicals that are at high enough levels in the environment to harm people or other living organisms.
  - Pollutants can enter the environment naturally (for example through volcanic eruptions) or through human activities.
  - Point sources of pollutants are single, identifiable sources.
  - Non-point sources of pollutants are dispersed.
  - Three unwanted effects of pollutants are:
    - They can disrupt or degrade the life-support systems of any organism.
    - They damage human health, wildlife and property.
    - They can produce nuisances in the form of noise, bad smells and tastes, and poor sight.
- Solutions: What can we do about pollution?
  - We use two basic approaches to deal with pollution.
    (1) Pollution prevention/input pollution control reduces or eliminates the production of pollutants.
    (2) Pollution clean-up/output pollution control cleans up or dilutes pollutants after they have been produced.
  - Problems with pollution clean-up include:
    - It is a temporary bandage without long-term pollution control technology, like the catalytic converter.
    - The pollutant is removed but causes pollution in another place, for example burning or burying garbage.
    - It is expensive to reduce pollution to an acceptable level; prevention is less expensive.

Why do we have environmental problems?

Reading activity

Study the section ''Why do we have environmental problems?'' in chapter 1 of the prescribed book.

Content summary

- The five major causes of environmental problems are:
  (1) population growth
  (2) wasteful use of resources
  (3) poverty

(4) poor environmental accounting
(5) ecological ignorance

- Affluence is the addiction to over-consumption of material goods.
  - *Symptoms:* high debt level, declining health, increased stress and more bankruptcies.
  - *Solutions*: admit the problem, shop less, avoid malls and other shopping addicts.
  - *Toynbee's law of progressive simplification*: transfer energy and attention to the non-material side of life.

- The affluence of developed countries can lead to environmental improvements.
  - Money is available for technological improvements.
  - Since 1970, air and water are cleaner than previously.
  - Money was spent on environmental improvements.

- Environmental world-views and ethics determine the way people view the seriousness of environmental problems.
  - Your environmental world-view is your assumptions and values about the world and your role in it.
    - The planetary management world-view holds that nature exists to meet our needs.
    - The stewardship world-view holds that we manage the Earth, but we have an ethical responsibility to be stewards of the Earth.
    - The environmental world-view holds that we are connected to nature and that nature exists for all species equally.

Read the case study: Chattanooga, Tennessee, was once one of the most polluted cities in the United States. In the mid-1980s civic leaders gathered together community members to identify problems and brainstorm solutions. After years of encouraging zero-emission industries, implementing recycling programmes and renovating much of the city, Chattanooga is an example of what can be accomplished when cities build their social capital.

What are four scientific principles of sustainability?

Reading activity

Study the section ''What are four scientific principles of sustainability?'' in chapter 1 of the prescribed book.

Content summary

- There are four major components of Earth's natural sustainability:

(1) reliance on solar energy
(2) reserve biodiversity
(3) population control
(4) nutrient recycling

Learning activities

Study the core case study at the beginning of chapter 1. The human population is growing exponentially, consuming vast amounts of resources. It is uncertain how many people the Earth can sustain, particularly in light of the pollution they create.

Complete all the questions in the ''Thinking about'' textboxes of chapter 1.

Complete the review questions at the end of chapter 1.

Complete the critical thinking questions (except question 10) at the end of chapter 1.

Complete the ecological footprint analysis exercise at the end of chapter 1.

Section B

What are some major environmental world-views?

Reading activity

Study the section ''What are some major environmental worldviews?'' in chapter 25 of the prescribed book.

Content summary

- Environmental world-views are how people think the world works, where they fit in and ethics. These can be human-centred or Earth-centre, or a combination of both.
- Human-centred views hold that human beings are the most important species on and stewards of the Earth.
  - People with a planetary management world-view think human beings are the dominant species and that we should manage the Earth for our own benefit.
  - People with the stewardship world-view think human beings have an ethical responsibility to care for the Earth.
- Life-centred and eco-centred world-views: People with a life-centred world-view believe human beings have an ethical responsibility to avoid causing the premature extinction of species.
- People with the environmental wisdom world-view think that human beings are not in charge and should study the history of the Earth to determine how it has maintained itself.
- People with the deep ecology world-view maintain that human beings should think about our obligations to all life forms and not reduce the interdependence and diversity of life.
- People with the ecofeminist environmental world-view believe that women should be equal to men in the human quest to develop more sustainable societies.

What is the role of education in living more sustainably?

Reading activity

Study the section ''What is the role of education in living more sustainably?'' in chapter 25 of the prescribed book.

Content summary

- Environmentally literate citizens are needed to build a more sustainable society.
  - This requires an understanding of how the Earth works, how we interact with the Earth and the methods we use to deal with environmental problems.
  - It requires an understanding of ecological identity.
- Nature has to be experienced directly to complete environmental education.

How can we live more sustainably?

Reading activity

Study the section ''How can we live more sustainably?'' in chapter 25 of the prescribed book.

Content summary

- Learning to live more simply with fewer material things is a key component of a sustainable lifestyle.
- The largest human impacts are agriculture, transportation, home energy use, water use, and overall resource consumption and waste. Sustainable lifestyles involve changes in all these components of our interaction with the Earth.
- Effective environmental citizens avoid feelings of hopelessness; blind technological optimism; paralysis by analysis; and are sceptic of simple, easy answers.
- Religion can play an important role in the sustainability revolution.
- Sustainability is an achievable goal.

Learning activities

Study the core case study at the beginning of chapter 25: Biosphere 2 was designed to be a self-sustaining life support system, but the experiment failed because of a breakdown in its nutrient cycling.

Complete all the questions in the ''Thinking about'' textboxes of chapter 1.

Complete the review questions at the end of chapter 25.

Complete the critical thinking questions (except question 10) at the end of chapter 25.

Form groups of between four and six students on the discussion forum facility on *my*Unisa in order to complete the ecological footprint analysis exercise at the end of chapter 25.

In conclusion

After studying this study unit, you should realise that we face an array of serious environmental problems. You should have identified that sustainability holds the key to our survival on Earth. Sustainability involves a lot of environmental terminology (for example ''natural capital'') and a number of basic environmental concepts (for example ''tragedy of the commons''), which you should now be familiar with. It is now time to find out how much you have learned and then to move on to studying the scientific background of these terms and concepts. When you have completed the learning activities, you may proceed to study unit 2.

References

Engel, M. 2004. The war on terra firma. *Earthyear* 1/2004:29–35.

Miller, GT & Spoolman, S. 2011. *Our living earth*. Custom edition. Belmont, CA: Brooks/Cole.

Study unit 2

Science, matter, energy and systems

Introduction

As we pointed out in the introduction to this study guide, it is essential that you know something about matter, energy and the natural systems/laws which govern life on Earth in order to really understand the environmental problems we face today. Every living thing, the food we eat, the ground we walk on, the water we drink and even the air we breathe consists of matter. Every step we take, every kilometre we drive, the growth of every plant, the heat we use to cook our food and even the light we read by is a form of energy or requires energy. Just to stay alive requires energy. Grossly oversimplified, we can say that our living world consists of matter and is sustained by energy but, of course, it is not as simple as this.

In this study unit, you will learn that our living world is a vast collection of complex systems that consist of matter and require energy to function. You will learn what matter and energy are, and that both matter and energy can be changed but never created or destroyed. The fact that matter and energy can neither be created nor destroyed is of immense importance in environmental systems and processes. It might well be the single most important scientific truth for any environmental scientist or environmental manager to know.

But what is ''a scientific truth''? For that matter, what is ''scientific''? And what is ''science''? In this study unit, you will learn the answers to these questions. You will also learn how scientists think and how they ''do science''. You should know these things in order to understand that the scientific concerns about the environment are not born from emotion, sentiment, nostalgia or non-scientific thinking (or, as Chiras [2001:18] states, ''faulty thinking''), but are based on what we think (believe) is the absolute (true), provable (verifiable) reality.

Sources to consult

Prescribed book: Chapter 2 ''Science, Matter, Energy, and Systems''.

Additional resources

***my*Unisa**

https://my.unisa.ac.za/portal/

- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 2''.

- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 2''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 2.

Learning outcomes

When you have completed this study unit, you should be able to

- analyse the ''nature of science'' and the role of science in our daily lives
- explain the concept ''matter'' and discuss the characteristics of matter
- identify and explain how matter can change
- describe what energy is and explain how it can be changed
- discuss what systems are and explain how they can respond to change

What is science?

Reading activity

Study the section ''What is science?'' in chapter 2 of the prescribed book.

Content summary

- Science assumes that events in the natural world follow orderly patterns and that, through observation and experimentation, these patterns can be understood.
  - Scientists collect facts or scientific data.
  - Based on observations of phenomenon, scientists form a scientific hypothesis (an unconfirmed explanation of an observed phenomenon that has to be tested).
  - The parts of the scientific process are scepticism, reproducibility and peer review.

- A scientific theory is a verifiable, believable, widely accepted scientific hypothesis.
- A scientific/natural law describes events/actions of nature that reoccur in the same way.
- Many types of scientific methods are used to gather data, formulate hypotheses, state theories and laws, and then test them. Observation leads to a hypothesis and then to an experiment that produces results, which lead to a conclusion.
  - In an experimental group, one chosen variable is changed.
  - In a control group, the chosen variable is not changed.
  - Multivariable analysis uses mathematical models to analyse interactions between many variables.

- Scientists try to establish that a particular theory/law has a high probability of truth. They always include a degree of uncertainty. (Read the science focus: Easter Island revisited – an example of how a once accepted hypothesis has been replaced as a result of new evidence.)

  - Scientists use both inductive reasoning and deductive reasoning.
    - *Inductive reasoning* uses specific observations and measurements to arrive at a general conclusion.
    - *Deductive reasoning* uses logic to arrive at a specific conclusion that is based on a generalisation.

- Paradigm shifts occur when new discoveries overturn well-accepted scientific theory.
- Frontier science is scientific results that have not been confirmed; sound science or consensus science results from scientific results that have been well tested and are widely accepted. (Read the science focus: Global warming – how global warming can be made to look like frontier science.)
- Environmental science has limitations.
  - Scientists can disprove things, but they cannot prove anything absolutely.
  - Scientists are sometimes biased.
  - Environmental scientists often rely on estimates.
  - Environmental phenomena often involve a multitude of interacting variables. (See the science focus: Statistics and probability – understanding how statistics work.)

What is matter?

Reading activity

Study the section ''What is matter?'' in chapter 2 of the prescribed book.

Content summary

- Matter is anything that has mass and takes up space, living or non-living. It comes in chemical forms, as an element or a compound.
  - An element is the distinctive building block that makes up every substance.
  - Chemists classify elements according to their chemical behaviour by arranging them in a periodic table of elements.

- The building blocks of matter are atoms, ions and molecules.
  - An atom is the smallest unit of matter that exhibits the characteristics of an element.
  - An ion is an electrically charged atom or combinations of atoms.
  - A molecule is a combination of two or more atoms/ions of elements that are held together by chemical bonds.

- Each atom has a nucleus that contains protons and neutrons. Electron(s) orbit the nucleus of an atom.
  - A proton (p) is positively charged, a neutron (n) is uncharged and an electron (e) is negatively charged.
  - Each atom has an equal number of positively charged protons in its nucleus and an equal number of negatively charged electrons outside its nucleus, so an atom has no net electrical charge.

- Each element has a specific atomic number that is equal to the number of protons in its nucleus.
- The mass number of an atom equals the total number of neutrons and protons in its nucleus.
- Isotopes are various forms of an element that have the same atomic number, but different mass numbers.

- The atoms of some elements can lose or gain one or more electrons to form ions with positive or negative electrical charges.
  - Elements that are known as metals tend to lose one or more electrons; they are electron givers.
  - Elements that are known as non-metals tend to gain more electrons; they are known as electron receivers.
  - The hydrogen ions (H+) in a solution are a measure of how acidic or basic the solution is. A neutral pH is 7, acid solutions are below 7 and basic solutions are above 7.

- Chemical formulas are a type of shorthand to show the type and number of atoms/ions in a compound.
  - Ionic compounds are made up of oppositely charged ions, (Na^+ and Cl^-).
  - Compounds that are made up of uncharged atoms are called covalent compounds (CH_4).

- Organic compounds contain carbon atoms that combine with one another and with various other atoms.
  - Hydrocarbons are compounds of carbon and hydrogen atoms.
  - Chlorinated hydrocarbons are compounds of carbon, hydrogen and chlorine atoms.
  - Simple carbohydrates are specific types of compounds of carbon, hydrogen and oxygen atoms.

- Polymers are larger and more complex organic compounds that have molecular units.
  - Complex carbohydrates contain two or more monomers of simple sugars that are linked together.
  - Proteins are formed by linking monomers of amino acids together.
  - Nucleic acids are made of sequences of nucleotides that are linked together.
    - Genes are specific sequences of nucleotides in a DNA molecule.
    - Chromosomes are combinations of genes that form a single DNA molecule, plus some proteins.
    - A genome is the complete sequence of DNA base pairs that combine to make up the chromosomes in a typical member of a species.

- All compounds without the combination of carbon atoms and other elements' atoms are inorganic compounds.
- According to the usefulness of matter as a resource, it is classified as having high or low quality.
  - High-quality matter is concentrated with great potential for usefulness and is usually found near the Earth's surface.

– Low-quality matter is diluted and is found deep underground and/or dispersed in air or water.

How can matter change?

Reading activity

Study the section ''How can matter change?'' in chapter 2 of the prescribed book.

Content summary

- When matter undergoes a physical change, its chemical composition remains unchanged but the molecules are organised in different patterns.
- In a chemical change, the chemical composition of the elements/compounds changes.
- The law of conservation of matter states that no atoms are created/destroyed during a physical or chemical change.
- Matter can undergo a change that is known as a nuclear change. Three types of nuclear change are (1) radioactive decay, (2) nuclear fission and (3) nuclear fusion.
- Radioactive isotopes emit high-energy radiation at a fixed rate until the original unstable isotope is changed into a stable isotope.
  - The nuclei of certain isotopes with large mass numbers (uranium 235) are split apart into lighter nuclei when they are struck by neutrons. This is nuclear fission.
- Nuclear fusion occurs at extremely high temperatures and involves the fusion of two isotopes of light elements (for example H).

What is energy and how it can be changed?

Reading activity

Study the section ''What is energy and how it can be changed?'' in chapter 2 of the prescribed book.

Content summary

- Energy is the capacity to do work and transfer heat; it moves matter.
  - Kinetic energy has mass and speed, for example wind and electricity.
  - Potential energy is stored energy that is ready to be used (for example an unlit match).
  - Potential energy can be changed to kinetic energy, for example dropping an object.
- Electromagnetic radiation is energy that travels as a wave as a result of changing electric and magnetic fields.

  - Each form of electromagnetic radiation has a different wavelength and energy content.
  - The electromagnetic spectrum describes the range of electromagnetic waves that have different wavelengths and energy content.

- Heat is the total kinetic energy of all moving atoms, ions or molecules in a substance.
  - It can be transferred from one place to another by convection, conduction and radiation.
  - Temperature is the average speed of the motion of atoms, ions or molecules in a sample of matter.
  - Energy quality is measured by its usefulness. High energy is concentrated and has high usefulness; low energy is dispersed and can do little work.

- The first law of thermodynamics states that energy can neither be created nor destroyed, but can be converted from one form to another.
- The second law of thermodynamics states that when energy is changed from one form to another, there is always less usable energy (in other words, energy quality is depleted).
  - In changing forms of energy, there is a loss in energy quality. Heat is often produced and lost.
  - Changing forms of energy produces a small percentage of useful energy because much energy is lost in the process.
  - In living systems, solar energy is changed to chemical energy and then to mechanical energy. High-quality energy is degraded to low-quality heat.
  - High-quality energy cannot be recycled/reused.
  - Energy efficiency/productivity measures the amount of useful work by a specific input of energy.

What are systems and how do they respond to change?

Reading activity

Study the section ''What are systems and how do they respond to change?'' in chapter 2 of the prescribed book.

Content summary

- A system is a set of components that interact. (Read the science focus: The usefulness of models – how models can be used to understand a system.)
- Most systems have inputs from the environment, throughputs of matter and energy within the system, and outputs to the environment.
- Systems are affected by feedback and feedback loops (positive and negative).
- Systems often show time delays between input and response.
- Problems can build slowly in systems until they reach a tipping point.
- Synergy is when processes interact to such an extent that the combined effect is greater than the individual effects.

In conclusion

You should now understand what we mean when we say ''we breathe O_2, we drink H_2O, we eat $C_6H_{12}O_6$ and $C_{14}H_9Cl_5$ will kill us''. However, even when organisms die, the matter that they consist of and the energy that kept them alive have not been and cannot be destroyed. Your scientific vocabulary and basic scientific knowledge should now have increased to such an extent that you can understand the complexity of life and our living world. Test your knowledge by completing the learning activities and then move on to study unit 3.

Learning activities

Study the core case study at the beginning of chapter 2: Controlled experiments involve an experimental group in which a known variable is changed and a control group in which the variable is not changed. The example involves two drainages that were dammed: One was deforested and one was left forested. The deforested landscape showed an increase in erosion and an increase in water flow that carried dissolved nutrients.

Complete all the questions in the ''Thinking about'' textboxes of chapter 2.

Complete the review questions at the end of chapter 2.

Complete the critical thinking questions (except question 10) at the end of chapter 2.

Complete the data analysis exercise at the end of chapter 2.

References

Chiras, DD. 2001. *Environmental science: creating a sustainable future*. 6th edition. Sudbury: Jones & Bartlett.

Study unit 3

Ecosystems: What are they and how do they work?

Introduction

So far in this module, you have learned quite a lot about science, matter, energy and the environmental impact of humankind. But you have learned relatively little about the living environment, the organisms that live in it, the relationships among them and their interactions with the non-living environment. This is what we focus on in this study unit.

Life on Earth is extremely diverse and highly organised. An enormous variety of living organisms live in – and depend on – biological communities, which are organised into larger units (namely ecosystems). A myriad of relationships exist within every biological community, while innumerable interactions occur within every ecosystem. This interconnected complexity of living matter is sustained perpetually through the flow of energy. In this process, numerous conversions, transfers and exchanges of energy and matter take place.

In this study unit, you will study the diversity of life, the composition and functioning of ecosystems, the cycling of energy and matter, and the impact of human activities on all of these. Throughout, you should bear in mind what you have already learned about matter and energy and the fact that they can be changed but never created or destroyed. You will soon see that there is no ''away'' in ecosystems. You will also see that the second law of thermodynamics is of crucial importance in the flow of energy through ecosystems and that the organisation and interactions in the system are determined by this law.

Sources to consult

Prescribed book: Chapter 3 ''Ecosystems: what are they and how do they work''.

Additional resources

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https://my.unisa.ac.za/portal/

- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 3''
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 3''
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 3.

Learning outcomes

When you have completed this study unit, you should be able to

- explain the term ''ecology'' and analyse the various components that make up an ecosystem
- describe what keep us and other organisms alive
- explain the role of energy and predict the consequences if energy was absent in an ecosystem
- analyse what happens to matter in an ecosystem
- evaluate how scientists study ecosystems

What is ecology?

Reading activity

Study the section ''What is ecology?'' in chapter 3 of the prescribed book.

Content summary

- Ecology is the study of connections in the natural world.
  - An organism is any form of life. The cell is the basic unit of life in organisms.
  - Organisms are classified as either eukaryotic or prokaryotic, based on the presence or absence of a membrane-bound nucleus.
  - Organisms are classified into a species, which groups organisms that are similar to each other together.
  - Sexually reproducing organisms are classified as a species if, under natural conditions, they can potentially breed with one another and produce live, fertile offspring.
  - Tiny microbes rule the world; they are unseen by the naked eye, but keep the natural world operating.
  - About 1,4 million species have been identified, but estimates of the number of species range from 3,6 million to 100 million.

- A population is a group of interacting individuals of the same species in a specific area. Genetic diversity explains why these individuals might not behave nor look exactly alike. A habitat is the place where a population or an individual usually lives. Its distribution or range is the area over which a species is found.
- A community represents populations of different species that live and interact in a specific area. A biological community consists of all the populations of different species that interact and live in a specific area. This is a network of plants, animals and micro-organisms. (Read the science focus: The importance of insects in maintaining the environmental balance.)
- An ecosystem is a community of different species that interact with each other and with their non-living environment of matter and energy. All of the Earth's diverse ecosystems comprise the biosphere.

What keeps us and other organisms alive?

Reading activity

Study the section ''What keeps us and other organisms alive?'' in chapter 3 of the prescribed book.

Content summary

- Various interconnected spherical layers make up the Earth's life-support system.
  - The atmosphere is the thin membrane of air around the planet.
  - The troposphere is the inner air layer that extends about 17 km thick above sea level.
  - The stratosphere is the next layer. It lies above the troposphere, stretching from 17 to 50 km above sea level and filters the sun's harmful radiation.
  - The hydrosphere consists of the Earth's water: liquid water, ice and water vapour.
  - The lithosphere is the crust and upper mantle of the Earth.
- The biosphere includes most of the hydrosphere, parts of the lower atmosphere and the upper lithosphere.
- Ecology's goal is to understand the interactions between the Earth's air, water, soil and organisms.
- Sun, cycles of matter and gravity sustain life on earth.
  - The one-way flow of high-quality solar energy through materials and living things (as they eat) produces low-quality energy. Energy cannot be recycled.
  - Matter cycles through parts of the biosphere.
  - Gravity causes the downward movement of chemicals as matter cycles through the Earth.
- Solar energy passes through the Earth as electromagnetic waves.
- As solar radiation interacts with the Earth, infrared radiation is produced. Greenhouse gases trap the heat and warm the troposphere. This natural greenhouse effect makes the planet warm enough to support life.

What are the major components of an ecosystem?

Reading activity

Study the section ''What are the major components of an ecosystem?'' in chapter 3 of the prescribed book.

Content summary

- The major components of ecosystems are abiotic (non-living) water, air, nutrients, solar energy and biotic (living) plants, animals and microbes.
- Populations have a range of tolerance to physical and chemical environments.
  - Law of tolerance: The distribution of a species in an ecosystem is determined by the levels of one or more physical or chemical factors being within the range that is tolerated by the species.

        - The limiting factor principle states that too much or too little of any abiotic factor can limit or prevent the growth of a population.

- The major biological components of ecosystems are the producers/autotrophs that are self-feeders and the consumers/heterotrophs.
  - Autotrophs make their own food from compounds in the environment.
  - Consumers (or heterotrophs) feed on other organisms or their remains.
    - Decomposers break down organic detritus (bacteria/fungi) into simpler inorganic compounds.
    - Omnivores feed on both plants and animals.
    - Carnivores feed on animals.
    - Detritivores feed on dead organic matter and break it down into smaller molecules.
    - Herbivores feed on plants.
  - Glucose and other organic compounds are broken down and energy is released through the process of aerobic respiration (the use of oxygen to convert organic matter back to carbon dioxide and water).
  - Some decomposers break down organic compounds without using oxygen. This process is called anaerobic respiration or fermentation. (See the science focus: The importance of microbes to our life.)
  - Matter is recycled; there is a one-way flow of energy.

What happens to energy in an ecosystem?

Reading activity

Study the section ''What happens to energy in an ecosystem?'' in chapter 3 of the prescribed book.

Content summary

- Food chains and food webs help us to understand how the eaters, the eaten and the decomposed are interconnected in an ecosystem.
- The sequence of organisms as they are eaten is called a food chain.
  - Trophic levels are feeding levels for organisms within an ecosystem.
    - Producers belong to the first tropic level.
    - Primary consumers belong to the second tropic level.
    - Secondary consumers belong to the third tropic level.
    - Detritivores and decomposers process detritus from all the trophic levels.
  - Food webs are complex networks of interconnected food chains.

- Energy flow in a food web/chain decreases at each succeeding organism in a chain or web.
- The dry weight of all organic matter within the organisms of a food chain/web is called biomass. ''Ecological efficiency'' is the term that describes the percentage of usable energy that is transferred as biomass from one trophic level to another; it ranges from 2 to 40%.

- The greater the number of trophic levels in a food chain, the greater the loss of usable energy.
- The pyramid of energy flow visualises the loss of usable energy through a food chain. The lower levels of the trophic pyramid support more organisms.
- Production of biomass takes place at different rates among different ecosystems.
  - The rate of an ecosystem's biomass production is the gross primary productivity (GPP).
  - Some of the biomass has to be used for the producers' own respiration. Net primary productivity (NPP) measures how fast producers can provide biomass that is needed by consumers in an ecosystem.
  - Ecosystems and life zones differ in their NPP.

- The planet's NPP limits the numbers of consumers who can survive on Earth.

What happens to matter in an ecosystem?

Reading activity

Study the section ''What happens to matter in an ecosystem?'' in chapter 3 of the prescribed book.

Content summary

- Nutrient cycles/bio-geochemical cycles are global recycling systems that interconnect all organisms.
  - These cycles include the carbon, oxygen, nitrogen, phosphorus and water cycles.

- The water/hydrologic cycle collects, purifies and distributes the Earth's water in a vast global cycle.
  - Solar energy evaporates water and the water returns as rain/snow.
  - Some water becomes surface run-off and returns to streams/rivers.
  - Water is the major form of transporting nutrients within and between ecosystems.

- The water cycle is altered by man's activities. (Read the science focus: The unique properties of water.)
  - We withdraw large quantities of fresh water.
  - We clear vegetation and increase run-off, reduce filtering and increase flooding.
  - We add nutrients such as fertilisers and modify the quality of the water.
  - The earth's water cycle might be speeding up due to a warmer climate. This can change global precipitation patterns and intensify global warming (water vapour increases in the troposphere).

- The carbon cycle circulates through the biosphere.
  - CO_2 gas is an important temperature regulator on Earth.
  - Photosynthesis and aerobic respiration circulate carbon in the biosphere.
  - Fossil fuels contain carbon.

- Carbon recycles through the oceans. The oceans act as a carbon sink, but release carbon dioxide when warming occurs.
- Excess carbon dioxide in the atmosphere contributes to global warming.

- Nitrogen is recycled through the Earth's systems by different types of bacteria.
  - The nitrogen cycle converts nitrogen (N_2) into compounds that are useful nutrients for plants and animals.
  - The nitrogen cycle includes the following steps:
    (1) Specialised bacteria convert gaseous nitrogen to ammonia during nitrogen fixation.
    (2) Special bacteria convert ammonia in the soil to nitrite ions and nitrate ions. The latter is used by plants as a nutrient. This process is called nitrification.
    (3) Decomposer bacteria convert detritus into ammonia and water-soluble salts during ammonification.
    (4) During denitrification, nitrogen leaves the soil. Anaerobic bacteria in soggy soil and the bottom sediments of water areas convert NH_3 and NH_4^+ back into nitrite and nitrate ions, and then nitrogen gas and nitrous oxide gas are released into the atmosphere.
  - Human activities affect the nitrogen cycle.
    - When we burn fuel, we add nitric oxide into the atmosphere. It can be converted to NO_2 gas and nitric acid, and can return to the Earth's surface as acid rain.
    - Nitrous oxide that comes from livestock, wastes and inorganic fertilisers that we use on the soil can warm the atmosphere and deplete the ozone layer.
    - We destroy forest, grasslands and wetland, and releases large amounts of nitrogen into the atmosphere.
    - We pollute aquatic ecosystems with agricultural run-off and human sewage.
    - We remove nitrogen from topsoil with our harvesting, irrigating and land-clearing practices.
    - Increased input of nitrogen into air, soil and water is affecting the biodiversity toward species that can thrive on increased supplies of nitrogen nutrients.

- We should use phosphorus-based fertilisers because the phosphorus cycle moves through the Earth's water, soil and organisms much slower and is often the limiting factor for plant growth.
  - Phosphorus is used as a fertiliser to encourage plant growth.
  - Phosphorus also limits the growth of producers in freshwater streams and lakes due to the low solubility in the water.

- Man interferes with the phosphorous cycle in harmful ways.
  - We mine phosphate rock to produce fertilisers and detergents.
  - We cut down tropical forests and thereby reduce the phosphorus in tropical soils.
  - We compromise aquatic systems with animal waste run-off and human sewage.

- Sulphur cycles through the Earth's air, water, soil and living organisms.
  - Natural sources of sulphur are hydrogen sulphide, which is released from volcanoes, swamps, bogs and tidal flats where anaerobic decomposition occurs.
  - Some marine algae produce dimethyl sulphide (DMS). Since DMS acts as nuclei for the condensation of water in clouds, it can affect the cloud cover and climate.
  - Sulphur compounds can be converted to sulphuric acid, which falls as acid deposition.
  - Burning coal and oil, refining oil and the production of some metals from ores all add sulphur to the environment.

How do ecologists study ecosystems?

Reading activity

Study the section ''How do ecologists study ecosystems?'' in chapter 3 of the prescribed book.

Content summary

- Ecologists do field research by observing and measuring an ecosystem's structure and function.
- New technologies, such as remote sensing and geographic information systems (GISs), enable scientists to gather data that is fed into computers for analysis and manipulation of data.
- Ecologist use tanks, greenhouses, and controlled indoor and outdoor chambers to study ecosystems (laboratory research). This allows control of light, temperature, CO_2, humidity and other variables.
- Field and laboratory studies have to be coupled for a more complete picture of an ecosystem.
- Systems analysts develop mathematical and other models that simulate ecosystems that are large and very complex and cannot be adequately learn about field and laboratory research. This allows for the analysis of the effectiveness of various alternate solutions to environmental problems and can help to anticipate environmental surprises.

In conclusion

In this study unit, you became acquainted with the essentials of life, namely organisms, ecosystems, the flow of energy and the cycling of matter. For the sake of clarity, we artificially separated the flow of energy and the flow of matter into two separate sections. In reality, these two can never be separated because energy is stored in the form of matter within ecosystems. Solar energy is used during photosynthesis and converted into potential energy, which is stored in carbohydrates. Thus energy and matter become indistinguishable and inseparable at some points in ecosystems. In short, you should now know how life on Earth is sustained. You should also know that the biosphere provides services that life – and therefore we – cannot do without. Life itself makes life on Earth possible. This ostensible contradiction is true in that life sustains life; if one form of life is extinguished, others are sure to follow.

Some obvious questions arise: Why is there life on Earth? Where, when, how and why did life emerge? What did life look like initially? Why and how did it change over time? In the next study unit, you will find answers to these questions. But first, you have to complete the learning activities.

Learning activities

Study the core case study at the beginning of chapter 3: Tropical rainforests make up only 2% of the Earth's land surface, but account for more than half of all its biodiversity. More than half of this area has already been destroyed and degradation is increasing. This will cause a reduction in biodiversity, an increase in climate change and changes in regional weather patterns.

Complete all the questions in the ''Thinking about'' textboxes of chapter 3.

Complete the review questions at the end of chapter 3.

Complete the critical thinking questions (except question 10) at the end of chapter 3.

Complete the ecological footprint analysis exercise at the end of chapter 3.

Study unit 4

Biodiversity and evolution

Introduction

The Earth is a unique place. It is different from all other celestial bodies. The existence of life on Earth sets the planet apart from all the other planets. As far as we know, the Earth is the only celestial body that supports life as we know it. All the other planets are either too hot or too cold, or so small that they cannot retain an atmosphere. When we consider how many millions of celestial bodies there are, we begin to realise exactly how special the Earth really is. But why is there life on Earth? Where, when and how did life emerge? How has it changed since then? Why has it changed? Why is it so diverse? These are the questions that we will attempt to answer in this study unit.

In order to answer all these questions, we have to be able to explain what ''life'' is. The problem is that no one has been able to formulate a generally accepted definition of life. James Lovelock, a highly regarded scientist and original thinker, says: ''They hate to admit it, but the life scientists, whether the natural historians of the nineteenth century or the biologists of the twentieth, cannot explain what life is in scientific terms ... in my view no one has yet succeeded in defining life'' (Lovelock 1995:16). The author of your prescribed book (wisely) has not even tried! You have to agree that this situation presents science with a huge problem: How can you study something if you cannot even tell exactly what it is! Here science relies on the ''intuitive'' knowledge of every scientist, student and thinking person: ''They all know what it is, as we have done since childhood'' (Lovelock 1995:16). Paradoxically perhaps, there is total agreement among scientists that life is very special and that it is found nowhere but on Earth.

No one can say with certainty how life started. There are hypotheses and theories as well as ideologies and beliefs about this. In this module, we do not argue the point, but present some of the evidence scientists use to build theories and we give the mainstream modern scientific thinking on it. Contrary to the very beginnings of life, we know a lot about the changes and adaptations (also called evolution) life has undergone over the last 3,7 billion years to result in the rich diversity of the present time. Today, we live in a time of incredible biological diversity, with numerous individuals and species interacting to form populations, communities and ecosystems that are essential to the maintenance of life as we know it (McKinney & Schoch 2003).

Sources to consult

Prescribed book: Chapter 4 ''Biodiversity and Evolution''.

Additional resources

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- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 4''.
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 4''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 4.

Learning outcomes

When you have completed this study unit, you should be able to

- explain what biodiversity is and evaluate its importance
- explain the origin of species
- evaluate how geological processes and climate change affect evolution
- analyse how speciation, extinction and human activities affect biodiversity
- explain what species diversity is, analyse its importance and predict the consequences if some species became extinct in an ecosystem

What is biodiversity and why is it important?

Reading activity

Study the section ''What is biodiversity and why is it important?'' in chapter 4 of the prescribed book.

Content summary

- Biodiversity is the variety of species, genes, ecosystems and ecosystem processes.
  - It includes species diversity, genetic diversity, ecosystem diversity and functional diversity.

Where do species come from?

Reading activity

Study the section ''Where do species come from?'' in chapter 4 of the prescribed book.

Content summary

- Evolution is the change in a population's genetic make-up over time.
- Populations evolve by becoming genetically different.
- All species descend from earlier, ancestral species – theory of evolution.

- Over time, a population's gene pool changes when mutations (beneficial changes) in DNA molecules are passed on to offspring.
  - Mutations are random changes in the structure/number of DNA molecules in a cell.
  - Mutations occur in two ways.
    (1) Gene DNA is exposed to external agents, such as X-rays, chemicals (mutagens) and radioactivity.
    (2) Random mistakes occur in coded genetic instructions.

- Natural selection occurs when members of a population have genetic traits that improve their ability to survive and produce offspring with those specific traits.
  - In order for natural selection to evolve in a population, three conditions are necessary:
    (1) The population must have genetic variability.
    (2) The trait must be heritable (capable of being passed from one generation to another).
    (3) The trait must enable individuals with the trait to produce more offspring than individuals without the trait. This is called differential reproduction.
  - Adaptation or adaptive traits are heritable traits that help organisms to survive and reproduce better under prevailing environmental conditions.

- Natural selection can only act on existing genes and is limited by reproductive capacity.

Read the case study: Human beings have thrived so well as a species because of their strong opposable thumbs, ability to walk upright and complex brain. These adaptations might not prove to be as beneficial as the environment continues to change, though our powerful brain might allow us to live more sustainably in the future.

How do geologic processes and climate change affect evolution?

Reading activity

Study the section ''How do geologic processes and climate change affect evolution?'' in chapter 4 of the prescribed book.

Content summary

- Processes such as the shifting of tectonic plates, volcanic eruptions and earthquakes influence the Earth's climate and in turn affect evolution by removing and/or isolating habitats and species.
- Long-term climate changes relocate ecosystems, thus determining where certain species can live.
- Asteroids and meteorites have caused environmental stress and mass extinctions. (See the science focus: The conditions that make Earth suitable for life.)

How do speciation, extinction and human activities affect biodiversity?

Reading activity

Study the section ''How do speciation, extinction, and human activities affect biodiversity?'' in chapter 4 of the prescribed book.

Content summary

- Natural selection can lead to the development of an entirely new species.
- During speciation, two species arise from one when some members of a population cannot breed with other members to produce fertile offspring. Speciation occurs in two phases:

  (1) Geographic isolation or physical separation for long time periods.
  (2) Reproductive isolation.

- When population members cannot adapt to changing environmental conditions, the species becomes extinct.
- When local environmental conditions change, some species disappear at a low rate. This is called background extinction.
- Mass extinction is a significant rise in extinction rates above the background extinction level. Usually, 25 to 70% of species are lost. There appear to have been five mass extinctions on Earth in the last 500 million years. (See the science focus: Artificial ways to control population genetics include artificial selection and genetic engineering.)

What is species diversity and why is it important?

Reading activity

Study the section ''What is species diversity and why is it important?'' in chapter 4 of the prescribed book.

Content summary

- Species diversity is the number of species (richness) combined with their relative abundance (evenness).
- Species rich communities tend to be more stable and more productive. (See the science focus: The size of a habitat affects the species richness of the habitat island.)

What roles do species play in ecosystems?

Reading activity

Study the section ''What roles do species play in ecosystems?'' in chapter 4 of the prescribed book.

Content summary

- An ecological niche is a species' way of life in an ecosystem (that is, everything that affects its survival and reproduction).
  - The niche includes the members' adaptations; its range of tolerance for physical and chemical conditions; its interactions with other components of the ecosystem; and its role in energy flow and matter recycling.
  - The fundamental niche is the full potential range of conditions and resources that a species can potentially use. Its realised niche is the part of the potential niche that allows a species to survive and avoid competition with other species for the same resources.

- Some species have broad ecological roles and are termed ''generalist species''.
- Some species have narrow ecological roles and are termed ''specialist species''.
- Niches can be occupied by native or non-native species.
- Indicator species give early warning of ecosystem damage because they have a narrow range of tolerance.
- Keystone species have a large affect on maintaining balance within an ecosystem.
  - They can be, but are not necessarily, pollinators and top predators.
  - Foundation species create and enhance habitats that benefit other species.

Read the case study: Cockroaches are the ultimate generalists. They can survive extreme conditions and have a wide variety of adaptations that allow them to avoid predation. By contrast, many other species are narrow specialists, although they sometimes have an advantage in their environment because they have few competitors.

Read the case study: Amphibians are indicator species that are declining globally. Factors that affect their survival include habitat loss, drought, pollution, an increase in UV radiation, parasites, fungal diseases, climate change, overhunting and the introduction of non-native species. Since they are indicator species, this is cause for alarm on a global scale.

Read the case study: Sharks are keystone species that have been overlooked by conservation efforts because of human bias. They tend to be considered dangerous and have gone without protection despite being heavily fished for their valuable fins. They also commonly drown in fishing nets. Shark populations have been declining since the 1970s and scientists are now calling for a ban on shark finning in international waters.

In conclusion

Now you know how life probably started and how it changed, adapted and diversified to become the richness we enjoy on Earth today. In this study unit, you learned that life is vulnerable, that certain species are more vulnerable than others, and that some species have remarkably survived environmental changes while others have disappeared from the face of the Earth. Complete the learning activities below and then move on to the next study unit where you will learn how the diversity of life is distributed and organised on Earth.

Learning activities

Study the core case study at the beginning of chapter 4: Alligators act as a keystone species, yet their numbers are seriously compromised by overhunting. Their activities provide important habitat for fish and avian species. They also control populations by their feeding behaviours. In 1967, the alligator was placed on the endangered species list and has made a dramatic recovery.

Complete all the questions in the ''Thinking about'' textboxes of chapter 4.

Complete the review questions at the end of chapter 4.

Complete the critical thinking questions (except question 10) at the end of chapter 4.

Complete the data analysis exercise at the end of chapter 4.

References

Lovelock, J. 1995. *The ages of Gaia: a biography of our living Earth*. New edition. Oxford: Oxford University Press.

McKinney, ML & Schoch, RM. 2003. *Environmental science: systems and solutions*. London: Jones & Bartlett.

Study unit 5

The ecology of biological communities

Introduction

In the previous study units, you learned that life on Earth is diverse and organised. The biosphere is hierarchically organised (McKinney & Schoch 2003). Organisms are grouped into populations and populations form biological communities, which then form ecosystems. Together, these form the biosphere, which constitutes all life on Earth.

The hierarchy of life is not static. Each level is dynamic, with many interactions occurring among its units (McKinney & Schoch 2003). The levels are interconnected: within each population, community and ecosystem, organisms interact with one another and with their environment to exchange energy and matter, which sustains life and maintains the stability of the system.

It is important to distinguish between ''stable'' and ''static''. ''Static'' means ''inactive'' or ''dormant''. A dormant or inactive ecosystem is a dead one. ''Stability'', on the other hand, means that the system – while changing all the time – is largely in balance and in equilibrium with its environment. This is the ideal state for an ecosystem. A stable ecosystem is not ''unchanging'' or ''fixed'', and will not necessarily look the same all the time. It is dynamic and ever-changing, and undergoes small to medium changes in response to small to moderate disturbances. Such a system has the best chance of surviving because this type of ''responsive'' balance (equilibrium) brings stability, which is a prerequisite for sustainability.

A stable ecosystem is organised or structured. It is composed of diverse species which are interconnected by numerous interactions. In this study unit, we take a closer look at biological communities and the interactions that are essential to sustain life in ecosystems.

Sources to consult

Prescribed book: Chapter 5 ''Biodiversity, Species Interactions, and Population Control'' and Chapter 7 ''Climate and Terrestrial Biodiversity''.

Additional resources

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https://my.unisa.ac.za/portal/

- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 5''.
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 5''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 5.

Learning outcomes

When you have completed this study unit, you should be able to

- describe how species interact
- explain how natural selection reduces competition between species
- explain how our ecological footprints are affecting the Earth
- analyse what limits the growth of populations
- discuss how communities and ecosystems respond to changing environmental conditions
- describe what factors influence climate
- explain how climate affects the nature and locations of biomes
- discuss how we have affected the world's terrestrial ecosystems

Section A

How do species interact?

Reading activity

Study the section ''How do species interact?'' in chapter 5 of the prescribed book.

Content summary

- The five basic species interactions are: (1) competition, (2) predation, (3) parasitism, (4) mutualism and (5) commensalism.
- Competition between species for food, sunlight, water, soil, space, nest sites and so on is called inter-specific competition.
  - With intense competition for limited resources, one species has to migrate and shift its feeding habits/behaviour or face extinction.
  - As human beings take more and more space, other species are compromised.
- In competitive situations, some species evolve adaptations to reduce/avoid competition for resources.
  - Over a long time, species evolve more specialised traits that allow them to use shared resources at different times, in different ways or in different places. This is termed ''resource partitioning''. For example: insect-eating warblers in Maine forests that eat insects in specific parts of a spruce tree, owls (which hunt at night) and hawks (which hunt during the day).
  - Predator-prey relationships define one species (the predator) that feed/prey on another species. Individual prey is harmed, but predation can help the population by eliminating the sick, weak and old.

- Predators have a variety of ways to capture prey. Herbivores feed on immobile plant species; carnivores pursue or ambush to capture prey. Some predators use camouflage, and others use chemical warfare (venom) to capture prey or deter predators.
- Prey species escape predators in different ways, such as swift movement, protective shells, camouflage, or use of chemicals to repel or poison. (See the science focus: Giant kelp, sea urchin and sea otter populations have evolved to be dependent on each other.)

- Parasitism, mutualism and commensalism.
  - Parasites are one species that live on or in another species. The host of this arrangement is obviously harmed by it, but the parasite can contribute to biodiversity by controlling the size of specific species populations.
  - Mutually beneficial interactions also exist in ecological environments.
  - Mutualism is a relationship that benefits both species. These benefits include dispersing pollen and seeds for reproduction, receiving food or getting protection.
  - Mutualism is not cooperation; each species exploits the other. Examples include:
    - birds and African buffalo, elephants and rhinoceroses
    - clownfish and anemones
    - fungi and plant root associations (called mycorrhizae)

- Some species' interaction helps one species, but does nothing for the other. This is called commensalism. Examples of this are bromeliads and orchids (epiphytes).

How can natural selection reduce competition between species?

Reading activity

Study the section ''How can natural selection reduce competition between species?'' in chapter 5 of the prescribed book.

Content summary

- Resource partitioning occurs when species that compete for similar scarce resources evolve specialised traits that allow them to use resources at different times, in different ways or in different places.

What limits the growth of populations?

Reading activity

Study the section ''What limits the growth of populations?'' in chapter 5 of the prescribed book.

Content summary

- Populations change in size, density and age distribution. Most members of populations live together in clumps or groups.
  - Three general patterns of population distribution occur in a habitat: (1) clumping, (2) uniform distribution and (3) random dispersion. Most species live in clumps or groups.
    - The availability of resources varies from place to place.
    - Living in groups offers better protection from predators.
    - Some predator species live in packs to have a better chance of getting a meal.
    - Temporary groups can form for mating purposes and caring for the young.
  - Uniform pattern distribution can occur where a resource such as water is scarce.

- Four variables influence/govern population size: (1) birth, (2) death, (3) immigration and (4) emigration.
  - An increase in population occurs through birth and immigration.
  - A decrease in population occurs through death and emigration.
  - The age structure of a population is usually described as the pre-reproductive stage, the reproductive stage and the post-reproductive stage. A population with a large reproductive stage will likely increase, while a population with a large post-reproductive stage will likely decrease. (See the science focus: Factors that have affected the southern sea otter's ability to increase in numbers.)

- No population can grow indefinitely because of limited resources (such as light, water and nutrients) and competitors/predators.
  - The biotic potential is the population's capacity for growth.
  - The intrinsic rate of increase (r) is the rate of population growth with unlimited resources.
  - Rapidly growing populations have four characteristics:
    (1) Individuals in the population reproduce early in life.
    (2) Individuals have short periods between generations.
    (3) Individuals have long reproductive lives.
    (4) Individuals reproduce multiple offspring each time when they reproduce.

- Environmental resistance consists of factors that limit population growth.
  - Carrying capacity (K) is determined by biotic potential and environmental resistance. This is the number of a species' individuals that can be sustained indefinitely in a specific space.
  - As a population reaches its carrying capacity, its growth rate decreases because resources become scarcer.

- A population can grow rapidly with ample resources.
  - With few resource limitations, a population will have exponential growth. This is a fixed rate of growth that will be a J-shaped growth curve as the base

size of population increases. This represents its intrinsic rate of increase (r) or biotic potential.
  - This exponential growth is converted to logistic growth when the population gets larger and faces environmental resistance. In logistic growth, the growth rate levels off as population size reaches or nears carrying capacity.
  - The sigmoid (s-shaped) population growth curve shows that the population size is stable, at or near its carrying capacity.

- When the population size exceeds its carrying capacity, organisms die unless they move or switch to new resources.
  - Exponential growth leads to logistic growth and might lead to the population overshooting the environment's carrying capacity.
    - Overshooting an environment's resources often results from a reproductive time lag.
    - The reproductive time lag can produce a dieback/crash of organisms unless the organisms can find new resources or move to an area with more resources.
    - If the carrying capacity of an area is exceeded, changes in the area itself can reduce future carrying capacity. Reducing grass cover by overgrazing allowed sagebrush to move in and reduce the number of cattle that the land could support.
    - Technological, social and cultural changes have extended the Earth's carrying capacity for human beings for the time being.

- The density of a population can affect how rapidly it grows.
  - Density-independent population controls affect a population's size regardless of its density. These are abiotic factors in the community.
  - Density-dependent population controls have a greater affect on the population as its density increases. An infectious disease is an example of density-dependent population control.

- Population sizes can stay about the same size, suddenly increase and then decrease, vary in regular cycles or change erratically.
  - Four general types of population fluctuations in nature are: (1) stable, (2) irruptive, (3) cyclic and (4) irregular.
  - A stable population fluctuates slightly above and below carrying capacity and is characteristic of many species that live under fairly constant environmental conditions.
  - Some species have a fairly stable population size that can occasionally irrupt to a high peak and then crash to below carrying capacity. This is characteristic of short-lived, rapidly reproducing species.
  - Cyclic fluctuations occur over a regular time period (generally a multiple-year cycle).
  - Irregular behaviour is poorly understood. Some scientists attribute irregular behaviour to chaos in the system.

- Interaction between predators and their prey change in cycles. This appears to be caused by species' interactions, but other factors can also be involved.

- The hypothesis of top-down control of prey by predators might not be the only explanation for the cyclic boom-and-bust that can be seen in these populations. It might also be related to the food supply of prey.
- The bottom-up control hypothesis refers to plants that are consumed too rapidly by prey for them to be replaced to maintain the ecosystem. If there is a crash of herbivores (plant predators), this leads to a crash of higher predators of the herbivores.
- These are not mutually exclusive hypotheses and it is more probable that there is interaction between predation and food supplies.

Read the case study: White tailed deer populations were in decline a century ago due to habitat loss and hunting. Subsequent protection and a decline in their natural predators led to a drastic increase in their numbers to the extent that they have become a nuisance and even a danger on the urban edge. Efforts to control their populations are very complicated and, in many cases, expensive.

How do communities and ecosystems respond to changing environmental conditions?

Reading activity

Study the section ''How do communities and ecosystems respond to changing environmental conditions?'' in chapter 5 of the prescribed book.

Content summary

- With new environmental conditions, community structures can change and one group of species can be replaced by another.
  - Ecological succession is the gradual change in the species composition of a given area.
  - Primary ecological succession is the gradual establishment of biotic communities on lifeless ground. In the soil, there is no terrestrial community; in an aquatic community, there is no bottom sediment. This process generally takes a very long time.
    - Pioneer species attach themselves to patches of bare rock to begin the process. Lichens and moss begin the building of soil particles.
    - Early successional plants include tiny annuals that reseed. This is followed by small perennial grasses, herbs and ferns that grow close to the ground.
    - Mid-successional plants include low shrubs and trees that require more soil and lots of sunlight. This process takes hundreds of years.
    - Late successional plant species are generally tree species that create and tolerate shade to become a complex forest community.
    - Primary succession can also take place in newly created small ponds that, over a long period, are transformed to a marsh and finally to dry land.
  - Secondary ecological succession defines a series of communities with different species that develop in places with soil or bottom sediment. The

soil or sediment remains after the natural community of organisms has been disturbed, removed or destroyed.

- Forest fires or deforestation, for example, can convert a particular stage of succession to an earlier stage.
- Changes in vegetation during secondary succession also change the numbers and types of animals and decomposers.

- The classic view of ecological succession is that it is an orderly sequence, with each stage leading to the next more stable stage until a climax community is reached. Such a community represents the balance of nature; one that is dominated by a few long-lived plant species that is in balance with its environment. Three factors have been identified that affect how and at what rate succession occurs:

  (1) *Facilitation.* An area is made suitable for a second species by the actions of the first.
  (2) *Inhibition.* Early species delay the establishment of later species.
  (3) *Tolerance.* Later species are unaffected by plants at earlier stages of succession.

- Changes in environmental conditions that disrupt a community can set back succession.

  – Disturbances such as fire, drought, mining, plowing and climate change can set back succession to an earlier stage.
  – Large catastrophic disturbances can devastate a community; however, in the long run such disturbances create unfilled niches and can encourage greater biodiversity.
  – The intermediate disturbance hypothesis contends that infrequent, moderate disturbances are large enough to create openings for colonising species, but mild enough for the survival of some mature species in undisturbed areas. There is some evidence to support this hypothesis, but not enough to state that this applies to all types of communities. (See the science focus: Factors that affect ecological succession.)

- Scientists cannot predict the course of a given succession in a community toward a stable climax community that is in balance with its environment.

  – The equilibrium model of succession was previously thought of as the balance of nature.
  – Ecologists now view a community as continuous change with instability rather than equilibrium.
  – Succession reflects a struggle for each species to obtain food, light, nutrients and space in order to gain an advantage by occupying as much of its fundamental niche as possible.
  – The term ''biotic change'' better describes the changes that occur than does the term ''succession''. ''Mature community'' better describes a relatively stable community with a mosaic of vegetation patches than does the term ''climax community''.

Study the core case study: Sea otters are a keystone species that is found on the west coast of the United States and are endangered. For many years, they have been in

recovery. Why should we be concerned about their status? Sea otters are charismatic, they generate tourist revenue and they are very valuable in terms of controlling biologic populations.

Learning activities

Complete all the questions in the ''Thinking about'' textboxes of chapter 5.

Complete the review questions at the end of chapter 5.

Complete the critical thinking questions (except question 10) at the end of chapter 5.

Complete the data analysis exercise at the end of chapter 5.

Section B

What factors influence climate?

Reading activity

Study the section ''What factors influence climate?'' in chapter 7 of the prescribed book.

Content summary

- Weather is a local area's short-term physical conditions, such as temperature and precipitation. Average temperature and average precipitation are the two major factors that determine the climate of a region, together with the related factors of latitude and elevation.
- The global air circulation is affected by the uneven heating of the Earth's surface by solar energy; seasonal changes in temperature and precipitation; the rotation of the Earth on its axis; and the properties of air, water and land.
  - Uneven heating of the Earth's surface: the equator is heated more than the poles.
  - Seasonal changes in temperature and precipitation due to the tilt of the Earth.
  - The rotation of the Earth on its axis results in the Earth moving faster beneath air masses at the equator and slower at the poles. Belts of prevailing winds are the result.
  - The properties of air, water and land affect global air circulation. Water evaporation sets up cyclical convection cells. These occur both vertically and from place to place in the troposphere. The result is an irregular distribution of climates and patterns of vegetation from pole to pole.

- Ocean currents influence climate by distributing heat from place to place and mixing and distributing nutrients.
  - Differences in water density and heat create ocean currents that are warm/cold.

- Currents (such as the Gulf Stream) redistribute absorbed solar heat from one place to another and influence vegetation and climate near coastal regions.
- Currents also help to mix ocean waters in order to distribute nutrients and dissolved oxygen aquatic organisms need.
- Winds and the Earth's rotation drive the currents.

- Water vapour, carbon dioxide and other gases influence climate by warming the lower atmosphere and the Earth's surface.
  - Water vapour, carbon dioxide, methane and nitrous oxide are known as greenhouse gasses. They allow mostly visible light, some infrared radiation and ultraviolet radiation to pass through the troposphere. This natural warming is called the greenhouse effect.

- Interactions between land and oceans, and disruptions of airflows by mountains and cities, affect local climates. Various topographic features can create local and regional microclimates.
  - An example of this is the rainshadow effect.
  - Bricks, asphalt and other building materials create distinct microclimates in cities.

How does climate affect the nature and location of biomes?

Reading activity

Study the section ''How does climate affect the nature and location of biomes?'' in chapter 7 of the prescribed book.

Content summary

- Different climates lead to different communities of organisms, especially vegetation. Differences in average temperature and precipitation due to global air and water circulation lead to differences in climate.
  - Average annual precipitation, temperature and soil type are the most important factors in producing tropical; temperate or polar deserts; grasslands; and forests.
  - Biomes are actually a mosaic of different biological communities.
  - Climate and vegetation vary with the latitude and elevation of an area. (See the science focus: Plants and animals have numerous adaptations to the harsh conditions in desert environments. These tend to revolve around avoiding heat and absorbing/retaining the maximum amount of water.)

- Deserts have little precipitation and little vegetation, and are found in tropical, temperate and polar regions. Deserts cover about 30% of the Earth's land surface, mostly in tropical and subtropical regions.
  - Tropical deserts are hot and dry most of the year and have few plants, rocks and sand.
  - Temperate deserts have high daytime temperatures in summer and low temperatures in winter, with more rain than tropical deserts.
  - Cold deserts have cold winters and warm summers, with low rainfall.

- Polar deserts experience very cold temperatures all year round and receive little or no rainfall annually.

- Grasslands have enough precipitation to support grasses, but not enough to support large stands of trees. The three main types of grasslands are (1) tropical, (2) temperate and (3) polar (tundra).
  - Savannas are tropical grasslands with scattered trees and enormous herds of hoofed animals.
    - Large herds of grazing and browsing animals feed there.
  - Temperate grasslands with cold winters and hot, dry summers have deep and fertile soils that make them ideal for growing crops and grazing cattle.
    - Organic matter accumulates and produces fertile soil because above-ground plant parts die each year.
    - North American grasslands are tall-grass prairies and short-grass prairies.
  - Polar grasslands are covered with ice and snow, except during a brief summer.
    - Under the snow, there is a thick, spongy mat of low-growing vegetation (grasses, mosses and dwarf woody shrubs).
    - Permafrost is a permanently frozen layer of soil that occurs when water freezes.
    - Global warming is causing some parts of the permafrost in parts of Alaska to melt.
    - Another type of tundra (alpine tundra) occurs above tree line, but below permanent snow line. This area gets more sunlight than arctic tundra and has no permafrost.

- Chaparral has a moderate climate, but its dense thickets of spiny shrubs are subject to periodic fire. Chaparral (or temperate shrubland) is found in coastal areas that border deserts.
  - The winter rainy season is longer than in the desert; fog during spring/fall reduces evaporation.
  - Low-growing evergreen shrubs with occasional trees are the main vegetation type.
  - Fires move swiftly when started in these areas. Chaparral has adapted to occasional fires.
  - Human beings like the climate of this biome, but risk losing their homes to fire.
  - Floods/mudslides sometimes occur after fires.

- Forests have enough precipitation to support stands of trees and are found in tropical, temperate and polar regions. There are three main types of forest: (1) tropical, (2) temperate and (3) boreal (polar).
  - Tropical rainforests have heavy rainfall on most days and a rich diversity of species occupy a variety of specialised niches in distinct layers. Tropical rainforests are near the equator and have hot, humid conditions.
    - Dominant plants are broadleaf evergreens with shallow roots.

- A dense canopy blocks most sunlight from reaching lower levels.
- Vines often drape individual trees.
- Tropical forests cover about 2% of the land surface, but are habitats for about half the terrestrial species on Earth.
- Very little litter is on the forest floor because of rapid recycling of dead materials.
- So far, at least half of these forests have been destroyed or disturbed by human activities.

– Temperate deciduous forests grow in areas with moderate average temperatures; abundant rainfall; and long, warm summers.

- Broadleaf, deciduous trees dominate this biome. Leaves drop in autumn, trees become dormant and new leaves grow in spring.
- More sunlight penetrates the canopy so there is richer diversity of ground-level plant life.
- On a worldwide basis, this biome has been disturbed by human activity more than any other terrestrial biome as a result of establishing settlements, industrialisation and urbanisation.

– Evergreen coniferous forests or boreal forests are located in areas just south of arctic tundra around the northern sub-arctic regions of the Earth. These forests consist mostly of cone-bearing evergreen trees (which keep their needles year-round) to help the trees survive long, cold winters.

- Long, dry, extremely cold winters are the norm. Summers are short.
- Dominant trees are coniferous (cone-bearing) spruce, hemlock, fir, cedar and pine.
- There is low plant diversity.

– Coastal areas support huge cone-bearing evergreen trees such as redwoods and Douglas fir in a cool and moist environment. Coastal coniferous forests or temperate rainforests are located along the western coast of Canada to northern California. Cool temperatures, abundant rain and dense fog are the norm.

- Most trees are evergreen, with much moss as epiphytes and ground cover.
- There is a dense canopy and little light reaches the forest floor.
- The winters are mild and the summers are cool.

– Mountains are high-elevation forested islands of biodiversity and often have snow-covered peaks that reflect solar radiation and gradually release water to lower-elevation streams and ecosystems. Mountains are places with dramatic changes in altitude, climate, soil and vegetation within very short distances.

- Mountains have important ecological roles, such as providing habitats for endemic species, biodiversity and sanctuaries for animal species that are driven from other habitats.
- They help to regulate the Earth's climate; snow peaks reflect much solar radiation into space.
- Mountains play a major role in the hydrologic cycle.

How have we affected the world's terrestrial ecosystems?

Reading activity

Study the section ''How have we affected the world's terrestrial ecosystems?'' in chapter 7 of the prescribed book.

Content summary

- Human activities have damaged or disturbed about 62% of the world's terrestrial ecosystems to some extent.
- Human beings have had a number of specific harmful effects on the world's deserts, grassland, forests and mountains.

In conclusion

In this study unit, you learned how ecosystems are organised and how they change in response to changing environmental conditions and disturbances. You also learned a crucially important principle of natural sustainability, namely that natural populations change when their numbers exceed the natural carrying capacity of their habitat or environment. At this stage, you should have no doubt that human activities have impacted detrimentally on natural systems and that humankind can learn a lot about sustainability from nature.

Learning activities

Study the core case study at the beginning of chapter 7: The location of terrestrial biomes is determined by climate. Wind is an important component of the Earth's climate. Wind transports nutrients from one place to another and can also transport pollutants. Because of wind, everything we do affects some part of the biosphere.

Complete all the questions in the ''Thinking about'' textboxes of chapter 7.

Complete the review questions at the end of chapter 7.

Complete the critical thinking questions (except question 10) at the end of chapter 7.

Complete the data analysis exercise at the end of chapter 7.

References

McKinney, ML & Schoch, RM. 2003. *Environmental science: systems and solutions*. London: Jones & Bartlett.

Study unit 6

Humankind: The ultimate consumer

Introduction

Now you know how natural ecosystems function, that one species feeds on another species, and that the primary producers convert solar energy to produce the food that forms the basis of the energy flow pyramid in the biosphere. At the apex of this pyramid is our own species, namely humankind. Human beings are tertiary consumers; they feed at the highest trophic level, where the least usable energy is available. This fact alone indicates a certain vulnerability that is inherent to the species. In natural ecosystems, the species that feed at the higher trophic levels always have smaller population numbers than those that feed lower down in the food chain. In order to be sustainable, a natural ecosystem has to have many more primary producers than primary consumers, more primary consumers than secondary consumers and so on. When the numbers of higher level feeders increase beyond what can be sustained, the carrying capacity of the system has been exceeded. The system has become unsustainable. This is how nature works and there is no way to sidestep it. It is determined by the second law of thermodynamics and we cannot get around it!

Humankind is the dominant species on Earth. Its population is burgeoning and currently stands at approximately 6,9 billion – that is, 6 900 000 000 people who have to be fed daily. Although this sounds quite frightening, enough food is produced to do this. Yet hunger, undernourishment (undernutrition) and malnourishment (malnutrition) abound. Although there is some confusion about the definitions of the terms and the published statistics vary greatly, there seems to be reasonable consensus that more than a billion people (that is, nearly one out of every five people) do not get enough to eat and consequently are undernourished and underweight (Lean et al 1990; Seager 1995; McKinney & Schoch 2003). And the situation is getting worse. More people are hungry now than ever before (Seager 1995).

The amount of food that is consumed every day by the average global citizen should amount to about 2400 calories (Lean et al 1990). If it is below this level, undernutrition can result. People who consume less than 2000 calories per day on a regular basis are considered chronically undernourished. In 1990, the per capita calorie intake per day in no less than 11 African states was below the 2000 calorie level and in 20 African states it was between 2000 and 2400 (Lean et al 1990). Hence, in 31 of Africa's approximately 50 states, the average person was either hungry or undernourished/malnourished. In some 26 states, more than 10% of the children under the age of five were known to be malnourished (Seager 1995), undernourished or both. What is even more disheartening is that the situation is deteriorating. Although the absolute, overall food production in Africa has increased over the past 40 years, population growth has outstripped it (Lean et al 1990). The per capita food production today is 27% lower than in the 1960s (Seager 1995). The number of hungry, undernourished and malnourished Africans has increased and is still rising.

The irony is that more than enough food to feed everybody on Earth is actually produced, but it is not available where it is needed. There are huge inequalities in the food production of the world. All developed regions have greatly increased their food production since the 1960s. So has Asia. Western Europe and North America produce over 30% more food than their per capita domestic requirements (Lean et al 1990). The developed countries produce enough grain to feed the hungry in Africa and the rest of the world, but the greater part of their grain production is used to feed livestock for slaughter. In the United States, 56% of farmland is used for beef production.

The spatial pattern of global food consumption shows similar inequalities. In the developed regions, food is available in abundance and an increasing percentage of the population is overfed and overweight or even obese. Obesity has become a serious community health concern in rich countries, most notably the United States, where one out of five adults suffers from overnutrition. The meat from the livestock that eat most of the grain that is produced in the developed regions now forms a large part of the ''western'' and specifically the American diet. Meat-eating is a habit of affluence (Seager 1995) and it is environmentally detrimental. Environmental scientist Phil Clapp, of the US National Environmental Trust, describes the environmental impact of the American diet and lifestyle as follows: "This nation is devouring itself" (Engel 2004:30).

In this study unit, we focus on the food resources for humankind. Although food production has undergone revolutions, more and more people are underfed while more and more people are overfed. This growing inequality is not only a moral dilemma and political problem, but has become one of humankind's most serious environmental issues. The agricultural practices of the developed regions cause immeasurable harm to the environment; so too do the overgrazing and slash-and-burn cultivation of the developing regions. All of these practices and the resultant environmental degradation are covered in this study unit. We pay special attention to soil degradation because the Earth's soil resources have been irreparably degraded by overcultivation, overfertilisation, overirrigation and overgrazing.

Sources to consult

Prescribed book: Chapter 6 ''The Human Population and Its Impact'' and chapter 12 ''Food, Soil and Pest Management''.

Additional resources

***my*Unisa**

https://my.unisa.ac.za/portal/

- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 6''.
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 6''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 6.

Learning outcomes

When you have completed this study unit, you should be able to

- analyse and calculate how many people the Earth can support
- discuss what factors influence the size of the human population
- analyse how a population's age structure can affect its growth or decline
- explain how the growth of the human population can be kept in check
- describe food security and analyse why it is difficult to ascertain
- explain how food is produced
- discuss the different environmental problems that arise from food production
- explain how crops can be protected from pests in a sustainable manner
- describe how food security can be improved in a sustainable manner

Section A

How many people can the Earth support?

Reading activity

Study the section ''How many people can the Earth support?'' in chapter 6 of the prescribed book.

Content summary

- The human population has grown rapidly due to technology, improved medical techniques, emphasis on hygiene, and expansion of agriculture and industry.
- Population growth has slowed, but this issue is troubling because we do not know how long we can continue without overshooting Earth's carrying capacity for human beings.
- No population, including human beings, can continue to grow indefinitely. (Read the science focus: Human activities have directly affected about 83% of the Earth's land surface, excluding Antarctica. Human beings have altered nature in eight major ways: They have (1) reduced biodiversity, (2) increased primary productivity, (3) increased genetic resistance in pests, (24) eliminated natural predators, (5) introduced harmful species, (6) used renewable resources unsustainably, (7) interfered with chemical cycling and energy flow, and (8) relied on fossil fuels.)

What factors influence the size of the human population?

Reading activity

Study the section ''What factors influence the size of the human population?'' in chapter 6 of the prescribed book.

Content summary

- Population increases through births and immigration and decreases through deaths and emigration: Population change = (Births + Immigration) – (Deaths + Emigration).
  - The crude birth rate is the number of live births per 1000 people in a population in a specific year.
  - The crude death rate is the number of deaths per 1000 people in a population in a specific year.

- The populations of China and India comprise 37% of the world's population. The next most populated country is the United Stated, with 4,5% of the world's population.
- Fertility is the number of births that occur to an individual woman or in a population.
  - The changing nature of fertility rates affects population growth.
    - Replacement-level fertility is the number of children that are needed to replace their parents.
    - The total fertility rate (TFR) is the average number of children that a woman has during her fertile years.

- Many factors influence birth and fertility rates.
  - More children work in developing countries; they are important to the labour force.
  - The economic cost of raising and educating children determines their numbers.
  - If private/public pension systems are available, adults have fewer children because they do not need children to take care of them in their old age.
  - People in urban areas usually have better access to family planning, so they have fewer children.
  - If women have educational and economic choices, they tend to have fewer children.
  - When the infant mortality rate is low, people have fewer children.
  - The older women are when they marry, the fewer children they bear.
  - If abortions are available and legal, women have fewer children.
  - The availability of reliable birth control allows women to space their children and determines the number of children they bear.

- Factors that have caused a decline in death rates are the following:
  - Better food supplies and nutrition, and safer water supplies, contribute to people living longer.
  - Advances in medicine and public health, and improved sanitation and personal hygiene, also contribute to people living longer.

- Measures of overall health are:
  - Life expectancy is the average number of years a newborn can be expected to live.
  - The infant mortality rate is the number of babies out of every 1000 born who die before their first birthday.

    - This rate reflects a country's level of nutrition and health care.
    - It is the single best measure of a society's quality of life.

  – The United States' infant mortality rate is higher than 40 other countries because of

    - inadequate health care for poor women and their babies
    - drug addiction among pregnant women
    - a high birth rate among teenagers

- Migration is also a factor in population change.

Read the case study: The population of the United States is currently 303 million people. Although a drop in the total fertility rate (TFR) has slowed the country's growth, it is still growing faster than any other developed country. Because of high per capita resource use and waste, growth in the United States' population has an enormous environmental impact.

Read the case study: Historically, the United States has admitted more immigrants than all other countries combined. Some 60% of the United States' population supports limiting legal immigration. A recent study suggests that in order to maintain a viable work force as baby boomers retire, the United States would have to absorb many more immigrants per year than it currently does. However, a reduction in immigration can help to mediate the enormous environmental footprint the United States currently has.

How does a population's age structure affect its growth or decline?

Reading activity

Study the section ''How does a population's age structure affect its growth or decline?'' in chapter 6 of the prescribed book.

Content summary

Age structure diagrams are visual aids that show the distribution of males and females in each age group.

- The percentages of males and females in the total population are divided into the following age categories:

  – pre-reproductive ages span birth to 14 years of age
  – reproductive ages include ages 15 to 44
  – post-reproductive ages include ages 45 and up

- The major determining factor in a country's future population growth is the number of people under the age of 15.

  – In 2004, 30% of the planet's population was under 15.

- Changes in the distribution of a country's age groups have long-lasting economic and social impacts. An example of this is the ''baby boom'' generation in the United States.

  - Such a group can dominate the population's demands for goods and services.
  - They influence elections, legislation and economic demand.
  - The retirement of baby boomers in the United States can create a shortage of workers.

- The ''baby bust'' generation compared to that of the ''baby boom'' generation:
  - There will be fewer people to compete for education, jobs and services.
  - Too few people in the labour force can increase wages.
  - It might be more difficult to get job promotions because a larger ''baby boom'' group will occupy most upper-level positions.
  - There is an echo-boom that consists of people who have been born since 1977.
  - These fluctuations in the population age structure have social and economic effects for decades.

- Reduced fertility and population decline can have long-term consequences, especially if the decline is rapid.
  - The harmful effects of a gradual population decline can usually be managed.
  - There can be a sharp rise in the proportion of older people.
    - This produces a sharp rise in public service costs for health and so on.
    - It might have fewer working taxpayers and labour shortages.
    - It might be necessary to raise the retirement age, raise taxes, cut retirement benefits and increase legal immigration which are generally unpopular moves.

- If the population declines because of deaths, the consequences are serious.
  - Deaths from disease such as AIDS disrupt a country's social and economic structure.
  - Large numbers of people in a particular age are removed from the country's future.
    - Life expectancy drops.
    - In the case of AIDS, the deaths are mostly young adults (those who usually help run the country and everyday life for millions).
    - Two major goals are to reduce the spread of HIV through education and health care and to provide financial help for education, health care, and volunteer teachers and social workers to compensate for the lost young adults.

How can we slow human population growth?

Reading activity

Study the section ''How can we slow human population growth?'' in chapter 6 of the prescribed book.

Content summary

- The demographic transition hypothesis states that as countries become industrialised, first their death rates rise and then their birth rates decline.
- Family planning helps to reduce the number of births and abortions throughout the world.
  - Information is given on birth spacing, birth control and health care.
  - Family planning has been responsible for at least 55% of the drop in TFRs in developing countries.
  - Family planning has also reduced both legal and illegal abortions per year.
  - This comes through educational and clinical services.
    - Almost one-half of pregnancies in developing countries are unplanned and 26% end in abortion.
    - Women want to limit their pregnancies, but have no access to contraceptives.
  - Empowering women by providing education, paid jobs and support for their human rights can slow population growth.
    - Women work two-thirds of all working hours, but receive 10% of the world's income.

Read the case study: Population growth in China has been controlled through a strongly enforced government programme. Between 1972 and 2004, China's birth rate was cut in half. Couples with one child are rewarded with extra food, larger pensions, better housing, bonuses, free school tuition and preferential employment treatment for the child. China currently faces challenges that relate to a large elderly population and a larger male population (more males than females). As the economy continues to grow, China's ecological footprint is bound to expand.

Read the case study: India has tried to control its population growth for years. Poverty, malnutrition and environmental problems abound in India. Efforts to limit population have not been especially successful because poor couples believe they need several children for work and care. There is a strong preference for male children and many people do not use birth control. India is currently experiencing tremendous economic growth that will likely continue. This can not only increase the ecological footprint of the nation, but can also serve to hasten demographic transition.

Learning activities

Study the core case study at the beginning of chapter 6: Each week about 1,6 million people are added to the global population. Since most of this population and the projected growth is in developing countries, it leads to the question of whether there are enough resources to provide an adequate standard of living for the growing population. Some people argue that there are enough resources to support a growing population and that technological advances will enable even more growth. Others argue that environmental degradation can increase and that rising death rates might be a consequence of an increasing population.

Complete all the questions in the ''Thinking about'' textboxes of chapter 6.

Complete the review questions at the end of chapter 6.

Complete the critical thinking questions (except question 10) at the end of chapter 6.

Complete the ecological footprint analysis exercise at the end of chapter 6.

Section B

What is food security and why is it difficult to attain?

Reading activity

Study the section ''What is food security and why is it difficult to attain?'' in chapter 12 of the prescribed book.

Content summary

- Global food production has stayed ahead of population growth, but one in six people in developing countries cannot grow or buy the food they need.
- Some people cannot grow or buy enough food to meet their basic energy needs and get enough protein and other key ingredients. People need fairly large amounts of macronutrients (protein, carbohydrates and fats) and smaller amounts of micronutrients (such as vitamins A, C and E) and minerals (iron, iodine and calcium).
- One in three people has a deficiency of one or more vitamins and minerals, especially vitamin A, iron and iodine.
- Droughts, floods, wars and other catastrophic events can lead to severe food shortages that cause mass starvation, many deaths, and economic and social disruption.
- In the developed world, the problem is overnutrition, which leads to obesity, reduced life quality, poor health and premature death.

How is food produced?

Reading activity

Study the section ''How is food produced?'' in chapter 12 of the prescribed book.

Content summary

- Food production from croplands, rangelands, ocean fisheries and aquaculture has increased dramatically.
- Wheat, rice and corn provide more than half of the calories in the food consumed by the world's people.
- About 80% of the world's food supply is produced by industrialised agriculture.
- Many farmers in developing countries use low-input agriculture to grow a variety of crops on each plot of land.

- The large increases in crop production over the last half of the 20th century are the result of the green revolution. This includes selective breeding of crops; use of fertilisers, pesticides and irrigation; and multiple cropping systems.

Read the case study: The United States uses industrialised agriculture and green revolution techniques to produce about 17% of the world's grain.

What environmental problems arise from food production?

Reading activity

Study the section ''What environmental problems arise from food production?'' in chapter 12 of the prescribed book.

Content summary

- Soil erosion lowers soil fertility and can overload nearby bodies of water with eroded sediment. Soil is eroding faster than it is forming on more than one-third of the world's cropland.
- About one-third of the world's land has lower productivity because of drought and human activities that reduce or degrade topsoil.
- Repeated irrigation can reduce crop yields by causing salt build-up in the soil and waterlogging of croplands.
- Industrialised food production requires large amounts of energy.
- New genetically modified food crops can have unintended negative ecological consequences, including the creation of ''superweeds'' that are resistant to herbicides.
- Agriculture has caused large declines in biodiversity.
- Meat and aquaculture systems have numerous environmental impacts.

How can we protect crops agaisnt pests more sustainably?

Reading activity

Study the section ''How can we protect crops from pests more sustainably?'' in chapter 12 of the prescribed book.

Content summary

- Organisms are found in nature control populations of most pest species as part of the Earth's free ecological services.
- We use chemicals to repel or kill pest organisms as plants have done for millions of years. To help control pest organisms, we have developed a variety of pesticides.
- Pesticide use has increased 50-fold and toxicity has increase 10 to 100 times. Many pesticides are persistent in the environment and have significant impacts on human and animal health.

- Modern pesticides save lives, increase food supplies and increase profits for farmers.
- Pesticides do not work forever because pest species evolve resistance to particular chemicals (co-evolution).
- Pesticides can promote genetic resistance to their effects, wipe out natural enemies of pest species, create new pest species, end up in the environment, and sometimes harm wildlife and people.
- There are cultivation, biological and ecological alternatives to conventional chemical pesticides. A number of methods are available:
  - Fool the pest by using cultivation practices such as crop rotation.
  - Provide homes for pest enemies.
  - Implant genetic resistance.
  - Bring in natural enemies.
  - Use insect pheromones to lure pest insects into traps or to lure natural predators to crop fields.
  - Use hormones that disrupt the normal insect life cycle and prevent them from reaching maturity. The disadvantages are that they take weeks to kill an insect, are often ineffective if the infestation is large and has to be applied at the right time in the insect life cycle.
  - Scald them. Hot water sprayed on crops has worked well on cotton, alfalfa, potato fiends and citrus groves.

- Integrated pest management (IPM) is an ecological approach to pest control that uses a mix of cultivation and biological methods, and small amounts of selected chemical pesticides, as a last resort.

How can we improve food security?

Reading activity

Study the section ''How can we improve food security?'' in chapter 12 of the prescribed book.

Content summary

- Use government policies to improve food production and security.
- Simple and relatively inexpensive actions can have large impacts. One-half to two-thirds of nutrition-related childhood deaths can be prevented for $5 to $10 (R40 to R80 in 2011) per child per year.
  - Provide immunisation.
  - Encourage breastfeeding.
  - Prevent dehydration.
  - Prevent blindness with a vitamin A capsule twice a year, at a cost of 75 US cents per child (R5,60 in 2011).
  - Provide family planning services.
  - Increase education for women.

How can we produce food more sustainably?

Reading activity

Study the section ''How can we produce food more sustainably?'' in chapter 12 of the prescribed book.

Content summary

- Sustainable agriculture through soil conservation: soil conservation seeks ways to reduce soil erosion and restore soil fertility, mostly by keeping the soil covered with vegetation.
- Restore soil fertility by using organic fertilisers, reduce soil salinisation and desertification, and use sustainable aquaculture techniques.
- Eat lower on the food chain and slow population growth. (Read the science focus: Develop new agricultural techniques – sustainable polycultures.)

Read the case study: Soil erosion in the United States during the dust bowl years lead to dramatic changes in agricultural policy.

Learning activities

Study the core case study at the beginning of chapter 12: New techniques in genetic engineering offer new possibilities for improving nutrition and productivity, but these techniques also generate concerns.

Complete all the questions in the ''Thinking about'' textboxes of chapter 12.

Complete the review questions at the end of chapter 12.

Complete the critical thinking questions (except question 10) at the end of chapter 12.

Complete the data analysis exercise at the end of chapter 12.

In conclusion

In this study unit, you learned how humankind uses and abuses the Earth's terrestrial and aquatic ecosystems to obtain its food. Food production is fast destroying these life-sustaining resource bases and, with an ever-increasing world population, food for future generations (food security) has become one of humankind's most serious problem complexes. There are millions of hungry and malnourished people in the world. These people can be fed with the surplus food that is currently produced if it were not for the global politico-economic system. While people as thin as sticks are dying of hunger and nutritional deficiencies are recognised in Africa, alarm bells about a dangerously overfed American population are ringing in the United States. At the same time, the natural environment is taking an incessant hammering.

References

Engel, M. 2004. The war on terra firma. *Earthyear* 1/2004:2935.

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Study unit 7

Fresh water: The Earth's most precious resource

Introduction

In the previous study unit, you learned that humankind needs food to live. Peoples' need for water is even greater than their need for food; without water, no food can be produced. You also learned that millions of people go hungry even while the soil, plant and animal resources of the Earth have been and are being degraded to produce food for humankind. Much the same is true of fresh water. While more than a billion people do not have access to safe drinking water (Seager 1995), fresh water is being wasted through injudicious irrigation and polluted by industrial and other processes. With food, we still have a limited choice because one type of food can be substituted for another; however, there is no substitute for fresh water. Water is a unique substance. It truly is the Earth's most precious resource!

Although water covers 71% of the Earth's surface, fresh water constitutes a very small portion of the total volume of water on Earth. What fresh water there is, is unequally distributed. Some regions have an overabundance of fresh water, while others have a chronic shortage. Wars have been fought over water and it can happen again. Water has and always will be used as a bargaining chip in political and economic negotiations. Human beings have always devised schemes to get water from its source to where it is needed. Masterpieces of modern engineering have been constructed at huge expense to impound water or to transfer it over impressive distances to supplement insufficient natural supplies.

The natural shortages of fresh water are greatly aggravated by the mismanagement of resources, particularly by wastage (also called ''lack of conservation'') and pollution. Wastage is most evident in commercial agriculture, which accounts for 67 to 75% of the water that is consumed worldwide (McKinney & Schoch 2003). Pollution is particularly serious in developing countries where a lack of adequate sanitation for three billion people can lead to untreated sewage being discharged into drinking water resources, causing diarrhoea which alone kills 4,6 million young children per year (Lean et al 1990). In this study unit, you will learn that water, with its deceptively simple chemical composition (H_2O), has special chemical and physical properties that make it one of the most remarkable materials on Earth (McKinney & Schoch 2003). The availability, distribution, impoundment, transfer, harvesting, conservation and management of this unique resource are also covered.

Sources to consult

Prescribed book: Chapter 13 ''Water Resources''.

Additional resources

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https://my.unisa.ac.za/portal/

- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 7''.
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 7''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 7.

Learning outcomes

When you have completed this study unit, you should be able to

- analyse and predict the duration of our continued access to usable water
- analyse and evaluate the extent to which extracting groundwater, building more dams, transferring water from one place to another or converting salty seawater into fresh water is the key to addressing global water shortages
- discuss how water can be used more sustainably
- analyse how we can reduce the threat of flooding

Will we have enough usable water?

Reading activity

Study the section ''Will we have enough usable water?'' in chapter 13 of the prescribed book.

Content summary

- Water keeps us alive, moderates climate, sculpts the land, removes and dilutes wastes and pollutants, and moves continually through the hydrologic cycle.
- Only about 0,024% of the Earth's water supply is available to us as liquid fresh water in accessible groundwater deposits and in lakes, rivers and streams. The hydrologic cycle collects, purifies, recycles and distributes the world's freshwater supply. Some countries have more water than they need, while other countries have far less.
- Some precipitation infiltrates the ground and percolates downward through spaces in the soil, gravel and rock. This water is known as groundwater, which is an important freshwater source.
- Water that does not sink into the ground or evaporate into the air runs off into bodies of water. This is known as surface water.
- We currently use more than half (54%) of the world's reliable run-off of surface water and could be using 70 to 90% by 2025. About 70% of the water we withdraw from rivers, lakes and aquifers is not returned to these sources. This is because most freshwater use is consumptive use and does not return water to its original sources, mostly because of losses such as evaporation, seepage into the ground, transport to another area or contamination.

- Irrigation is the largest category of water use (70%), followed by industries (20%) and cities and residences (10%).

Read the case study: The United States has plenty of fresh water; however, supplies vary in different areas, depending on climate. This unequal distribution of water can be seen in figure 13-4. There are water hot spots in 17 western states (figure 13-5) that could trigger intense conflict in the next 20 years.

Miller & Spoolman (2011) use the word ''watershed'' to describe a catchment (or drainage basin) of a river. A watershed is not really the same thing as a catchment or drainage basin. The entire area of the Earth's surface that is drained by one river system is that river's catchment or drainage basin. All the run-off from that area flows to the different tributaries and eventually to the main stream (the big river), which ends in some ocean. A watershed is a high-lying area that separates the catchments or drainage basins of two streams. On the one side of the watershed, the run-off flows to the one stream and on the other side of the watershed, water flows to the other stream. It is not clear why Miller uses the word ''watershed'' to describe a catchment.

Is extracting groundwater the answer?

Reading activity

Study the section ''Is extracting groundwater the answer?'' in chapter 13 of the prescribed book.

Content summary

- Most aquifers are renewable resources, unless water is removed faster than it is replenished or the aquifers are contaminated. Aquifers provide almost one-fourth of the world's water.
- In many parts of the world, aquifers are being depleted faster than they are renewed.
  - Water tables are falling in many areas of the world because the rate of pumping out water (mostly to irrigate crops) exceeds the rate of natural recharge from precipitation.
  - The widespread drilling of inexpensive tube wells by small farmers, especially in Asia, has accelerated aquifer overpumping.
  - Saudi Arabia gets 70% of its water from the world's largest desalination complex.
- Groundwater overpumping can increase the gap between the rich and the poor, cause land to sink and contaminate freshwater aquifers near coastal areas with saltwater.
- Sustainable use of aquifer water requires controlling the rate of water removal, identifying and protecting aquifer recharge zones from development, wasting less water and slowing population growth. (See the science focus The possibility of deep aquifer water supplies.)

Read the case study: In the United States, groundwater is being withdrawn four times faster than it is being replenished. In the central United States, government subsidies to farmers have increased the depletion of the Ogallala aquifer.

Is building more dams the answer?

Reading activity

Study the section ''Is building more dams the answer?'' in chapter 13 of the prescribed book.

Content summary

- Although large dams and reservoirs can produce cheap electricity, reduce downstream flooding and provide year-round water for irrigating cropland, they also displace people and disrupt aquatic systems. Figure 13-12 shows both the benefits and drawbacks of dams and reservoirs.
- There is debate over whether the advantages of the world's largest dam and reservoir will outweigh its disadvantages.
- Some dams are removed for ecological reasons and because they have outlived their usefulness.

Read the case study: The Colorado River has so many dams and withdrawals that it often does not reach the ocean. The Colorado River is 2 250 km long and has been altered by 14 major dams and reservoirs to the point that water now rarely reaches the Gulf of California. This endangers many species that spawn in the river system and has led to increased salt contamination of aquifers near the coast.

Read the case study: When completed, the Three Gorges Dam on the Yangtze River (in China) will be the largest hydro-electric dam and reservoir in the world. 1,2 million people are being relocated to make way for the dam's construction. Proponents of the project say the dam will reduce China's dependence on coal and hold back the Yangtze's floodwaters. Opponents are concerned about the widespread ecological impacts the dam will have and the potential risk to populations if the dam were to collapse (the dam is built over a seismic fault and there is worry that millions of people will be killed if it does collapse).

Is transferring water from one place to another the answer?

Reading activity

Study the section ''Is transferring water from one place to another the answer?'' in chapter 13 of the prescribed book.

Content summary

- Transferring water can make unproductive areas more productive, but can also harm the environment.
- A massive transfer of water from water-rich northern California to water-poor southern California has brought many benefits, but remains controversial. Figure 13-17 gives an overview of the project.

Read the case study: Diverting water from the Aral Sea and its two feeder rivers (mostly for irrigation) has created a major ecological, economic and health disaster. This activity has tripled the salinity of the sea since 1961, the surface area has decreased and 90% of its water volume has been lost. About 85% of the area's wetlands have been eliminated and roughly half its birds and mammal species have disappeared. The fishing industry has also disappeared, and salt and contaminant-rich dust from exposed lake sediments are now a major pollution source for the region. Some artificial wetlands and lakes have been constructed to help restore the area's aquatic vegetation, wildlife and fisheries. With the various improvements, the water volume in the Aral Sea has stabilised (though at a much lower level than prior to water diversions).

Is converting salty seawater to fresh water the answer?

Reading activity

Study the section ''Is converting salty seawater to fresh water the answer?'' in chapter 13 of the prescribed book.

Content summary

- Removing salt from seawater by current methods is expensive and produces large amounts of salty wastewater that has to be disposed of properly. Methods include distillation, desalination and reverse osmosis. All these methods are technically challenging. (See the science focus: The search for improved desalination technology.)

How can we use water more sustainably?

Reading activity

Study the section ''How can we use water more sustainably?'' in chapter 13 of the prescribed book.

Content summary

- We waste about two-thirds of the water we use, but this waste can be cut to 15% through reduced evaporation and leakage and improved efficiency of use.
- 60% of the world's irrigation water is currently wasted. With improved irrigation techniques (such as centre-pivot, low-pressure sprinkler irrigation; low-energy precision application (LEPA) and drip irrigation systems), this waste can be reduced to 5 to 20%.

- Many poor farmers in developing countries use low-tech methods to pump groundwater and make more efficient use of rainfall.
- Industries can recycle much of the water they use; homeowners can use water-saving toilets and appliances, fix leaks, use drip irrigation and yard plants that need little water (xeriscaping), save and reuse rainwater, and reuse wastewater.

How can we reduce the threat of flooding?

Reading activity

Study the section ''How can we reduce the threat of flooding?'' in chapter 13 of the prescribed book.

Content summary

- Heavy rainfall, rapid snowmelt, the removal of vegetation and the destruction of wetlands cause flooding.
- We can reduce flooding risks by controlling river water flows, protecting mountainside forests, preserving and restoring wetlands, identifying and managing flood-prone areas, and (if possible) choosing not to live in such areas.

Read the case study: Bangladesh has experienced increased flooding because of upstream deforestation in the Himalayas and the clearing of mangrove forests on its coastal floodplains. Bangladesh is one of the world's most densely populated countries and is very flat. The people of Bangladesh depend on the moderate annual flooding to maintain soil fertility. Great floods used to occur about every 50 years but since the 1970s, they now occur about every four years.

Learning activities

Study the core case study at the beginning of chapter 13: Almost 41% of the world's population lives in river basins that do not have enough fresh water. More than 30 countries face water scarcity. This situation could reach 60 countries by 2050. Scarcity of water could increasingly lead to conflicts between countries.

Complete all the questions in the ''Thinking about'' textboxes of chapter 13.

Complete the review questions at the end of chapter 13.

Complete the critical thinking questions (except question 10) at the end of chapter 13.

Complete the ecological footprint analysis exercise at the end of chapter 13.

In conclusion

In this study unit, you learned why water is such a remarkable substance, how little fresh water is actually available to sustain terrestrial life and how precious every drop of fresh water really is. We should have no illusions: humankind is squandering this unique and most undervalued resource. In a few decades, there will simply not be enough

unpolluted fresh water to meet our needs. The only way most countries (developed and developing alike) can hope to cope with the mounting pollution in their freshwater resources is to evolve and implement integrated management strategies to not only help clean up water courses but also prevent pollution in the first place (Lean et al 1990). South Africa is one of the countries where integrated catchment management has been adopted as a policy. As yet, no country has fully managed to successfully implement this model and, unfortunately, real integration of water management has not proved possible in most countries. Despite the problems, it is clear that in order to safeguard the Earth's remaining water resources, integrated management of land and water will have to become the norm worldwide.

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Study unit 8

Energy drives it all

Introduction

Without energy, no life can exist. The global ecosystem is dependent on the continuous flow of energy. Life is maintained by the continuous conversion of energy from a higher to a lower quality and with every conversion, a little of the energy is lost as heat. Thus, as energy flows through the Earth's ecosystem, it becomes less useful. According to the second law of thermodynamics, all natural systems strive towards a state of maximum entropy (that is, the disorder or randomness in the system always increases until all the high-quality energy has been spent and converted into low-quality dispersed energy). The global ecosystem is therefore simply behaving as all natural systems should. And energy cannot be created, as determined by the first law of thermodynamics. If the sun does not continuously supply the Earth with ''new'' high-quality energy, the planet would long ago have dwindled into cold lifelessness.

The sun's energy maintains life on Earth. Humankind cannot harness the sun's energy efficiently enough to power factories, vehicles or air conditioners. We use the high-quality energy that has been stored – over many millions of years – within the system (in the form of fossil fuels) for this purpose. As technology has advanced, the amount of energy human beings use has increased dramatically. Energy consumption per capita in a technologically developed society today is at least a hundred times what it was when human beings first evolved and over six times what it was 200 years ago. Today, more people are living on Earth than at any time in the past, so total energy use has increased even more dramatically than per capita energy use. Fossil fuels are non-renewable and are now being used at an unsustainable rate. Concerns that we are running out of affordable fuel reserves are fully justified.

The more energy we use, the greater our detrimental impact on the environment because, as you already know, impact is the product of population times consumption. Virtually all our environmental problems can be traced back to energy use (McKinney & Schoch 2003): the use of fossil fuels is the major source of air pollution and global warming; mining for coal and oil has destroyed vast tracts of land; dams that are necessary for hydroelectric power production have wreaked havoc on natural ecosystems. In per capita fossil fuel use, the United States has no equal. The American nation has a gargantuan appetite for energy. Americans contribute a quarter of the world's carbon dioxide (CO_2) emissions (Engel 2004). In order to reduce the world's CO_2 emissions to a modest 7% below the 1990 levels, the United states will have to cut back their emissions by a third and this is clearly not going to happen (Engel 2004).

In this study unit, we evaluate the different types of renewable and non-renewable energy resources that are available to human beings and assess their environmental

impacts. We consider energy efficiency and alternative resources, which are less damaging, and also ways of simply using less energy. Right through this study unit, energy use (or overuse) in the United States receives special attention.

Sources to consult

Prescribed book: Chapter 14 ''Geology and Non-renewable Minerals'', chapter 15 ''Non-renewable Energy'' and chapter 16 ''Energy Efficiency and Renewable Energy''.

Additional resources

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- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 8''.
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 8''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 8.

Learning outcomes

When you have completed this study unit, you should be able to

- analyse and predict how long non-renewable mineral resources might last
- discuss how we can use mineral resources more sustainably
- describe the major sources of energy that we currently use
- compare the advantages and disadvantages of natural gas, coal and nuclear power
- explain why energy efficiency is an important energy source and discuss how we can waste less energy
- compare the advantages and disadvantages of solar and geothermal energy cycles and wind
- compare the advantages and disadvantages of biomass and hydrogen as energy sources
- discuss how we can make a transition to a more sustainable energy future
- explain some of the incentives that are offered to South Africans to conserve energy

Section A

What major sources of energy do we use?

..... *Reading activity*

Study the section ''What major sources of energy do we use?'' in chapter 6 of the prescribed book.

Content summary

- About 99% of the energy we use for heat comes from the sun and the remaining 1% comes mostly from burning fossil fuels. Without the sun's energy, there can be no life on Earth. The sun is a giant nuclear fusion reactor. It provides other indirect forms of renewable solar energy, such as wind, falling/flowing water and biomass.
- About 76% of the commercial energy we use comes from non-renewable fossil fuels, with the remainder coming from renewable sources. About 50% of the people in developing countries burn wood and charcoal to heat dwellings and to cook. (Read the science focus: Net energy is the amount of high-quality usable energy that is available from a resource after subtracting the energy that is needed to make it available for use. The net energy that is available for use is calculated by estimating the total energy that is available from the resource over its lifetime and subtracting the amount of energy that is used (the first law of thermodynamics), automatically wasted (the second law of thermodynamics), and unnecessarily wasted in finding, processing, concentrating and transporting the useful energy to users.)

What major sources of energy do we use?

Reading activity

Study the section ''What major sources of energy do we use?'' in chapter 6 of the prescribed book.

Content summary

- Crude oil is a thick liquid (containing hydrocarbons) that we extract from underground deposits in sedimentary bedrock and separate into products such as gasoline, heating oil and asphalt. Crude oil is transported to a refinery where it is broken down into components with different boiling points. This process accounts for about 8% of all the United States' energy consumption. Oil, like other fossil fuels, is located in reserves that are easily accessed and some that are not as easy to exploit.
- Eleven of the countries that are members of the Organisation of Petroleum Exporting Countries (OPEC) – most of them in the Middle East – have 78% of the world's proven oil reserves and most of the world's unproven reserves. Oil is the most widely used resource in the world. The United States imports about 60% of its oil. The United States, China and Japan are the top three oil importing countries.
- As global oil production peaks (or as demand exceeds supply as it does now), oil prices rise. These price increases are seen in the costs of food and fuel.
- The United States – the world's largest oil user – has only 2,9% of the world's proven oil reserves and only a small percentage of its unproven reserves. The country uses about 25% of the crude oil that is extracted worldwide each year. About 29% of the United States' domestic oil production and 21% of its domestic natural gas comes from offshore drilling, mostly in the Gulf of Mexico. Another 17% comes from Alaska's North Slope. The United States' oil production peaked in 1974. Most of the oil that is extracted costs $7.50–10/

barrel (R55–75/barrel) compared to about $1–2/barrel (R7.50–15/barrel) from Saudi Arabia.

- Conventional oil is a versatile fuel that can last for at least 50 years, but burning it produces air pollution and releases the greenhouse gas carbon dioxide into the atmosphere.
- Heavy and tar-like oils from oil sand (such as those that are currently mined in Alberta, Canada) and oil shale (located mostly in sub-economic reserves in Colorado, Utah and Wyoming) can supplement conventional oil, but extracting them create environmental problems (including their high sulphur contents and very high energy requirements for extraction). North-eastern Alberta in Canada has about three-quarters of the world's oil sand reserves. Oil shale reserves might have up to 240 times more global supplies than conventional oil. At present, it costs more to produce than the fuel is worth.

Read the case study: The Arctic National Wildlife Refuge (ANWR) might contain enough oil to meet seven to 24 months of the United States' demand, but is located in an ecological sensitive area.

What are the advantages and disadvantages of natural gas?

Reading activity

Study the section ''What are the advantages and disadvantages of natural gas?'' in chapter 6 of the prescribed book.

Content summary

- Natural gas consists mostly of methane and is often found above reservoirs of crude oil. Natural gas also contains small amounts of heavier hydrocarbons and a small amount of hydrogen sulphide. It provides about 23% of the United States' energy needs, heating about 53% of homes and providing about 12% of the country's electricity. The United States imports about 20% of its natural gas and this is expected to rise in the future. Imports come mostly from Canada. Natural gas is a versatile fuel that can be burned to heat space and water and to propel vehicles with fairly inexpensive engine modifications. Natural gas releases less CO_2 per unit of energy than burning oil, oil sand or coal.
- Coal beds and bubbles of methane that are trapped in ice crystals deep under the arctic permafrost and beneath deep-ocean sediments are unconventional sources of natural gas. Coalbed methane gas is found in coal beds across parts of the United States and Canada. These resources are now actively used, but have large potential impacts on air and water quality. Methane hydrate deposits are another source of unconventional natural gas and are found in the arctic permafrost and deep beneath the ocean bottom. Extraction techniques are too expensive at present, but are rapidly being developed. Methane hydrates have to be kept cold or they release methane into the atmosphere when they reach the surface.

- Russia and Iran have almost half the world's reserves of conventional natural gas. Global reserves should last 62 to 125 years. Natural gas use should increase because it is fairly abundant and has lower pollution and CO_2 rates/unit of energy compared to other fossil fuels. Projections suggest that natural gas should last the world at least 200 years at the present consumption rate and 80 years if usage rates increase 2% per year.
- Natural gas is a versatile and clean-burning fuel, but it releases the greenhouse gases carbon dioxide (when burned) and methane (from leaks) into the troposphere.

What are the advantages and disadvantages of coal?

Reading activity

Study the section ''What are the advantages and disadvantages of coal?'' in chapter 6 of the prescribed book.

Content summary

- Coal is an abundant energy resource that is burned mostly to produce electricity and steel. Coal is solid fossil fuel which is formed from land plants that lived 300 to 400 million years ago. It is mostly carbon with small amounts of sulphur and trace amounts of mercury. Burning coal releases SO_2, trace amounts of mercury and radioactive materials. Coal is burned in power plants to produce 62% of the world's electricity and three-quarters of the world's steel. In the United States, coal produces 50% of the electricity, followed by nuclear power (20%), natural gas (17%), renewable energy (10%) and oil (3%). Coal is extracted underground in dangerous circumstances (accidents and black lung disease). Area strip mining is used to extract coal that is close to the surface. Scars from this mining are rarely restored after mining is finished. In some cases of mountaintop mining, entire mountains have been removed and dumped into the valleys below to expose seams of coal.
- Coal reserves in the United States, Russia and China could last hundreds to thousands of years. Coal is the world's most abundant fossil fuel. The United States has 27% of the world's proven coal reserves, Russia has 17%, China has 13%, India has 10% and Australia has 9%. The coal reserves in the United States and China should last for about 300 years at current consumption rates. If coal consumption in the United States increases by 4% a year – as the industry projects – the reserves could last only 64 years.
- Coal is the most abundant fossil fuel. However, compared to oil and natural gas, it is not as versatile, has a much higher environmental impact and releases much more carbon dioxide into the troposphere. Coal has a severe environmental impact on air, water and land; over one-third of the world's annual CO_2 emissions come from coal.
- Coal can be converted to gaseous and liquid fuels that burn cleaner than coal, but the costs are high and burning them adds more carbon dioxide to the troposphere than burning coal. Coal can be converted into synthetic natural gas (SNG or syngas) through coal gasification or into liquid fuel through coal liquefaction. These procedures require that 50% more coal be mined and will add 50% more CO_2 emissions to the atmosphere. They also cost more to

produce than coal. Coal gasification plants can be designed to remove all carbon dioxide from their emissions (geological carbon sequestration).

Read the case study: At present, the use of coal in China is increasing rapidly.

What are the advantages and disadvantages of nuclear energy?

Reading activity

Study the section ''What are the advantages and disadvantages of nuclear energy?'' in chapter 6 of the prescribed book.

Content summary

- When isotopes of uranium and plutonium undergo controlled nuclear fission, the resulting heat produces steam that spins turbines to generate electricity. Control rods absorb neutron-absorbing materials, and move in and out of spaces between the fuel assemblies in the core. This regulates the rate of fission and the amount of power the reactor produces. A moderator (material that slows down neutrons) keeps the reaction going. This can be water, graphite or deuterium. A coolant (usually water) circulates through the core to remove heat to keep the components from melting and to produce steam for generating electricity.
- Even after more than 50 years of development and enormous government subsidies, the United States has not built a nuclear power plant since 1973 although this can change soon. The decision to stop the construction of nuclear facilities is related to fears of accidents (see the case study: Three Mile Island) and very high (and uncertain) construction costs. Disposal of high level nuclear waste is also a major concern.
- The nuclear power fuel cycle has a fairly low environmental impact and a very low accident risk. But costs are high, radioactive wastes have to be stored for thousands of years, facilities are vulnerable to terrorist attack and the spread of nuclear reactor technology gives more countries the knowledge to build nuclear weapons.
- There is long-term storage of high-level radioactive waste and there is scientific disagreement about the best approach to storage. (See the case study: Radioactive waste disposal in the United States.)

Read the case study: The world's worst nuclear power plant accident occurred in 1986 in the Ukraine. On April 26 1986, a series of explosions at the Chernobyl nuclear plant blew the roof off a reactor building, the reactor partially melted down, and its graphite moderator caught fire and burned for 10 days. The disaster was caused by poor reactor design and human error.

Learning activities

Study the core case study at the beginning of chapter 15: Based on different assumptions, geologists expect 80% of the world's oil to be depleted between 2050 and 2100.

Complete all the questions in the ''Thinking about'' textboxes of chapter 15.

Complete the review questions at the end of chapter 15.

Complete the critical thinking questions (except question 10) at the end of chapter 15.

Complete the ecological footprint analysis exercise at the end of chapter 15.

Section B

Why is energy efficiency an important energy source?

Reading activity

Study the section ''Why is energy efficiency an important energy source?'' in chapter 16 of the prescribed book.

Content summary

- Energy that is saved through efficiency reduces the need for the production of energy from another source. Energy efficiency is a measure of the useful energy that is produced compared to the energy that is converted to low-quality heat energy. About 84% of all commercial energy that is used in the United States is wasted. About 41% is wasted because of the degradation of energy quality that is imposed by the second law of thermodynamics. About 43% of the energy that is used in the United States is unnecessarily wasted by using such things as motor vehicles and furnaces and by living and working in leaky, poorly designed buildings. Since the 1980s, the United States has reduced the amount of energy that is used per person; however, unnecessary energy waste still costs the country about $300 billion (R2.25 trillion) per year.
- Net energy efficiency is how much useful energy we get from an energy resource after subtracting the energy that is used and wasted in making the energy available. Net energy efficiency includes the efficiency of each step in the process of making energy available for use. Two general principles for saving energy are:

  (1) Keep the number of steps in an energy conversion process as low as possible.
  (2) Strive to have the highest possible energy efficiency for each step in an energy conversion process.

How can we waste less energy?

Reading activity

Study the section ''How can we waste less energy?'' in chapter 16 of the prescribed book.

Content summary

- Industry can save energy and money by producing both heat and electricity from one energy source and by using more energy-efficient electric motors and lighting.
- We can save energy in transportation by increasing fuel efficiency and making vehicles from lighter and stronger materials.
- More energy-efficient vehicles are being produced and more are planned.
  - Hybrid gasoline-electric engines with an extra plug-in battery could be powered mostly by electricity that is produced by wind and get twice the mileage of current hybrid cars. There is increased interest in developing superefficient and ultra-light cars that could get 34–127 km per litre. Sales of hybrid vehicles are projected to grow rapidly and could dominate sales by 2025.
  - Fuel-efficient vehicles, which are powered by a fuel cell that runs on hydrogen gas, are on the road in California and more are being developed. The hydrogen fuel combines with oxygen in the air to produce water vapour and electrical energy for power. Fuel cells are at least twice as efficient as internal combustion engines. They have no moving parts and require little maintenance. They produce little or no pollution.
- We can save energy in buildings by getting heat from the sun, super-insulating them and using plant-covered green roofs. We can save energy in existing buildings by insulating them; plugging leaks; and using energy-efficient heating and cooling systems, appliances and lighting.

Read the case study: Dow Chemical cuts in energy consumption are an example of energy and cost savings.

What are the advantages and disadvantages of solar energy?

Reading activity

Study the section ''What are the advantages and disadvantages of solar energy?'' in chapter 16 of the prescribed book.

Content summary

- Solar energy offers two forms of heating: passive and active. We can heat buildings by orienting them toward the sun (passive solar heating) or by pumping a liquid such as water through rooftop collectors (active solar heating). The trade-offs are listed in figure 16-11.
- Building design can be used to maximise solar gain.
- Large arrays of solar collectors in sunny deserts can produce high-temperature heat to spin turbines and produce electricity, but costs are high. Solar thermal systems can collect and transform radiant energy to high-temperature thermal energy (heat), which can be used directly or converted to electricity. The trade-offs are given in figure 16-14.
- Solar energy can be used to provide electricity. Solar cells convert sunlight to electricity. The trade-offs are listed in figure 16-20, with the primary barrier to use being the high initial cost (though it falls rapidly). Photovoltaic (PV) cells/ solar cells convert solar energy directly into electrical energy. The solar cell is a transparent wafer that is energised by sunlight, which causes electrons in the semiconductor to flow and create an electrical current.

Read the case study: Rocky Mountain Institute (for an example of how buildings can be designed with passive solar principles).

What are the advantages and disadvantages of producing electricity from the water cycle?

Reading activity

Study the section ''What are the advantages and disadvantages of producing electricity from the water cycle?'' in chapter 16 of the prescribed book.

Content summary

- Water in rivers and streams can be trapped in reservoirs behind dams and released as needed to spin turbines and produce electricity. Hydropower is an indirect form of renewable solar energy. Hydropower supplied 20% of the world's electricity in 2004.
- The pros and cons are given in figure 16-21. There is pressure on the World Bank to stop funding large-scale dams because of their environmental and social consequences. Small-scale projects eliminate most of the harmful environmental effects of large-scale projects.
- Ocean tides and waves, and temperature differences between surface and bottom waves in tropical waters, are not expected to provide much of the world's electricity needs. The costs are high and there are few favourable locations for this technology.

What are the advantages and disadvantages of producing electricity from wind?

Reading activity

Study the section ''What are the advantages and disadvantages of producing electricity from wind?'' in chapter 16 of the prescribed book.

Content summary

- Wind power is the world's most promising energy resource because it is abundant, inexhaustible, widely distributed, cheap, clean and emits no greenhouse gases. The use of wind power has increased dramatically in the United States and Europe. The US Department of Energy points out that the Great Plains states could produce electricity from wind to more than meet the United States' electricity needs, although this power would not necessarily be available during periods of peak demand.
- The advantages and disadvantages of using wind power are shown in figure 16-23. Overall, wind power has more advantages and fewer disadvantages than any other energy resource.

What are the advantages and disadvantages of biomass as an energy source?

Reading activity

Study the section ''What are the advantages and disadvantages of biomass as an energy source?'' in chapter 16 of the prescribed book.

Content summary

- Plant materials and animal wastes can be burned to provide heat or electricity, or it can be converted into gaseous or liquid biofuels. Most biomass is burned directly for heating and cooking. This comprises up to 95% of the energy that is used in the poorest developing countries. The general advantages and disadvantages of burning solid biomass are listed in figure 16-24.
- Motor vehicles can run on ethanol, biodiesel and methanol that are produced from plants and plant wastes. The biggest producers (Brazil, the United States, the European Union and China) plan to double their production of biofuels by 2020. Biofuels have advantages over gasoline and diesel fuel. Crops that are used to produce biofuels can be grown almost anywhere. The plants have to be produced and harvested sustainably, resulting in no net increase in carbon dioxide. Biofuels are available now and are easy to store and transport. The rapid expansion of biofuels can (and might already) reduce the food that is available for consumption and result in higher food prices. Extensive use of biofuels can have dramatic impacts on the use of agricultural land.
- Crops (such as sugarcane, corn and switchgrass) and agricultural, forestry and municipal wastes can be converted to ethanol. Ethanol can be made through the fermentation and distillation of sugars in plants. Figure 16-26 lists the advantages and disadvantages of using biodiesel and figure 16-27 the pros and cons of ethanol as a vehicle fuel compared to gasoline.

Read the case study: Is ethanol the answer? Gasohol is made of gasoline that is mixed with 10 to 23% of pure ethanol and can be used in gasoline engines. If all of the corn that is grown in the United States were used for ethanol production, it would cover only about 55 days of current driving and leave none for cattle feed and food. Another approach is to use cellulosic ethanol, which entails using bacteria to convert plant cellulose (the non-food portions of the plant) into ethanol. This is not yet widely available.

What are the advantages and disadvantages of geothermal energy?

Reading activity

Study the section ''What are the advantages and disadvantages of geothermal energy?'' in chapter 16 of the prescribed book.

Content summary

- We can use geothermal energy that is stored in the Earth's mantle to heat and cool buildings and to produce electricity. Geothermal heat pumps use a pipe and duct system to retrieve heat that is stored in underground rocks and fluids. The Earth is used as a heat source in winter and a heat sink in summer. Geothermal exchange or geo-exchange uses buried pipes that are filled with fluid to move heat in or out of the ground for heating/cooling needs. The US Environmental Protection Agency (EPA) declared this the most energy-efficient, cost-effective and environmentally clean way to heat or cool a building. The advantages and disadvantages of geothermal energy are listed in figure 16-29.

What are the advantages and disadvantages of hydrogen as an energy source?

Reading activity

Study the section ''What are the advantages and disadvantages of hydrogen as an energy source?'' in chapter 16 of the prescribed book.

Content summary

- Some energy experts view hydrogen gas as the best fuel to replace oil during the last half of this century, but there are several hurdles to overcome. Hydrogen gas can be produced from water and organic molecules, and produces non-polluting water vapour when burned. Widespread use of hydrogen as a fuel would eliminate most of the air pollution problems we face today, but it takes energy and money to produce hydrogen from water and organic compounds. It is not a source of energy; it is a fuel that is produced by using energy.
- Current versions of fuel cells are expensive, but are the best way to use hydrogen to produce electricity. Whether a hydrogen-based energy system produces less carbon dioxide than a fossil fuel depends on how the hydrogen is produced. H fuel can be produced by electricity from coal-burning power plants, from coal itself or by stripping it from organic compounds, but this can add more carbon

dioxide to the atmosphere. It might be possible to produce hydrogen by growing bacteria and algae that will produce hydrogen rather than oxygen as a by-product.

- Iceland plans to run its economy mostly on hydrogen, but doing this in industrialised nations is more difficult. The United States gets 65% of its electricity from burning non-renewable coal and natural gas and only 10% from renewable hydro-electric power. Changing this will present a difficult political and cultural challenge. Running motor vehicles on hydrogen would require building and strategically placing at least 12 000 hydrogen-fuelling stations throughout the United States at a cost of $1 million (R7.5 million) each. The advantages and disadvantages of using hydrogen for fuel are given in figure 16-31.

How can we make a transition to a more sustainable energy future?

Reading activity

Study the section ''How can we make a transition to a more sustainable energy future?'' in chapter 16 of the prescribed book.

Content summary

- Decisions about energy for the future require consideration of long periods of time (decades) and considerable investment in infrastructure. Figure 16-32 shows a potential mix of energy solutions for the future.
- There are three general conclusions about energy transformations:

  (1) There will be a gradual shift from large, centralised macropower systems to smaller, decentralised micropower systems.
  (2) The best alternatives combine improved energy efficiency and the use of natural gas and sustainably produced biofuels in making the transition to a diverse mix of locally available renewable-energy resources.
  (3) Because of their abundance and price, fossil fuels will continue to be used in large quantities. This means that there will still be a need to find ways to reduce the environmental impacts of these fuels.

- Governments can use a combination of subsidies, tax breaks, rebates, taxes and public education to promote or discourage the use of various energy alternatives. Economics and politics are basic strategies to help stimulate or dampen the short-term and long-term use of a particular energy resource. (See the case study: California efforts to improve energy efficiency.)

Learning activities

Study the core case study at the beginning of chapter 16: Iceland. In deeper and more concentrated underground hydrothermal reservoirs of geothermal energy, we find dry steam (with no water droplets) and wet steam (steam and water droplets). There is also hot water trapped in porous or fractured rock. Wells can be used to withdraw wet and dry steam, as well as hot water, for heat or to produce electricity.

Complete all the questions in the ''Thinking about'' textboxes of chapter 16.

Complete the review questions at the end of chapter 16.

Complete the critical thinking questions (except question 10) at the end of chapter 16.

Complete the ecological footprint analysis exercise at the end of chapter 16.

In conclusion

Humankind does not use energy in an efficient way and energy is the one thing that cannot be recycled. We – especially the United States – are wasting the energy that has been stored in fossil fuels. In the process, enormous environmental damage is being done. Despite all the research, no safe, affordable and environment-friendly alternative energy source has yet been found. Right now, the use of fossil fuels seems set to continue until the reserves are exhausted or become too expensive. Fossil fuel use and the air pollution and surface destruction that are associated with it are set to continue. More and more greenhouse gases will be poured into the atmosphere, making the consequences of global warming all the more real (as you will learn in the following study units). These are realities that we have to deal with. Another reality that we have to face is that the entire world is held to ransom by the United States. With its insatiable greed for energy, the United States can change the whole world's climate. A sobering thought, indeed.

References

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Study unit 9

The air we breathe

Introduction

In the previous study unit, you learned that energy use (more specifically the burning of fossil fuels and biomass) causes air pollution. Air pollution is one of humankind's oldest environmental problems. Although the concept of environmental problems did not form part of human thinking during the Middle Ages, the thick haze of wood smoke that hung over the cities was well known and well described. As early as the middle of the 19th century, people realised that air pollution was a problem with serious risks to human health. During the industrial revolution, coal-burning factories in cities belched huge volumes of noxious smoke into the atmosphere. Under certain weather conditions, this smog – a mixture of fog and smoke – became a lethal concoction that killed thousands. That city air was unbearable and dangerously polluted was unquestioningly accepted for a century. Only after this, driven by concerns for human health, did the clean-up start with strict anti-air pollution legislation and industrial standards. Today, cities in Western Europe and North America are largely smogless (except on so-called smoggy days and under specific weather conditions). The same cannot be said of cities in other parts of the world where industrial production takes precedence and control measures are lax.

Despite the strict pollution controls of developed countries (such as the United States) that are still the largest producers of pollutants and despite international cooperation to reduce air pollution, this problem is not something of the past. Air pollution continues to be humankind's most recognised environmental issue because it is so widespread and occurs at all scales: indoor, local, urban, regional and global (McKinney & Schoch 2003). In the 1980s and early 1990s, local and regional pollution received more attention than global and indoor pollution. However, it is at the indoor and local (urban) scales that regulation and control have had the most success, while the regional and global varieties are still proving problematic because polluters are often very far from those who are damaged by their emissions (McKinney & Schoch 2003).

In this study unit, we discuss the different types of air pollutants and their effects. We explain the reasons why certain climatic and weather conditions (synoptic conditions) worsen the local and regional effects of air pollution. Lastly, we consider solutions and prevention measures. The knowledge you gained in study unit 2 about chemical compounds is indispensable in understanding this study unit. You have to understand the chemistry of the pollutants and be able to read and write the reactions and compounds in ''science language''. The natural laws of matter and energy are, of course, important as always because now the consequences of ''there is no away'' become apparent.

Sources to consult

Prescribed book: Chapter 18 ''Air Pollution'' and chapter 19 ''Climate Change and Ozone Depletion''.

Additional resources

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- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 9''.
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 9''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 9.

Learning outcomes

When you have completed this study unit, you should be able to

- describe the nature of the Earth's atmosphere
- discuss the major challenges that are associated with indoor and outdoor air pollution and propose practical solutions to overcome the effects of air pollution
- describe acid deposition and analyse its consequences on the environment
- describe the effects of air pollution on health and discuss how we should deal with air pollution
- describe how the Earth's temperature and climate might change in the future
- discuss the possible effects of a warmer atmosphere
- identify and analyse some of the solutions to overcoming climate change
- explain the significance of the ozone layer in the stratosphere and discuss what interventions can be introduced to sustain the ozone layer

Section A

What is the nature of the atmosphere?

Reading activity

Study the section ''What is the nature of the atmosphere?'' in chapter 18 of the prescribed book.

Content summary

- The atmosphere consists of several layers with different temperatures, pressures and composition. Density and atmospheric pressure vary throughout the atmosphere due to gravitational forces that pull the gas molecules toward the Earth's surface. Air at sea level has a higher density than air at the top of a mountain.

- About 75 to 80% of the Earth's air mass is found in the troposphere, the atmospheric layer closest to the Earth's surface. This layer extends about 11 miles (17.5 km) above sea level at the equator and about five miles (8 km) above the poles. About 99% of the volume of air is made up of nitrogen (78%) and oxygen (21%), with the rest consisting of water vapour, argon, carbon dioxide and traces of several other gases.
- The stratosphere is the second layer of the atmosphere and extends from 11 to 30 miles (18–48 km) above the Earth's surface. The concentration of ozone in this layer is much higher than in the troposphere. Ozone is produced when oxygen molecules interact with ultraviolet radiation ($3\ O_2 + UV \rightarrow 2\ O_3$). This ''global sunscreen'' keeps about 95% of the sun's harmful UV radiation from reaching the Earth's surface.

What are the major outdoor air pollution problems?

Reading activity

Study the section ''What are the major outdoor air pollution problems?'' in chapter 18 of the prescribed book.

Content summary

- Air pollutants come mostly from natural sources and from burning fossil fuels. Primary pollutants are pollutants that are emitted into the air. They react with one another and/or with air to form secondary pollutants.
- Outdoor air pollution comes mostly from natural sources, burning fossil fuels in vehicles and for power, and industrial plants. Chemicals in the atmosphere in concentrations that are high enough to affect climate, materials and health are what constitute air pollution.
- Photochemical smog is formed by the reaction of nitrogen oxides and volatile hydrocarbons under the influence of sunlight. Industrial smog is a mixture of sulphur dioxide, droplets of sulphuric acid and a variety of suspended solid particles that are emitted by burning coal and oil.
- Air pollution is influenced by atmospheric conditions. Inversions: A layer of warm air that sits on top of a layer of cool air near the ground can prevent outdoor pollutants from rising and dispersing. A temperature inversion (where a layer of warm air sits over a layer of cold air) prevents any mixing and, therefore, dense, colder air becomes stagnant and accumulates more pollutants. This is a particular problem for cities in a valley (for example Los Angeles and Johannesburg).

What is acid deposition and why is it a problem?

Reading activity

Study the section ''What is acid deposition and why is it a problem?'' in chapter 18 of the prescribed book.

Content summary

- Acid deposition occurs when sulphur dioxide, nitrogen oxides and particulates react in the atmosphere to produce acidic chemicals that travel long distances before returning to Earth. Acidic particles remain in the atmosphere for two to 14 days, depending on the prevailing winds, precipitation and other weather patterns. The acidic substances return to Earth in one of two forms:
  (1) *wet deposition* as acidic rain, snow, fog and cold vapour with a pH of less than 5,6
  (2) *dry deposition* as acidic particles

- Acid deposition can cause or worsen respiratory disease, attack metallic and stone objects, decrease atmospheric visibility and kill fish.
- Acid deposition can deplete some soil nutrients, release toxic ions into soil and weaken plants that become susceptible to other stresses. The effect of acid deposition on plants is caused partly by chemical interaction in the soil. (Read the science focus: Hubbard Brook ecosystem studies.)
- The 1990 amendments to the Clean Air Act in the United States have lead to significant reductions in SO_2 and NO_x emissions. A number of prevention and control methods can further reduce acid deposition, but they are politically difficult to implement. The best approaches are those that reduce or eliminate emissions of SO_2, NO_x, and particulates. The use of low sulphur coal is both good and bad: it lowers the amount of SO_2 that is released but because more coal has to be burned to generate the same amount of electricity, it emits more mercury, CO2 and radioactive particles.

What are the major indoor air pollution problems?

Reading activity

Study the section ''What are the major indoor air pollution problems?'' in chapter 18 of the prescribed book.

Content summary

- Indoor air pollution is usually a much greater threat to human health than outdoor air pollution. EPA studies have shown that levels of 11 common pollutants are two to five times higher inside homes and commercial buildings than outside. Inside cars in traffic-clogged areas, the pollution can be 18 times higher than outside. Health risks are magnified because people usually spend 70 to 98% of their time indoors or in vehicles.
- Formaldehyde is a chemical that causes difficulties for most people in developed countries. It is used to manufacture common household materials.

Read the case study: Radon-222 gas is found in some soils and rocks. It can seep into homes and increase the risk of lung cancer. Radon is produced by the radioactive decay of Uranium-238. Radon gas tends to be pulled into homes because of the slightly lower atmospheric pressure inside most homes. Radon is thought to be the second leading cause of lung cancer deaths each year in the United States.

What are the health effects of air pollution?

Reading activity

Study the section ''What are the health effects of air pollution?'' in chapter 18 of the prescribed book.

Content summary

- Your respiratory system helps to protect you from air pollution in several ways, for example hairs in your nose filter out large particles. However, prolonged or acute exposure to air pollutants can overload or break down your natural defences and you can get respiratory diseases, such as asthma, lung cancer, chronic bronchitis and emphysema. People with respiratory diseases, older adults, infants, pregnant women and people with heart disease are especially vulnerable to air pollution.
- Each year, air pollution kills about 3 million people, mostly from indoor air pollution in developing countries. Air pollution deaths in the United States range from 150 000 to 350 000 people per year.

How should we deal with air pollution?

Reading activity

Study the section ''How should we deal with air pollution?'' in chapter 18 of the prescribed book.

Content summary

- Clean Air Acts in the United States have greatly reduced outdoor air pollution from six major pollutants. The United States Congress passed Clean Air Acts in 1970, 1977 and 1990. National air quality standards (NAAQS) were established for six outdoor criteria pollutants. Two limits were established: a primary standard to protect human health and a secondary standard to prevent environmental and property damage.
- Outdoor air pollution in the United States has been reduced since 1970. However, problems continue, including whether CO_2 should be regulated as an air pollutant, high levels of ozone in some urban areas, problems with acid rain and problems with indoor air quality.
- Allowing producers of air pollutants to buy and sell government air pollution allotments in the marketplace can help to reduce emissions. In the United States, the Clean Air Act of 1990 allows an emissions trading policy that permits companies to buy and sell SO_2 pollution rights. This cap-and-trade approach can be an improvement over command-and-control as long as it reduces SO_2 emissions. The cap can gradually be lowered.
- There are a number of ways to prevent and control air pollution from coal-burning facilities and motor vehicles. Indoor air pollution is a greater threat to human health, but little effort has been made to reduce it.

Learning activities

Study the core case study at the beginning of chapter 18: South Asia's massive brown cloud.

Complete all the questions in the ''Thinking about'' textboxes of chapter 18.

Complete the review questions at the end of chapter 18.

Complete the critical thinking questions (except question 10) at the end of chapter 18.

Complete the data analysis exercise at the end of chapter 18.

Section B

How might the Earth's temperature and climate change in the future?

Reading activity

Study the section ''How might the Earth's temperature and climate change in the future?'' in chapter 19 of the prescribed book.

Content summary

- Temperature and climate have been changing throughout the Earth's history. Climate shifts occur due to volcanic emissions, changes in solar input, continents moving on shifting plates, meteor strikes and other factors. Alternating cycles of freezing and thawing are known as glacial and interglacial periods.
- Geologic records and atmospheric measurements provide a wealth of information about past atmospheric temperatures and climates. On average, over the past 900 000 years, there has been a cycle of glaciations (~90 000 years) and interglacials (~10 000 years).
- Certain gases in the atmosphere absorb heat and warm the lower atmosphere. A natural process that is called the greenhouse effect warms the lower troposphere and surface.
- The four major greenhouse gases in the lower atmosphere are: (1) water vapour, (2) carbon dioxide, (3) methane and (4) nitrous oxide.
- Climate change and human activities.
  - Human beings have increased the levels of greenhouse gases in the troposphere through the use of fossil fuels, farming, the use of inorganic fertilisers, burning forests and so on. Greenhouse gases are at higher levels than in the past 160 000 years. Burning fossil fuels has generated much of the CO_2 increase; deforestation and clearing grasslands release CO_2 and N_2O; increased raising of cattle and other livestock has added methane release; the use of inorganic fertilisers in rice cultivation releases N_2O into the troposphere.
  - There is evidence that the Earth's troposphere is warming, mostly because of human actions. The Intergovernmental Panel on Climate Change (IPCC) was formed in 1988 to evaluate possible future climate changes. Conclusions

and projections use several levels of certainty: virtually certain (a more than 99% probability), very likely (a 90–99% probability) and likely (a 66–90% probability). See the science focus: The seven findings of the IPCC which support the scientific consensus that the troposphere is most likely getting warmer are:

(1) The 20th century was the hottest century in the past millennium.
(2) Since 1861 the average global temperature has risen 0,6 degrees centigrade, with most of the increase occurring since 1980.
(3) The 10 warmest years since 1861 occurred since 1990.
(4) Over the past 50 years, Arctic temperatures have risen almost twice as fast as those in the rest of the world.
(5) Glaciers and floating sea ice in some parts of the world are melting and shrinking at increasing rates.
(6) Warmer temperatures in Alaska and Russia are melting the permafrost, releasing more greenhouse gases into the troposphere.
(7) The world's average sea level has risen by four to eight inches (10–20cm).

– There is strong evidence that human activities will play an important role in changing the Earth's climate during this century.

  ■ ''Global warming'' refers to temperature increases in the troposphere, which can cause climate change.
  ■ ''Global climate change'' is a broader term that refers to changes in any aspect of the Earth's climate.

– A rapid increase in the temperature of the troposphere during this century will give us little time to deal with its harmful effects.

What are some possible effects of a warmer atmosphere?

Reading activity

Study the section ''What are some possible effects of a warmer atmosphere?'' in chapter 19 of the prescribed book.

Content summary

- A warmer troposphere can have both beneficial and harmful effects. Rich, temperate countries will likely benefit from moderate global warming, while poorer tropical and subtropical countries will experience more harmful effects.
- The melting of some of the world's ice means that less sunlight is reflected back into space, which helps to warm the troposphere further. (See the science focus: Melting ice in Greenland.)
- Global sea levels will likely rise during this century. The projected rise in sea level is about 0,6 to 1,9 feet (18–59 cm), but higher amounts are possible.
- Global warming can alter ocean currents and cause excessive warming in some parts of the world and severe cooling in others.
- A warmer troposphere can decrease the ability of the ocean to remove and store carbon dioxide by decreasing the nutrient supply for phytoplankton and increasing the acidity of ocean water.

- Global warming will lead to prolonged heat waves and droughts in some areas and prolonged heavy rains and increased flooding in other areas.
- A warmer troposphere will change the distribution and population sizes of wild species, shift locations of ecosystems, and threaten some protected reserves and coral reefs.
- Global warming will increase deaths from heat, disrupt food supplies in some areas, spread some tropical diseases to temperate areas, and greatly increase the number of environmental refugees from drought and flooding.

What can we do to slow climate change?

Reading activity

Study the section ''What can we do to slow climate change?'' in chapter 19 of the prescribed book.

Content summary

What can we do to slow climate change?

- Climate change is difficult to deal with because it has many causes, its effects are uneven and long term, and there is disagreement over what should be done.
  - The problem is global.
  - The effects will last a long time.
  - The problem is a long-term political issue.
  - The harmful and beneficial impacts of climate change are not spread evenly.
  - Many actions that can reduce the threat of climate change, such as phasing out fossil fuels, are controversial because they can disrupt economics and lifestyle.
  - These factors confront us with difficult scientific, economic, political and ethical issues.

- There is disagreement over what we should do about the threat of global warming. There are two basic ways to deal with global warming; one is mitigation and the other is adaptation.
- The solutions that are offered for slowing the rate and degree of global warming come down to three major strategies: (1) improve energy efficiency to reduce fossil fuel use, (2) shift from carbon-based fossil fuels to a mix of carbon-free renewable energy resources and (3) sequester or store as much CO_2 as possible in soil, in vegetation, underground and in the deep ocean.
- We can remove and store some of the CO_2 that we produce as shown in figure 19-15.
- Governments can tax emissions and energy use, increase subsidies and tax breaks for saving energy and using renewable energy, and decrease subsidies and tax breaks for fossil fuels.
- It will probably cost less to help slow and adapt to global warming now than to deal with its harmful effects later. It is projected that global warming will cost the world $300 billion (R2250 billion) annually by 2050.

- The Kyoto Protocol, which was developed in 1997, requires 38 developed countries to cut emissions of some gases by about 5,2% below 1990 levels by 2012.

Read the case study: California emission reductions. Many countries, states, cities, companies, schools and individuals are reducing their greenhouse gas emissions, improving energy efficiency and increasing their use of carbon-free renewable energy.

How have we depleted ozone in the stratosphere and what can we do about it?

Reading activity

Study the section ''How have we depleted ozone in the stratosphere and what can we do about it?'' in chapter 19 of the prescribed book.

Content summary

- Widespread use of a number of useful and long-lived chemicals has reduced ozone levels in the stratosphere. The first, chlorofluorocarbon (CFC), was discovered in 1930 by Thomas Midgley and became widely used in cooling and other industrial applications.
- CFCs remain in the atmosphere because they are insoluble in water and chemically unreactive.
  - These chemicals are lifted into the stratosphere over 11 to 20 years, mostly by convection currents and the turbulent mixing of air. CFC molecules break down under the influence of high-energy UV radiation. Chlorine is released and is highly reactive. Fluorine, bromine and iodine are also released. This causes ozone to be broken down faster than it is formed. (Read the science focus: Ozone chemistry.)

- During four months each year, up to half of the ozone in the stratosphere over Antarctica and a smaller amount over the Arctic are depleted. Ozone loss is often called the ozone hole, but it is actually ozone thinning. The polar vortex is a swirling mass of very cold air that is isolated from the rest of the atmosphere for several months. Ice crystals in this mass collect CFCs and other chemicals and set up conditions for the formation of ClO, the molecule that is most responsible for seasonal loss of ozone.
- Increased UV radiation that reaches the Earth's surface due to ozone depletion in the stratosphere is harmful to human health, crops, forests, animals, and materials such as paints and plastics. The effects of ozone depletion are listed in figure 20-21.
- Exposure to UV radiation is a major cause of skin cancers. The primary cause of squamous cell and basal cell skin cancers is years of exposure to UV-B radiation. Fortunately, 90 to 95% of these cancers can be cured if they are detected early enough. Malignant melanoma is a third type of skin cancer that occurs anywhere on the body. It kills a fourth of its victims (most under the age of 40) within five years.
- Protecting the ozone layer.

– The goal of the 1987 Montreal Protocol was to cut emissions of CFCs by about 35% between 1989 and 2000. Representatives met again in 1990 and 1992 and adopted the Copenhagen Protocol (an amendment to the Montreal Protocol) that accelerated the phase-out of key ozone-depleting chemicals. These agreements have now been signed by 180 countries.

Learning activities

Study the core case study at the beginning of chapter 19: Computer models are used to project future changes in the Earth's average temperature.

Complete all the questions in the ''Thinking about'' textboxes of chapter 19.

Complete the review questions at the end of chapter 19.

Complete the critical thinking questions (except question 10) at the end of chapter 19.

Complete the ecological footprint analysis exercise at the end of chapter 19.

In conclusion

Now you know how air pollution happens and what it does to our health, our water, our soil and our forests on local and regional scales. All the pollutants that we have been pumping into the atmosphere for 200 years have in fact already changed the composition of the atmosphere. The global climate and life on Earth are, to a greater or lesser degree, determined by and adapted to the composition of the atmosphere. If the composition of the atmosphere is changed, changes to other components of the global ecosystem will surely follow. In the next study unit, we will concentrate on the global climate change and ozone loss that have probably resulted from centuries of sustained air pollution.

References

McKinney, ML & Schoch, RM. 2003. *Environmental science: systems and solutions.* London: Jones & Bartlett.

Study unit 10

Destroying the Earth with waste

Introduction

As if you have not heard enough about the waste humankind dumps in the environment, we will now look at the mountains of solid and hazardous waste that are growing by the day. The amount of waste that is generated every year is staggering (McKinney & Schoch 2003). No one really knows how much waste human beings generate, but much of it originates from the developed countries since wealth tends to generate far more waste than poverty. Just as the Unites States is the leader in energy consumption and pollution, it also produces the most waste per capita (McKinney & Schoch 2003). Depending on how the calculation is made, the United States generates an estimated 5,4 to 9 billion metric tons of solid waste per year. This amounts to nearly 20 metric tons of waste per person per year, or slightly more than 54 kg per day! Most waste in the United States is not directly generated by individual Americans, but by mining, agriculture and industrial operations. Yet, these operations exist to provide the food and consumer goods people need and want. Municipal solid waste (household rubbish that consists of things like paper, plastic wrapping, packaging, polystyrene, tins and empty bottles) makes up only 2 to 4% of the United States' enormous mountain of solid waste. The only ray of hope is that more than a quarter of the municipal waste in the United States is recycled or otherwise recovered (McKinney & Schoch 2003). However, compared with the total amount of solid waste that is generated, this is insignificant.

Although the United States far outstrips any other country in waste production, solid waste is being generated by every citizen of the world. Globally, the total amount of waste that is generated every day is horrendous. No one knows how much it is, but it is way too much. The Earth is being turned into one big waste dump. People tend to think that when waste has been dumped in a landfill or waste dump, it is ''gone''. But, of course, nothing just ''goes away''.

Solid waste is one of humankind's most pressing environmental problems. The situation is already unsustainable. If we continue to generate solid waste as we do, it spells disaster. In the developed countries, a sincere effort is being made to reduce the waste stream through reuse and recycling. However, as we pointed out above, this takes care of a very small part of the total waste load. Moreover, in the developing countries the amount of waste that is recycled is negligible.

What is most disconcerting is that a portion of the total waste load is toxic or hazardous. Developed countries do not want to have this dangerous waste in their own backyards, so they export it to some developing countries that are only too eager to accept it for a handsome fee. The major producers of hazardous waste are once again the United States and Western Europe, with Germany being by far the chief exporter of

this type of waste (Seager 1995) and France not far behind. In the late 1980s, African states began to reject shipments of hazardous waste and in 1991 they signed the Bamako Convention that prohibits importing hazardous wastes into Africa (Glazewski 2000). By 1993, South Africa was the only African state which had not banned the import of hazardous waste (Seager 1995). This was still the case in 2010 and South Africa has to date neither signed nor acceded to the Bamako Convention (Glazewski 2000). Shipments of hazardous waste are still arriving in South African waters and ports, but some are now rejected on an ad hoc basis after an outcry from environmental watchdogs and NGOs. No outright ban has been issued and it is not quite clear whether the country still imports hazardous waste. However, it is fairly certain that it still accepts some radioactive nuclear waste despite the fact that the Basel Convention – to which South Africa is a signatory – specifically excludes radioactive material (Glazewski 2000).

Sources to consult

Prescribed book: Chapter 21 ''Solid and Hazardous Waste''.

Additional resources

***my*Unisa**

https://my.unisa.ac.za/portal/

- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 10''.
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 10''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 10.

Learning outcomes

When you have completed this study unit, you should be able to

- explain how solid and hazardous waste contribute to environmental degradation
- identify and analyse relevant solutions to overcome the challenges of solid and hazardous waste
- discuss ''reducing, reusing and recycling'' materials
- compare and explain the advantages and disadvantages of burning or burying solid waste
- discuss strategies for how we can make the transition to a more sustainable low-waste society

What are solid waste and hazardous waste, and why are they problems?

Reading activity

Study the section ''What are solid waste and hazardous waste, and why are they problems?'' in chapter 21 of the prescribed book.

Content summary

- Solid waste is any discarded material that is not liquid or gas.
  - Industrial solid waste is produced by mines, agriculture and industry.
  - Municipal solid waste (MSW) is produced by homes and workplaces.
- Hazardous or toxic waste is poisonous, reactive, corrosive or flammable.
  - It includes radioactive waste.
- The United States has 4,6% of the world's population, but produces about one-third of the world's solid waste.
  - The United States leads the world in rubbish production per person.

Read the case study: Residents of New York City are actually throwing away less rubbish today than they have historically. Despite mandatory recycling, the city has run out of landfill space. It now has to ship its rubbish to other states, sometimes as much as 300 miles (480 km) away. As oil prices rise, this practice can become prohibitively expensive.

How should we deal with solid waste?

Reading activity

Study the section ''How should we deal with solid waste?'' in chapter 21 of the prescribed book.

Content summary

- One method to reduce waste and pollution is to implement waste management. This high-waste approach accepts waste production as a result of economic growth.
  - It attempts to reduce environmental harm.
  - It transfers the waste from one part of the environment to another.
- The other method is waste reduction. This low-waste approach sees solid waste as a potential resource that should be reused, recycled or composted.
  - It discourages waste production in the first place.
  - It encourages waste reduction and prevention. (See the science focus: Garbologists, who study the composition of landfills like archaeologists, have found that items in landfills can resist decomposition for long periods of time due to compaction.)
- Waste reduction is based on the three Rs: reduce, reuse and recycle.
- In order to cut waste production and promote sustainability, we have to reduce consumption and redesign our products. There are seven priorities for doing this.

(1) Redesign manufacturing processes and products in order to use less material and energy.
(2) Redesign manufacturing processes in order to produce less waste and pollution.
(3) Develop products that are easily repaired, reused, remanufactured, composted or recycled.
(4) Eliminate or reduce unnecessary packaging.
(5) Introduce a fee-per-bag system of waste collection.
(6) Cradle to grave responsibility.
(7) Restructure urban transportation systems.

Why is reusing and recycling materials important?

Reading activity

Study the section ''Why is reusing and recycling materials important?'' in chapter 21 of the prescribed book.

Content summary

- Reusing products helps to reduce resource use, waste and pollution; it also saves money.
  - Developing countries reuse their products, but there is a health hazard for the poor.
- During recycling, waste materials are collected, turned into useful products and sold as new products.
  - There are two types of recycling: primary recycling involves reprocessing discarded solid materials into new, useful products and secondary recycling involves converting materials into different products.
  - Pre-consumer/internal waste is generated from a manufacturing process and recycled. Post-consumer/external waste is generated by consumer use of products.
- Solid waste recycling can be done in a materials recovery facility (MRF). The wastes are recycled and/or burned to produce energy. However, these plants are expensive and they have to process a large input of rubbish.
- Source separation recycling relies on households and businesses to separate their rubbish, which is collected and sold to other dealers.
  - This produces less air and water pollution.
  - This method has less start-up and operating costs.
  - It saves more energy and provides more jobs than MRFs.
  - Pay-as-you-throw (PAUT) waste collection systems charge for the mixed waste that is picked up, but not for the recycled, separated materials.
- Composting biodegradable organic wastes is a great way to mimic nature.
- Factors that hinder reuse and recycling are:
  - The cost of a product does not include harmful environmental health costs in its life cycle.

- Resource-extracting industries receive government tax breaks and subsidies, while recycle and reuse industries do not.
- Because the demand for and price of recycled materials fluctuate, there is less interest in committing to this method. (See the science focus: Most of today's plastics are derived from petrochemicals. However, bioplastics date back to the early 1900s. Environmental problems that are associated with oil have triggered a renewed interest in bioplastics. One advantage of bioplastics is that they can be composted.)

Read the case study: Refillable containers lessen waste. Parts of Canada and 11 American states require deposit fees on all beverage containers. Some people are now calling for a ban on all beverage containers that cannot be reused. Reusable cloth shopping bags also reduce waste substantially. Plastic bags can take a very long time to break down and they litter the landscape of many locales. There are governments all over the globe that have banned the use of plastic bags.

Read the case study: About 55% of the world's industrial tree harvest is used to make paper. Paper is easy to recycle and it uses 64% less energy than making new paper from wood. The global recycling rate for wastepaper is about 43%.

Read the case study: There are many different types of plastics and many of them end up distributed throughout our environment, particularly our oceans. Only about 4% of all plastics in the United States are recycled. Plastic recycling is uncommon because plastics are difficult to isolate in different materials, not much individual plastic resin is recoverable per product and recycled resin is much more expensive than virgin plastic resin.

What are the advantages and disadvantages of burning or burying solid waste?

Reading activity

Study the section ''What are the advantages and disadvantages of burning or burying solid waste?'' in chapter 21 of the prescribed book.

Content summary

- Municipal solid waste is burned in waste-to-energy incinerators, which produce steam for heating or producing electricity.
- The advantages and disadvantages of burning solid waste are set out in figure 24-13:
  - high operating costs
  - air pollution concerns
  - citizen opposition to the process
- Most solid waste is buried in landfills, which eventually leak toxic liquids into the soil and water.

- Open dumps in the ground hold rubbish; sometimes these are covered with dirt.
- At sanitary landfills, solid waste is spread out in thin layers, compacted and covered daily with clay/plastic foam. At modern landfills, the bottom is lined with an impermeable liner that collects leachate; rainwater is contaminated as it percolates through the solid waste. The leachate is collected, stored in tanks and then sent to a sewage treatment plant. All landfills eventually leak contaminants.

How should we deal with hazardous waste?

Reading activity

Study the section ''How should we deal with hazardous waste?'' in chapter 21 of the prescribed book.

Content summary

- There are three priorities in dealing with hazardous waste: (1) produce less, (2) convert to less hazardous substances and (3) put the rest in long-term safe storage.
- Chemical and biological methods can be used to reduce the toxicity of hazardous wastes or to remove them.
  - One biological treatment (bioremediation) uses bacteria and enzymes to help destroy hazardous or toxic substances. They are converted to harmless compounds in the process.
  - Phytoremediation uses natural or genetically engineered plants to absorb, filter and remove contaminants from polluted water and soil.

- Hazardous waste can be incinerated to break them down and convert them to less harmful chemicals.
- Burial on land is the most widely used method in the United States to dispose of waste.
  - Deep-well disposal: liquid hazardous waste is pumped into porous rock formations beneath aquifers.
  - Surface impoundments: hazardous waste is punt into ponds that are lined.
  - Some highly toxic materials cannot be detoxified, destroyed or safely buried. Reducing their use is the best solution.
  - Secure hazardous waste landfills: hazardous waste is put into containers and monitored.

Read the case study: More than 70% of the world's e-waste ends up in China. Over 30 000 workers toil in unsafe conditions and are exposed to toxins. Some computer companies now offer recycling, though only 10 to 15% of the e-waste in the United States is recycled (80% of which is shipped overseas).

Read the case study: The Resource Conservation and Recovery Act (RCRA) regulates about 5% of the United States' hazardous waste. The Comprehensive Environmental Response, Compensation and Liability Act (CERLA/Superfund programme) was passed

in 1980. It identifies hazardous waste sites and provides for the clean-up of these sites on a priority basis. The worst sites go on a national priorities list (NPL) and are scheduled for total clean-up. There are also laws that provide for cleaning up brown fields and abandoned sites that are contaminated with hazardous wastes (like factories, gas stations, junkyards and so on).

How can we make the transition to a more sustainable low-waste society?

Reading activity

Study the section ''How can we make the transition to a more sustainable low-waste society?'' in chapter 21 of the prescribed book.

Content summary

- Individuals have organised to protest the construction of many treatment and storage facilities.
- Environmental justice means that every person is entitled to protection from environmental hazards regardless of race, gender, age, national origin, income, social class and so on.
  - Studies show that a disproportionate share of polluting facilities is located in minority communities.
- The Basel Convention is an international treaty that bans developed countries from shipping hazardous waste to other countries without their permission.
- In 2000, a global treaty to control 12 persistent organic pollutants (POPs) was developed. In order for it to come into effect, 50 countries have to ratify the treaty.
  - POPs are toxic chemicals that are stored in the fatty tissue of human beings and other organisms.
  - 12 chemicals (the dirty dozen) have to be phased out, detoxified and/or isolated.
- To make the transition to a low-waste society, we have to understand that
  - everything is connected
  - there is no place to send wastes ''away''
  - diluting waste is not the solution to pollution
  - polluters and producers should pay for the wastes they produce
  - different categories of waste should not be mixed
  - the best solution is to prevent waste and pollution
  - we should mimic nature by reusing/recycling the materials that we use

Learning activities

Study the core case study at the beginning of chapter 21: E-waste consists of discarded computers and other electronic waste. It contains many valuable metals as well as toxic pollutants. Much of this waste is transferred from the developed world to the developing world, particularly China. Efforts are underway to stop this trade and to encourage recycling.

Complete all the questions in the ''Thinking about'' textboxes of chapter 21.

Complete the review questions at the end of chapter 21.

Complete the critical thinking questions (except question 10) at the end of chapter 21.

Complete the ecological footprint analysis exercise at the end of chapter 21.

In conclusion

By now, you should be quite despondent about the state of the environment and the future prospects for our living Earth. Unfortunately, there is no word of comfort. Humankind really is messing up! And more bad news is to follow. Complete the review questions at the end of chapter 21, then brace yourself and proceed to study unit 11.

References

Glazewski, J. 2000. *Environmental law in South Africa.* Durban: Butterworth.

McKinney, ML & Schoch, RM. 2003. *Environmental science: systems and solutions.* 3rd edition. London: Jones & Bartlett.

Seager, J. 1995. *The state of the environment atlas.* London: Penguin.

Study unit 11

In for the kill

Introduction

We borrowed the title of this study unit from Joni Seager's *State of the environment atlas* (1995). He uses it in the section that deals specifically with hunting and species extinction. This title might seem a tad melodramatic, but you will soon see that humankind has actually wiped out an array of species and is still doing so. In fact, by the year 2050, half of all the species that are alive today could be extinct (Seager 1995). This is dramatic! No euphemism or pussy-footing will change the fact that we are quite literally killing the animals and eradicating the plants and insects.

By some estimates, as many as 500 million kinds of plants, animals and micro-organisms have lived on the Earth since the beginning of life (Chiras 2001). The number of species that are living today can be anything from 10 to 80 million (anyone's guess is equally good), although only approximately 1,4 million have been identified and named. Based on these estimates, we can assume that some 420 to 490 million species have become extinct over a period of 3,5 billion years. This, of course, was not humankind's doing; it is simply an evolutionary fact of life. Natural extinction (like natural erosion) is neither good nor bad; it is simply the way the natural ecosystem works. But what humankind is doing, is known as accelerated extinction and it (like accelerated erosion) is definitely ''bad'' because it upsets the balance in natural ecosystems.

Natural extinction differs markedly from accelerated extinction in two important ways (Chiras 2001). Firstly, natural extinction represents a kind of evolutionary passing. This means that millions of species have become extinct, but have not disappeared. They evolved into new species and are today represented by their descendants. Accelerated or modern extinction eliminates species entirely. It represents a dead end in evolution (Chiras 2001). Secondly, the rate of natural extinction is much slower. On average, it is estimated at one species every 1000 years/millennium. Accelerated extinction wipes species out at a rate of anything from 40 to 140 per day (Chiras 2001)! Many scientists believe that we are living in an era of extinction which is unparalleled in the history of the Earth.

In this study unit, we focus on the current rapid loss of wild species (also called the loss of biodiversity and often referred to as the ''extinction crisis'') (McKinney & Schoch 2003). In the introduction to the first study unit of this study guide, we mentioned that the loss of biodiversity is one of the most pressing environmental issues of our time. Here we examine why it is being lost, why it should be preserved and how it can be saved. Students who are sensitive to animal suffering should be prepared for some disturbing visual material in the prescribed book and are advised to cover the offending photographs.

Sources to consult

Prescribed book: Chapter 9 ''Sustaining Biodiversity: The Species Approach''.

Additional resources

***my*Unisa**

https://my.unisa.ac.za/portal/

- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 11''.
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 11''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 11.

Learning outcomes

When you have completed this study unit, you should be able to

- identify and explain the role human beings play in the premature extinction of species
- explain the significance of preventing the premature extinction of species
- identify and explain how human beings contribute to the acceleration of the premature extinction of species
- analyse various solutions that can be implemented in order to conserve wild species

What role do human beings play in the premature extinction of species?

Reading activity

Study the section ''What role do humans play in the premature extinction of species?'' in chapter 9 of the prescribed book.

Content summary

- Background extinction is a historic, continuous and low level of extinction.
- The extinction rate is the percentage or number of species that become extinct each year.
- Mass extinction is the loss of many species in a short period of time.
- Local extinction occurs when a species disappears from one of the many areas it once inhabited.
- Ecological extinction occurs when the number of individuals is so low that they cannot fulfil their ecological roles.
- Biological extinction occurs when a species has disappeared from the Earth.
- Human activities increase the pace of extinction.
  - The current rate is 100 to 1000 times the background rate (0,01–1% per year).
  - Extinction estimates are likely conservative.

    - The rates will likely increase with the growing human population.
    - The rates tend to be much higher in biodiversity hotspots.
    - Habitat fragmentation limits the potential for speciation.

- Species that are heading toward biological extinction are either endangered or threatened.
  - Endangered species are so few in number that the species could soon become extinct.
  - Threatened/vulnerable species are still abundant, but will likely become endangered in the near future.
    - The World Conservation Union keeps *red lists,* which are the world standard for listing all threatened species throughout the world.

See the science focus: Estimating rates of extinction is problematic because extinction takes a long time, we are uncertain of how many species are on Earth and we know little about the species that have been identified. There are several methods for estimating extinction rates, including studying fossil records and rates of mutation, applying a species-area relationship to habitat destruction and building mathematical models. Scientists acknowledge the shortcomings of estimates of extinction rates, but are certain that human beings have caused an increase in the rate of extinction.

Why should we care about preventing premature species extinction?

Reading activity

Study the section ''Why should we care about preventing premature species extinction?'' in chapter 9 of the prescribed book.

Content summary

- Wild species have instrumental value.
  - *Use values*: economic goods and services, ecotourism and genetic information.
    - Many plants and some animals have medicinal properties.
    - Genetic information in species helps them to adapt and produce new species. This information can be used to develop food and medicines for people. Wild species provide a bank of genetic information.
    - Recreational value is provided by plants and animals.
  - *Non-use values*: existence value and aesthetic value.

- Ecological value: each species is a vital component of the functioning of the ecosystem. (See the science focus: Poachers slaughter about 25 000 elephants per year for their ivory. Since 2007, scientists have used a DNA map of elephant populations to trace the origin of ivory that is sold on the black market. This helps them to identify regions where poaching occurs so that they can focus their efforts on eliminating it.)

- Intrinsic or existence value: species have an inherent right to exist, regardless of their utility to human beings.
  - *Biophilia* is the belief that human beings have an inherent genetic kinship with the natural world.
    - Many people have a preference for natural scenes over urban environments.
    - Some believe that certain organisms have more of a right to life than others.
  - *Biophobia* is the fear of certain forms of wildlife. (See the science focus: There are about 950 species of bats. They reproduce slowly and live in large colonies, which make them vulnerable to extinction. Bats are important for controlling insect populations, pollinating crops, and distributing fruit and seeds. Currently one-fourth of bat species are listed as endangered or threatened.)

How do human beings accelerate species extinction?

Reading activity

Study the section ''How do humans accelerate species extinction?'' in chapter 9 of the prescribed book.

Content summary

There are several causes of the depletion and premature extinction of wild plants and animals. The acronym HIPPCO describes these causes.

- The loss, degradation and fragmentation of habitat are the greatest threat to a species.
  - Deforestation in tropical forests is the greatest species eliminator, followed by loss of wetlands and ploughing of grasslands.
  - Island species are especially vulnerable to extinction. Many are endemic.
  - Habitat islands are isolated and surrounded by other habitats.
  - Habitat fragmentation occurs when large contiguous habitats are divided into isolated patches.
    - Certain species are more vulnerable to habitat fragmentation. They tend to be those that are rare, require a large range or have low reproductive capacity. (See the science focus: Tropical forests are generally very diverse. As these forests are fragmented, there is growing concern over the loss of biodiversity. Research shows that within 100 m of the edge of the fragment, up to 36% of the biomass of old-growth trees is lost in 10–17 years. This information can help scientists to estimate how large a fragment has to be to prevent the loss of biodiversity.)
- After habitat loss, introduced species are the biggest cause of extinction.
  - The alien species can be introduced accidentally or deliberately.
  - Some of these species threaten and endanger native species.

        - They have no natural predators, competitors or pathogens in their new habitat.
        - They can trigger ecological disruptions.
        - There are an estimated 7100 invasive species that have caused ecological or economic harm in the United States.

    - Invasive species are often introduced accidentally.
        - Argentine ants aggressively attack native ant populations.

    - The best control is to prevent the non-native species from being introduced.

- Population growth, overconsumption, pollution and climate change.
    - Overpopulation and the excessive consumption of resources eliminate habitat.
    - Pollution from chemicals such as pesticides can have unintended effects on species.
    - Human activities induce rapid climate changes, increasing extinction rates.

- Poaching is the illegal killing of protected species.
    - Some protected species are killed for their valuable parts or are sold live to collectors.
    - Smugglers can earn $10 billion (R75 billion) per year.
    - It is a low-risk crime because smugglers are rarely caught and punished.
    - The internet is the main tool in this trade and education is the key to combating it.

- Global legal and illegal trade in wild species for pets is a very profitable business.
    - More than 60 bird species, mostly parrots, are endangered or threatened because of the wild bird trade.
    - Amphibians, reptiles, mammals and tropical fish are also being depleted because of pet trade.
    - Ex-poachers in Thailand are now making more money by taking eco-tourists into the forest than they did by poaching hornbills. They also protect these birds from poachers.
    - Collecting exotic pets and plants (such as orchids and cacti) kill large numbers of them and endanger these species and others that depend on them.

- Bushmeat supplies indigenous people with food and has been harvested sustainably. However, as demand for bushmeat has risen, illegal hunting has skyrocketed.
    - There has been an eightfold increase in Africa's population, which increases the demand for bushmeat.
    - Logging roads give ranchers, miners and settlers access to areas that were previously too remote/inaccessible.
    - These hunting practices have resulted in negative ecological impacts and have driven at least one species to extinction.

Read the case study: About 70% of the world's bird species are declining in number and about 12% is threatened with extinction. The primary cause of the decline is habitat loss and fragmentation. Since birds are indicator species, this signals an environmental change in their habitats. Birds play a number of important economic and ecological roles. Their loss can trigger a cascade of extinctions.

See the science focus: Three species of vulture in India and South Asia were driven to the brink of extinction in a few years at the beginning of the 1990s. The cause was poisoning from a pharmaceutical that had been given to the cows they often fed on. The ecological ramifications of this population decline led to an increase in rabies amongst human beings. The loss of vultures led to a greater food supply for wild dogs and an increase in the number of dogs carrying rabies. Conservation biologists believe that the fates of wildlife and human beings are often interconnected.

Read the case study: The Kudzu Vine was deliberately introduced in the 1930s to control erosion, but got out of hand. It is prolific and difficult to control, engulfing hillsides, gardens and trees (among other things).

Read the case study: The populations of many vital pollinators are currently in decline. Honeybees, in particular, are important pollinators of commercially grown crops. Since the 1980s, there has been a decline in bee populations and in the last few years, the situation has become more severe. Colony collapse disorder describes the sharp decline in some species of bees and can lead to agricultural collapse in the regions where the pollinators are lost.

Read the case study: Polar bears are distributed in 19 populations across the polar arctic. They are dependent on the ice that expands every winter for their feeding behaviours. As the climate warms, their summer fasting period becomes longer. Also, ice shrinkage is forcing them to swim longer distances in search of food. According to the International Union for Conservation of Nature (IUCN), polar bears could decline by 35% by mid-century and could be confined only to zoos by the end of the century. The IUCN now lists polar bears as a threatened species.

How can we protect wild species from premature extinction?

Reading activity

Study the section ''How can we protect wild species from premature extinction?'' in chapter 9 of the prescribed book.

Content summary

- There are treaties to help protect endangered and threatened species, but enforcement is difficult and punishment inadequate.
- The 1975 Convention on International Trade in Endangered Species (CITES) protects 900 species from being commercially traded and restricts international trade in 29 000 species that could become threatened.
  - Enforcement is difficult and varies from country to country.

- Many countries are not signatories and still trade in animals.
- The Convention on Biological Diversity (CBD) binds governments to reverse the global decline in biological biodiversity. The United States has not ratified this treaty. There are no severe penalties or other enforcement mechanisms in place.

Read the case study: The Endangered Species Act of 1973 (ESA) identifies and legally protects endangered species in the United States and abroad.

- In the United States, the National Marine Fisheries Service identifies endangered, threatened ocean species and the Fish and Wildlife Service is responsible for identifying and listing all other endangered and threatened species.
  - Biological facts form the basis for inclusion on the endangered list.
  - The habitats of endangered species have to be protected.
- Efforts have been made to repeal/weaken the ESA.
  - Some developers, timber companies and other private landowners avoid government regulations and loss of economic value by managing land to reduce its use by endangered species.
  - Habitat conservation plans (HCPs) are designed to reach a compromise between the interests of private landowners and that of endangered/ threatened species.
  - The HCP allows the destruction of some critical habitat or killing of a population if the developer or landowner takes steps to protect the species (such as protecting critical nesting sites, setting aside part of the habitat as protected land, maintaining travel corridors or moving the species to another suitable habitat).
- Conservation biologists believe that the ESA should be strengthened and modified to correct deficiencies.

- The sanctuary approach is being used to protect wild species.
  - Wildlife is protected in 547 federal refuges, but habitats are deteriorating due to invasive species, pollutants, and little operational or maintenance funding.
  - More than three-quarters of the refuges are concentrated along major bird migration corridors.
  - About one-fifth of endangered and threatened species in the United States have habitats in the refuge system. (See the science focus: The ESA is often criticised because only 37 species have been removed from its endangered lists. Biologists claim that the ESA has not been a failure because species are only listed when they face serious danger of extinction; it takes years for a species to become endangered and a long time for them to recover; conditions for more than half the species are stable or improving; and the ESA operates on a small budget. Some recommended changes include a larger budget, more rapid development of recovery plans and a provision calling for the immediate establishment of a core area of survival habitat.)

- Gene banks, botanical gardens and farms can be used to raise threatened species and help protect species from extinction, but funding is inadequate.

- The world's 1600 botanical gardens and arboreta contain almost one-third of the world's known plant species, but only 3% of the world's rare and threatened species.
- Raising some threatened or endangered species on farms can take some of the pressure off them and some can perhaps be offered for commercial sale.
- Zoos and aquariums can help to protect some endangered animal species, but both are notoriously underfunded.
  - Egg pulling is when the eggs of endangered, wild bird species are collected and hatched in zoos/research centres.
  - Captive breeding is when wild individuals are taken into captivity for breeding, with the commitment to reintroduce their offspring back into the wild.
  - Artificial insemination, the use of surrogate mothers, the use of incubators and cross-fostering by a similar species are more ways to increase the populations of rare species.
  - The ultimate goal is to reintroduce these species into the wild.
  - Reintroductions of endangered species to the wild fail because
    - there is not suitable habitat
    - individuals that are bred in captivity cannot survive in the wild
    - there is renewed overhunting/capture of the returned species. (Read the case study: The California condor was nearly extinct, with only 22 birds left in the wild. These birds were captured and bred in captivity. In 2007, there were 135 birds in the wild. A major threat to these birds is lead that is used in ammunition. When the birds eat carcasses, lead poisoning can make them very weak.)

- Precautionary principle: When substantial preliminary evidence indicates that an activity can harm human health or the environment, we should take precautionary measures to reduce or prevent such harm.

South Africa has a particularly serious problem with alien invader plant species. Millions of hectares in the Western Cape, Southern Cape and Eastern Cape; the entire KwaZulu-Natal; the Eastern Free State; the entire Gauteng and Mpumalanga (that is, all the slightly wetter parts of the country) have been invaded by alien species. Some of these were deliberately introduced, mostly from Australia because of the climatic similarity between the two countries. Examples are: bluegums (various eucalyptus species), which were introduced as timber for the gold mines; wattles (various acacia species) were imported for different uses, such as in the tanning industry; the Port Jackson willow (Acacia saligna), rooikrans (Acacia cyclops) and hakeas (various Hakea species) were introduced to stabilise wind-blown sand in the Western and Southern Cape. These Australian species are perfectly adapted to South Africa's climate, all are vigorous pioneers and the acacias are prolific reproducers. They invaded South Africa with overwhelming success. They consume massive volumes of scarce freshwater resources. Today, millions of Rands are spent in eradication attempts. The prickly pear (various Opuntia species) was deliberately introduced from Central America as livestock fodder and has invaded the whole country, including the drier parts. Accidentally introduced aliens include a long list of weeds such as the cosmos (which beautify Gauteng and vast tracts of the Free State, KwaZulu-Natal and Mpumalanga during the late summer), the khaki-bush or khaki-weed (Alternanthera achyrantha) and the blackjack. These weeds were all imported from Mexico and Central America

together with fodder for the horses of the British troops during the South African War of Independence (1899–1902). These weeds are not as aggressively invading as the abovementioned acacias since they tend to grow only on disturbed and otherwise abused land. However, when they do grow, they take over completely. KwaZulu-Natal has a particularly serious problem with a more aggressive invader, the triffid weed or paraffienbos (Chromolaena odorata), which invades disturbed and undisturbed land equally swiftly. Another aggressive, widely tolerant, large shrub that is spreading like wildfire on mostly disturbed and degraded (but also undisturbed) land and is already dominating some watercourses and forest margins along the entire eastern and southern coastal plains and the wetter eastern parts of the country is Lantana camara (Henderson 1995).

Learning activities

Study the core case study at the beginning of chapter 9: Passenger pigeons were once one of the most numerous bird species on Earth. Uncontrolled hunting and habitat loss led to their extinction by the year 1900. There have been five mass extinctions on Earth and it appears that we are currently entering the sixth. It is predicted that human activities will lead to the premature extinction of one-fourth to one-half of plant and animal species.

Complete all the questions in the ''Thinking about'' textboxes of chapter 9.

Complete the review questions at the end of chapter 9.

Complete the critical thinking questions (except question 10) at the end of chapter 9.

Complete the ecological footprint analysis exercise at the end of chapter 9.

In conclusion

Now you are done with the worst of the doom and gloom, the death and destruction, the despoilment and degradation, the defiling and depletion. Certainly, it is not a comforting ''feel good'' experience to find out what humankind has done to our living Earth. But, we are a thinking, reasoning and ingenious species. We know that we have messed up badly, but we have the cognitive capacity and the technology (if necessary) to fix our mess. In some of the previous study units and in this study unit, you learned about the protection of the more spectacular of the species – those that have grabbed the imagination of people and that they now pay to see.

The picture is pretty bleak for animals and plants that live unprotected on private, state and communal land. An increasing percentage of the world's human resources are being used to protect the remainder of the Earth's natural species inside protected – usually formidably fenced – sanctuaries, zoos and reserves. Nature tourists (incorrectly, but popularly, called ecotourists) from all over the world travel thousands of kilometres and spend large amounts of money to see the protected wildlife. The hospitality sector that caters for nature tourists is ballooning. Global ecotourism has become a massive industry. In some developing countries, it is the major generator of income. How ironic that we had to wipe some species out and kill others to the very brink of extinction before realising that we have squandered Eden.

It is not too late, but it will soon be if we do nothing. We can still save most of the species that currently live on Earth but only if we adopt the ecosystem approach to sustaining biodiversity. This will be the topic of the next study unit. Do the review questions for study unit 11 before you proceed to study unit 12.

References

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Seager, J. 1995. *The state of the environment atlas*. London: Penguin.

Study unit 12

For those who come after us

Introduction

Study unit 11 ended on a more optimistic note than most of the previous study units. Yes, there is still hope. You have seen that some threatened and even endangered species have been or can still be saved from extinction by protecting them in sanctuaries, reserves, wildlife parks and the like. This is good, but not good enough from a holistic ecosystems approach. We have to think ''systems'' rather than ''species''.

Our living Earth is one big, complex, interconnected, ever-changing and living wholeness. Another way to think of it is as one big ecosystem that consists of countless smaller ones which are intricately linked by the flow of matter and energy. At this stage of human development, we are not really able to intervene in the bigger, global ecosystem although international environmental organisations, treaties, conventions and summits are tentative first steps in this direction. We can, however, intervene at the local ecosystem level. This is what this study unit is about.

The principles of ecosystem protection, conservation, rehabilitation, restoration and so on are the same for all parts of the world. So too are the threats. Although the details (particulars) differ from biome to biome and from country to country, ecosystems all over the world are threatened by the same things, namely agriculture, development, mining, any form of harmful land use, overuse, degradation, depletion and many more. In your prescribed book the focus is firmly on the United States; however, everything that applies to the United States applies to any other country, with the necessary adaptations and emendations to allow for differences in climate, level of development, legislative frameworks and local conditions.

Sources to consult

Prescribed book: Chapter 10 ''Sustaining Terrestrial Biodiversity: The Ecosystem Approach''.

Note: At this stage, we expect you to be fully familiar with the content of the previous study units. All of that knowledge is presupposed now. If you come across anything that has been explained before and is now simply assumed as existing knowledge, you better make sure that you really know what it is. If you cannot remember what it is, or the exact meaning is vague, you should refer back to the study unit where we originally dealt with it and revise it. Make copious use of the glossary and the index at the back of your prescribed book; use the notes that you have been making in your scribbler or

notepad. While you study this study unit, you might particularly want to refer back to the material in study units 3, 4, 5 and 7. The moment when you find that you are uncertain about something, do not delay and go back.

Additional resources

***my*Unisa**

https://my.unisa.ac.za/portal/

- Go to the discussion forum link and participate in the discussion forum under the heading ''Study Unit 12''.
- Go to the additional resources link and download the PowerPoint lecture(s) and summaries under the heading ''Study Unit 12''.
- Go to the self-assessment link and complete the multiple-choice quiz for study unit 12.

Learning outcomes

When you have completed this study unit, you should be able to

- explain the major threats to forest ecosystems
- discuss how we should manage and sustain forests
- discuss how we should manage and sustain grasslands
- devise a strategy for the sustainable management of parks and nature reserves
- discuss how the ''ecosystem approach'' can be implemented to sustain biodiversity

What are the major threats to forest ecosystems?

Reading activity

Study the section ''What are the major threats to forest ecosystems?'' in chapter 10 of the prescribed book.

Content summary

- Forests with at least 10% tree cover occupy about 30% of the Earth's surface, excluding Greenland and Antarctica.
- Forests are classified, according to their age and structure, into three major types.
  (1) *Old growth/frontier forests* are those that have not been seriously disturbed by human activities/natural disasters for hundreds of years. These forests are storehouses of biodiversity because of the ecological niches they provide for wildlife species.
  (2) *Second-growth forests* develop in an area after human activities or natural forces have removed them.
  (3) *Tree plantations/tree farms* replant and clear-cut one species of trees in a regular cycle.

- The harmful effects of deforestation (temporary/permanently removing trees) are:
  - Deforestation reduces biodiversity and the ecological services that forests provide.
  - Deforestation can change the regional climate, causing forests not to regenerate.
  - Deforestation emits carbon dioxide, which affects global climate change.

- Logging roads has many negative consequences.
  - They increase erosion and sediment run-off, fragment habitats and contribute to loss of biological diversity.
  - They expose forest to invasion by non-native pests, diseases and wildlife species.

- Different harvesting methods affect the continuing growth of forests.
  - In *selective cutting*, intermediate-aged/mature trees are cut singly or in small groups.
  - In *clear-cutting*, every single tree is removed in one cutting.
  - In *strip cutting*, a strip of trees is removed along the contour of the land and the cutting is spread out over several decades. (See the science focus: Researchers are trying to devise a method to place a monetary value on ecosystem services. They hope that these efforts will make people aware that ecosystem services are essential for human beings and their economies, the economic value of ecosystem processes is substantial and sustainably managed ecosystems are a long-term source of income.)

- Three types of fires affect forest ecosystems:
  (1) Surface fires usually burn underbrush, leaf litter and small seedlings, but most wild animals survive. They have benefits such as burning flammable ground material to prevent more destructive fires and release nutrients, stimulate the germination of some seeds, and control pathogens and insects.
  (2) Crown fires are extremely hot and leap from treetop to treetop. The build-up of ground litter increases the likelihood of crown fires that result in greater destruction and soil erosion.
  (3) Protecting forest resources from crown includes fire prevention and prescribed burning.

- Accidental and deliberate introductions of forest diseases and insects are a major threat to forests.
- Climate change threatens many forests.
  - Some species are sensitive to heat.
  - Insects and disease can move into forests where they were not previously found.
  - Drier conditions exacerbate the risk of fire.

- Deforestation is widespread across the planet and is continuing.
  - World Resources Institute surveys indicate that original forest cover has decreased by about 46%.

  - Global deforestation occurs by at least 0,2 to 0,5% per year, with most losses taking place in developing countries.
  - If conditions do not change within the next 10 to 20 years, 40% of the world's remaining forests will be logged or converted to other uses. (Read the case study: Forests cover about 30% of the land area in the United States. Early in the nation's history, forests were decimated. Today, however, forests cover more land area in the United States than they did in 1920. Much of this is second growth. In addition, much of the nation's old-growth forest has been replaced with simplified tree plantations.)

- Tropical forests make up 6% of the Earth's land area.
  - They once covered twice as much area. Most destruction has occurred since 1950.
  - Brazil and Indonesia lead the world in tropical forest loss.
  - At least half of the world's terrestrial plant and animal species are found in tropical rainforests.
  - Annual tropical forest loss is estimated to be between 50 000 and 170 000 square kilometres.

- Six primary causes of tropical forest destruction are:
  (1) Population growth and poverty drive subsistence farmers to tropical forests, where they attempt to farm.
  (2) Government subsidies make tropical forest resources cheap – relative to their full ecological value.
  (3) Degradation begins when roads are cut into the forest for logging. Selective cutting removes the best timber (high grade).
  (4) Ranchers come in behind the timber cutters and overgraze land. They then move on and subsistence farmers come in and practise slash-and-burn farming to complete the destruction of the land.
  (5) Healthy rainforests do not burn, but logging, settlements, grazing, and farming fragment the forests. They dry out, making them more flammable when lightning and people start fires.
  (6) Burning contributes to global climate change and accounts for 20% of the annual greenhouse gas emissions.

How should we manage and sustain forests?

Reading activity

Study the section ''How should we manage and sustain forests?'' in chapter 10 of the prescribed book.

Content summary

- Fire management can be improved.
  - The Smokey Bear educational campaign taught that fire is bad. Ecologists suggest that putting out all fires increases the risk of a catastrophic fire event.
  - According to the Forest Service, severe fire could threaten 40% of federal forest lands due to fuel build-up.

  - Risk can be reduced via prescribed fire, allowing natural fires to burn, and clearing vegetation from around structures. (See the science focus: Scientific Certification Systems [SCS] is part of the Forest Stewardship Council [FSC], which certifies timber and products that are generated from environmentally sound and sustainable practices. Since 1995, the area of the world's forests that meets these standards has grown 16-fold. Still, less than 10% of the world's forested area is certified.)

- Improving the efficiency of wood use can reduce pressure to harvest trees on public and private land.
  - Up to 60% of the wood that is consumed in the United States is wasted due to inefficient use of construction materials, excess packaging, overuse of junk mail, inadequate paper recycling and failure to reuse wooden shipping containers.

- The use of tree-free fibres in papermaking is another way to reduce pressure on tree harvest.
  - Use of fibres from agricultural residues and crops such as kenaf are alternatives to tree fibres. (Read the case study: About half of the wood that is harvested each year in the United States and three-fourths of that in developing countries is used for fuel. Rings of deforested land surround cities and the demand for fuelwood in urban areas exceeds the sustainable yield of nearby forests. Community forestry projects involve local people planting small plantations of fast-growing fuelwood trees in community woodlots. People can use more efficient and less polluting woodstoves, solar ovens or electric hotplates that are powered by the wind to reduce the demand for fuelwood.)

- In order to reduce deforestation and the degradation of tropical forests
  - we have to help settlers learn methods to practise in small-scale sustainable agriculture and forestry
  - we have to harvest sustainable fruits and nuts in the rainforests
  - we should consider using debt-for-nature swaps, which allow countries that owe foreign aid/foreign debt to act as custodians of protected forest reserves so that they can have their debt written off
  - we have to develop an international system for evaluating and certifying that tropical timber has been produced by sustainable methods
  - loggers can harvest trees more gently, for example cutting canopy vines to prevent damage to nearby trees and using the most open paths to remove felled trees

How should we manage and sustain grasslands?

Reading activity

Study the section ''How should we manage and sustain grasslands?'' in chapter 10 of the prescribed book.

Content summary

- Grasslands provide many important ecological services, yet are the second-most altered ecosystem.
- Livestock often overgraze rangelands (non-managed grasslands) and pastures (managed grasslands), causing soil erosion and exploitation by invasive plants.
- Grasslands also suffer from undergrazing, which can reduce the net primary productivity of the area.
- To use grasslands in a sustainable way, we have to control the number and distribution of livestock.
- Ranchers, ecologists and environmentalists in the United States are working together to protect grasslands by rotating livestock.
- Invasive plants can be combated with herbicides, mechanical removal and controlled burning.

Read the case study: Since 1980, there has been a population surge in the ranch country of the Southwestern United States. This has led to uncontrolled urban development. Now ranchers and environmentalists are working together to conserve ranchland as a means of sustaining the remaining grassland habitats. One strategy is to pay ranchers for conservation easements, which bar future owners from developing land.

How should we manage and sustain parks and nature reserves?

Reading activity

Study the section ''How should we manage and sustain parks and nature reserves?'' in chapter 10 of the prescribed book.

Content summary

- There are more than 1100 national parks in more than 120 countries.
  - Parks in developing countries have the greatest biodiversity, but are least protected. (Read the case study: The United States' national park system has 58 major national parks. Their popularity leads to pollution and its associated problems because of overuse. Non-native species threaten biodiversity in parks, which are often isolated amidst development. Inadequate budgets add to the challenges national parks face.)
- Conservation biologists call for strict protection of at least 20% of the Earth's global system as biodiversity reserves that include multiple examples of all the Earth's biomes.
- Large reserves are usually the best way to protect biodiversity, but in some locales several well-placed, medium-sized, isolated reserves can be a better way to protect a variety of habitats.
  - Buffer zones establish an inner zone of intact habitat.
  - The United Nations has established 529 biosphere reserves globally on the basis of this principle.

- Establishing habitat corridors helps to support more species and allows for the migration of vertebrates with large ranges.
  - Individuals can migrate when environmental conditions deteriorate within a range.
  - They can also threaten isolated populations by allowing movement of pest species, disease, fire and exotic species between reserves.
  - They can be costly to acquire, protect and maintain. (Read the case study: The most impressive country for conserving its land and natural resources is Costa Rica. Costa Rica once had one of the highest rates of deforestation and now has one of the lowest.) It has established a system of reserves and national parks and it devotes a larger portion of its land to biodiversity conservation than any other country. It has consolidated its parks and reserves into eight mega-reserves, which help to generate $1 billion (R7.5 billion) per year in the ecotourism industry.

- The wilderness concept provides for large tracts of undeveloped land. (Read the case study: The Wilderness Act was passed in the United States in 1964. Only about 4,6% of land in the United States is protected as wilderness, with almost three-fourths of it in Alaska. Only about 1,8% of the lower 48 states are protected as wilderness. Only 81 of the 233 distinct ecosystems are protected in wilderness. Industries see these areas as sources of increased profits and short-term economic growth. The protection of areas that are under consideration for wilderness status was discontinued in 2003.)

See the science focus: Scientists are monitoring the gray wolves that have been reintroduced to Yellowstone National Park in the United States. The effects of this reintroduction have been many: They are impacting the populations and behaviours of large grazing animals. This has helped to restore riparian zones that were degraded by elk. Coyote populations have also been decreased. It will take decades of research to understand the way these animals impact the functioning of their ecosystem.

What is the ecosystem approach to sustaining biodiversity?

Reading activity

Study the section ''What is the ecosystem approach to sustaining biodiversity?'' in chapter 10 of the prescribed book.

Content summary

- We should focus on protecting ecosystems and their biodiversity rather than distinct species.
  - Map and inventory ecosystems.
  - Identify the most endangered ecosystems.
  - Restore degraded ecosystems.
  - Make development biodiversity-friendly via tax breaks.

- Biodiversity hotspots are areas that are especially rich in species and are at great risk of extinction.
  - In all 34 hotspots, a total of 86% of the habitat has been destroyed. (Read the case study: The Eastern Arc Mountains of Tanzania have the highest concentration of endangered animals on Earth. The area is a hotspot because of threats to habitat. So far, 70% of the ancient forests have been cleared. The forest is now fragmented, but protected, in government reserves where people can still forage and gather fuelwood.)

- Another approach to biodiversity conservation is to protect areas where vital ecosystem processes are impaired.
- Life-raft ecosystems are ecosystems where people live in extreme poverty and are forced to degrade the ecosystem's processes in order to survive. (See the science focus: Guanacaste National Park in Costa Rica is the site of one of the world's largest ecological restoration projects. The project involves local community members in the restoration effort. Many local students have been trained in restoration ecology. This project is guided by the belief that it will ultimately fail unless the local communities see some economic benefit in its success.)
- Environmental degradation can be partially reversed through ecological restoration.
- Scientists are studying how natural systems recover and are learning to speed up repair operations through the following approaches:
  - Restoration returns a degraded habitat to a condition as close to its natural state as possible.
  - Rehabilitation involves trying to restore an ecosystem to a functional state rather than its original state.
  - Replacement is replacing a degraded ecosystem with a productive pasture or tree farm.
  - Creating artificial ecosystems is another possibility.

- Applied ecology involves inventing, establishing and maintaining new habitats for species to coexist with human beings. (Read the case study: The Blackfoot River comprises a large and diverse watershed. It is also home to many people who witnessed environmental degradation due to poor mining, logging and grazing practices. This stimulated activism at the community level. In 1993 community members organised the Blackfoot Challenge, which resulted in drastic improvements and became a classic example of reconciliation ecology.)

Learning activities

Study the core case study at the beginning of chapter 10: Gray wolves once roamed in abundance throughout the United States. By 1900, most of their population had been decimated. In 1974 the wolf was listed as endangered. Its declining population had many effects at the ecosystem level. Decreased predation allowed for growth in populations of grazing animals, which had devastating effects on vegetation and other animal populations. At the beginning of 1995, wolves were reintroduced to Yellowstone National Park. Since then, their population has increased and they have been removed from protection under the ESA.

Complete all the questions in the ''Thinking about'' textboxes of chapter 10.

Complete the review questions at the end of chapter 10.

Complete the critical thinking questions (except question 10) at the end of chapter 10.

Complete the ecological footprint analysis exercise at the end of chapter 10.

In conclusion

Almost the entire land surface on Earth, except most of Antarctica, has been degraded to a greater or lesser degree by human activities. Even in the protected or restricted-use areas, some degradation or other traces of human activity can be found (Beazley 1990). Not even the so-called wilderness areas are entirely free of all signs of human interference in nature. High mountains used to be free of human traces, but not anymore. The climbing routes up Mount Everest, Kilimanjaro and every other high peak in the world are today strewn with human refuse and waste (Vernon 1997). Nowadays even Antarctica bears some scars of human habitation. We have literally been everywhere and have left behind more than our footprints.

Despite the laudable motto ''Leave no trace'', the so-called protected areas of the world are hardly pristine. Mismanaged through ignorance or greed, many of these areas have been degraded or despoiled. And there simply are too few of them. For future generations, we desperately need to set aside more land to be protected as natural ecosystems. We owe this to those who come after us.

References

Beazley, M. 1990. *The last rain forests: a Mitchell Beazley world conservation atlas*. London: Mitchell Beazley.

Vernon, K. 1997. *Ascent and dissent*. Johannesburg: Jonathan Ball.