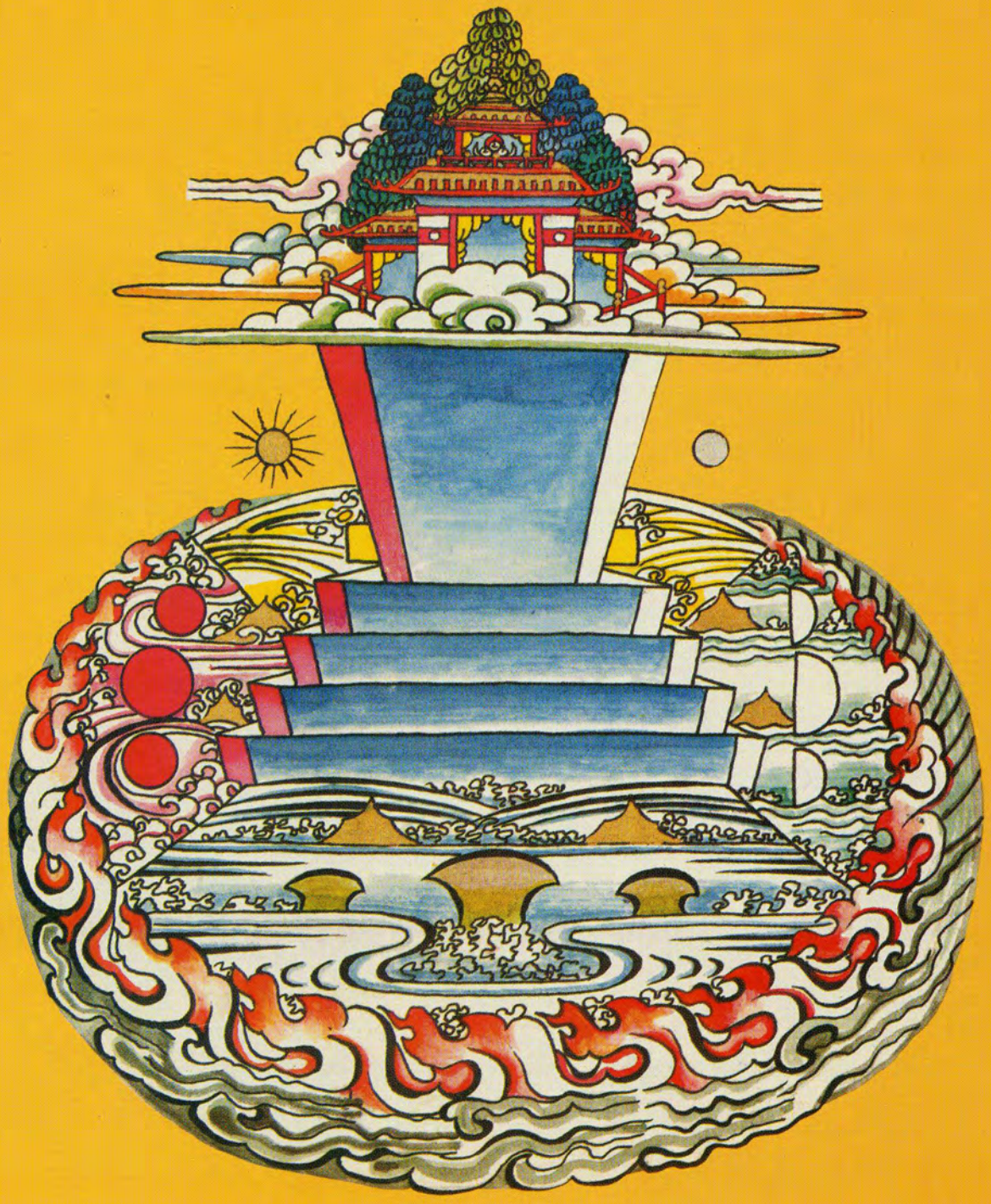
A GEOGRAPHY OF BHUTAN



COURSEBOOK FOR CLASSES IX AND X

A Geography of Bhutan

Coursebook for class IX & X

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FOREWORD

Education is the prerequisite to and a vital element of progress and development of a nation, provided it is relevant and appropriate. The Ministry of Education is vigorously moving forward to fulfill the need recognized by the Royal Government of Bhutan to make education meaningful to our children and outline the roles they are expected to play as future subjects of His Majesty the King and citizens of our country.

In the course of our children's education in the schools, the contents related to our own country play the most significant role in inculcating in them our rich cultural, traditional and social values that have been developed and passed down by our forefathers. A good knowledge of the land information, climatic conditions and their impact on the vegetation and the activities of the people, lead to a better understanding of our country. Bhutan, in spite of its small size, possesses a diverse and pristine natural environments, ranging from the almost tropical to the frigid area. Within these varied environments our people have evolved, in course of time, unique cultural and traditional systems which have in turn contributed to the safeguarding of the sovereignty and independence of our country.

Bhutan's geography should teach us and our children to be proud of our landscape and help us to sustain them. This book for class IX and X in our schools, which is the third in the series of geography course books on Bhutan, will help our teachers and students to become acquainted with the richness of Bhutan's natural resources and at the same time create in them an awareness of the likely consequences of our overuse. Our students should be made to appreciate the need to make prudent decisions in the use of the available resources so that the generations of Bhutanese in the distant future will also be able to enjoy the richness of our land as much as we do today. The purpose of this book is therefore to develop positive attitudes amongst our students, as tomorrow's citizens, that the wise steps they take in delivering the benefits from our country's environment today will have far reaching effects on the sustainability of our mountain environment both now and in the future.

I am sure that our students will enjoy this course book on Geography of Bhutan and utilizes the ideas and principles therein for their education as well as for the good of the nation.

Trashi Delek

(Thinley Gyamtsho)
MINISTER
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INTRODUCTION

Geography is s synthesizing subject as it draws ideas and facts from various disciplines to build up a coherent platform on which both human and the natural world are seen as interacting elements. Since geography integrates the natural and human worlds, it is a unique subject in the school curriculum. It acts as a bridge between the science subjects and the arts subjects. Without geography, the relevance of discoveries made by those studying the natural sciences could be lost as the application of their findings to the real world might not be fully explored.

Geography is no more considered to be just the study of atlases, place names, statistics and encyclopedic information. Geography has advanced from these stereotype notions of the past. It is now also an avenue for the discussion of questions such as:

- How are our natural resources such as water, air and forests maintained?
- What is the relationship between people and natural environment?
- What information is needed to make wise decisions regarding resource use and commercial development?
- How do we ensure the sustainability of our limited resources as we expand our economic activities?
- How can we promote international understanding as the world grows smaller everyday?
- How can we ensure that our rich and unique cultural heritage is maintained?

The concepts, ideas and principles explained in this book are generally universally applicable. Many specific examples from Bhutan, as well as those from other parts of the world, have been cited to illustrate these general principles and concepts. This is to help our students gain a deeper understanding of the principles and concepts themselves, as well as expand their knowledge of their own country and to show how Bhutan interacts and relates to the rest of the world.

In some chapters, case studies have been drawn up based on the interviews with relevant people. The case studies are given here in order to help develop a deeper understanding of the matters discussed in the chapter and are not just stories and anecdotes of some individuals.

Questions and activities have been inserted wherever necessary, thereby dividing the chapters into sections or lessons, so that on completion of each of the sections, both teachers and students can carry out on revising and confirming what has been taught and learned. There is also a set of summary activities given at the end of each chapter, mainly to make sure students have understood the terms used in the text since this is an essential part of learning geography lessons. The flow diagrams help summarize main ideas and also give our students practice in note taking.

Any limitations that this book contains should be brought to the attention of the CAPSD, without any hesitation.

Dr. Jagar Dorji
Chairperson
Social Studies Subject Committee

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Chapter 1

FORMATION OF THE HIMALAYAS

KEY IDEAS

The Plate Tectonics Theory
The Tethys Sea
Earthquakes
The Himalayas
Landforms
Reshaping the mountains

This chapter looks at the geological history of the mighty Himalayas. It tells one of the most dramatic stories in geography. The story spans more than 200 million years and tells the tale of how the highest mountains in the world grew out of the ocean floor. It also explains how the rocks, once thrust up into the sky, were sculpted by the elements of nature to form some of this planet's most rugged and beautiful landscapes. Finally, it discusses how we, as Bhutanese, interact with this very special mountain environment in which we were born.

In the geography lesson of your previous classes you learned about the crust of the earth and its interior structure. You also learned that the interior of the earth is always in motion. This movement affects the formation of landforms on the surface of the earth and this is why we study this topic in geography courses as well as in geology classes.

There is a long-standing belief that the continents and ocean basins have always been in their present forms since the beginning of the earth's history about 4.5 billion years ago. Recent developments ins science have helped us to understand more about the interior of the earth on which we live. Scientific discoveries have led us to think that the continents and oceans have not always been in their present positions. It is now believed that they have been in a constant state of motion from the beginning of the earth's history.

The Theory of Continental Drift

One scientific theory about the movement of the earth is the theory of **Continental Drift** put forward by Alfed Wegner of Germany. This theory was supported by the discovery of fossils of the **mesosaurus,** a late Palaeozoic reptile, on both sides of the South Atlantic. Since the mesosaurus did not swim well, its existence on both sides of the ocean suggests that South America and Africa were once attached to each other. (See Figure 1-1).

Evidences in favour of the Continental Drift Theory.

1. **Geographical Similarities between the opposing coasts of the Atlantic Ocean**.

   The outlines of the coast on the two sides of the Atlantic are such that they can be easily joined together and appear to be a detached portion of the other.

   Wagener also found that the eastern coast of the South America could be fitted into the western coast of Africa; and similarly the eastern coast of North America could also be fitted into the western coast of Europe. This fitting process was called the Jig- Saw Fitting.

2. **Remarkable similarities in the geological structure and history of the lands located on the two coasts of the Atlantic Ocean.**

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The structure and the relief features are found transverse to the coast.

3. **Remains of fossils animals and plants.** There is marked similarity in the fossils and vegetation remains found on the Eastern Coast of South America and the Western Coast of Africa.

4. **Evidences of sea floor spreading.** It has been reported from geodetic evidence that Greenland is drifting westward at the rate of 20 cm per year. The evidence of Seafloor Spreading after 1960 have confirmed the movement of landmasses with respect to each other.

Wegener thought that, in the beginning, the present continents were part of a bigger land mass which is called **Pangaea.** The northern part of Pangaea he named **Laurasia** and the southern part **Gondwanaland**. According to his history, the shapes of the continents at present are such

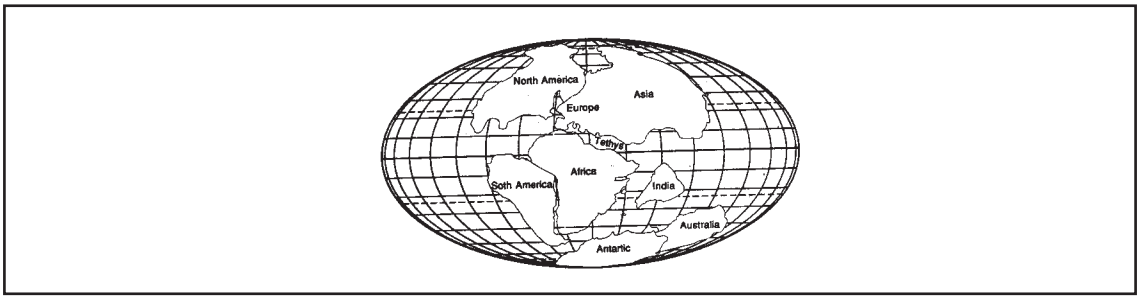
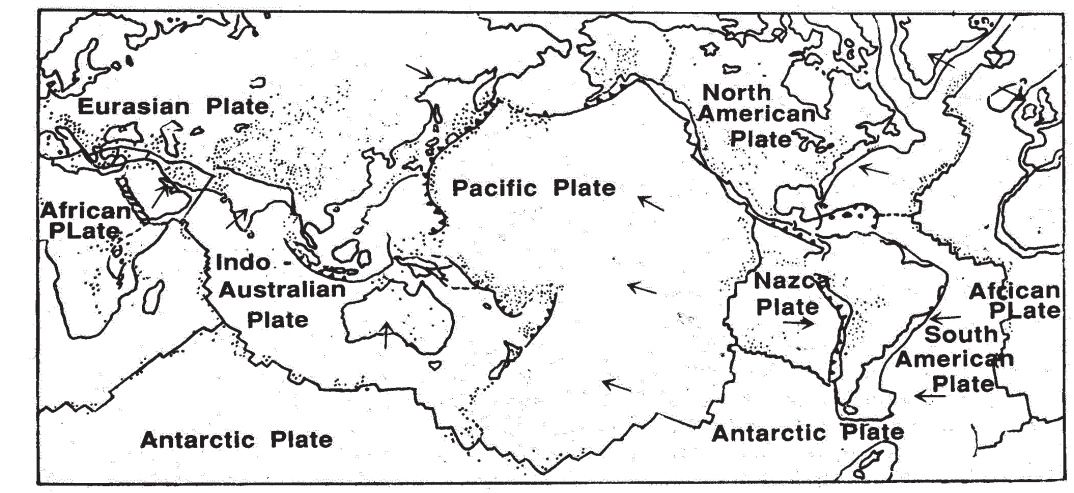


Figure 1-1 Map showing Pangaea, Gondwanaland and Laurasia.



Earthquake Zone — **Collision Zone**
Subduction Zone — **Direction of Plate Movement**
Spreading Oceanic ridge

Figure 1-2 Map of the world showing plate boundaries

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that they can be fitted together like pieces in a jigsaw puzzle. From this study, he explained that the continents might have drifted apart from the common land mass–Pangaea.

The Theory of Plate Tectonics

In the 1960s, Tuzo Wilson's theory of **plate tectonics** emerged and supported Wegener's ideas of drifting continents. Tectonics is a geological term meaning 'movement'. According to this theory, the lithosphere, the outer shell of the earth, which is nearly a hundred kilometers thick, is broken into six primary slabs called **plates.** These plates behave as if they were floating over another layer beneath. As Figure 1-2 shows, each of these six primary plates has either a continent or a part of an ocean basin above it.

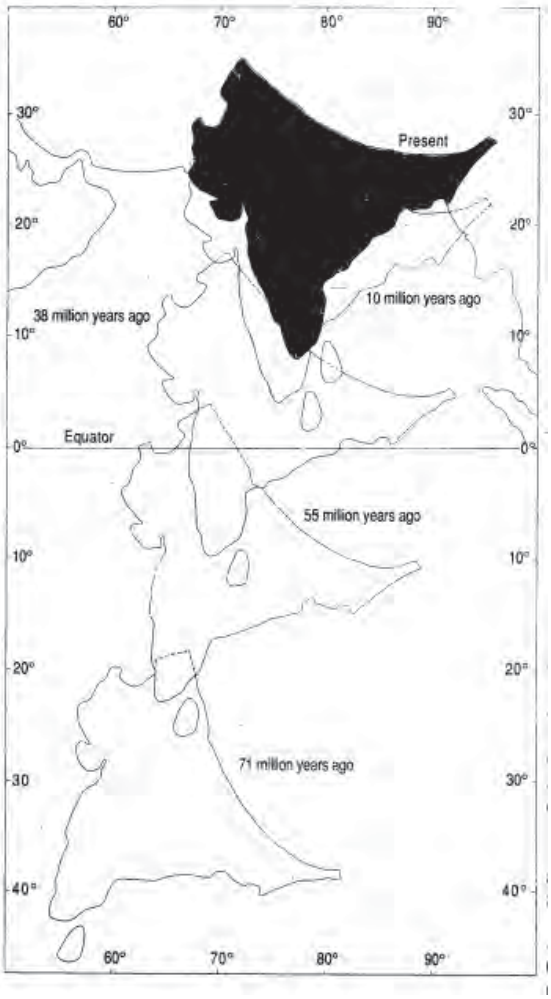

Figure 1-3 Map showing the position of Indian Sub-continent about 70 million years ago. Over millions of years, it has slowly pushed its way northward, across the line of equator and eventually collided with Eurasia

The theory explains that the plates move in different directions. When the plates move away from one another it is called **divergent** movement. But when the plates move towards one another it is called **convergent** movement.

In the middle of the floor of the Atlantic Ocean basin, a linear gap is created by two diverging plates. Along this gap magma pours out of the earth's interior. When magma comes out of the earth it is known **lava.** As the lava comes in contact with the cold water of the ocean, it cools quickly and hardens to form a part of the ocean floor (here, the Atlantic) which is called the **Mid-Atlantic Ridge**. See Figure 1-4 a.

Colliding plates exert pressure on both sides of the plate boundary. The pressure causes the rock strata to buckle and bend. The bend rock strata then rise above the neighbouring low lands to form **Fold Mountains**. The Alps, the Andes, and the Himalayas are all fold mountains. At the point where the plates converge under the sea another landform is created which is called a **trench**. This occurs where one plate forming a deep valley in the ocean floor. The Mariana Trench in the Western Pacific is an example of this feature. (See Figure 1-4 b)

All these movements make the earth unstable. It is the drifting and ultimate collision of the continental plates that has led to the creation of the Himalayan Mountain System in which Bhutan is located. With our background knowledge of plate tectonics we shall now proceed to learn how the Himalayas were formed.

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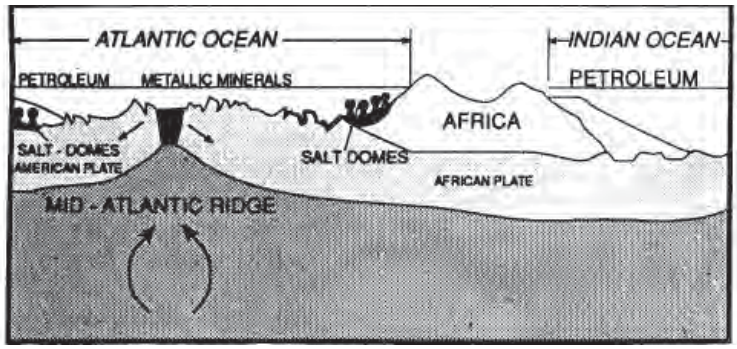
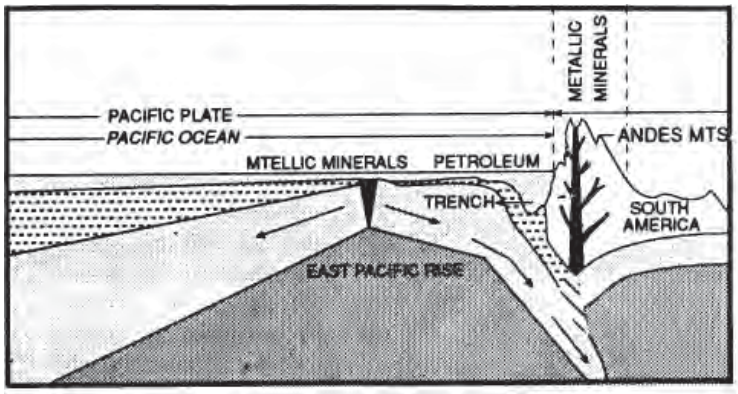


Figure 1-4 a Cross section of how sea floor spreads; and



1.4b Cross section of how trenches are formed.

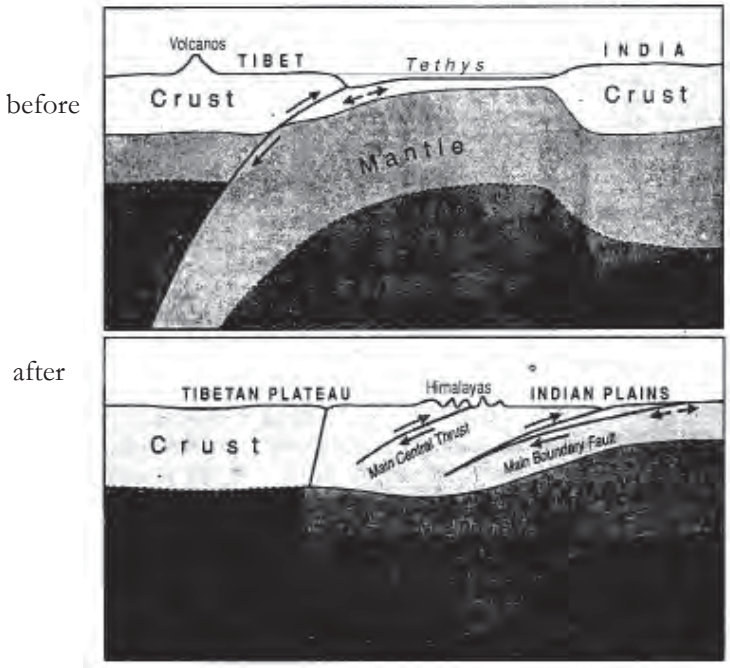


Figure 1-5 Cross section of how Himalayas were formed.

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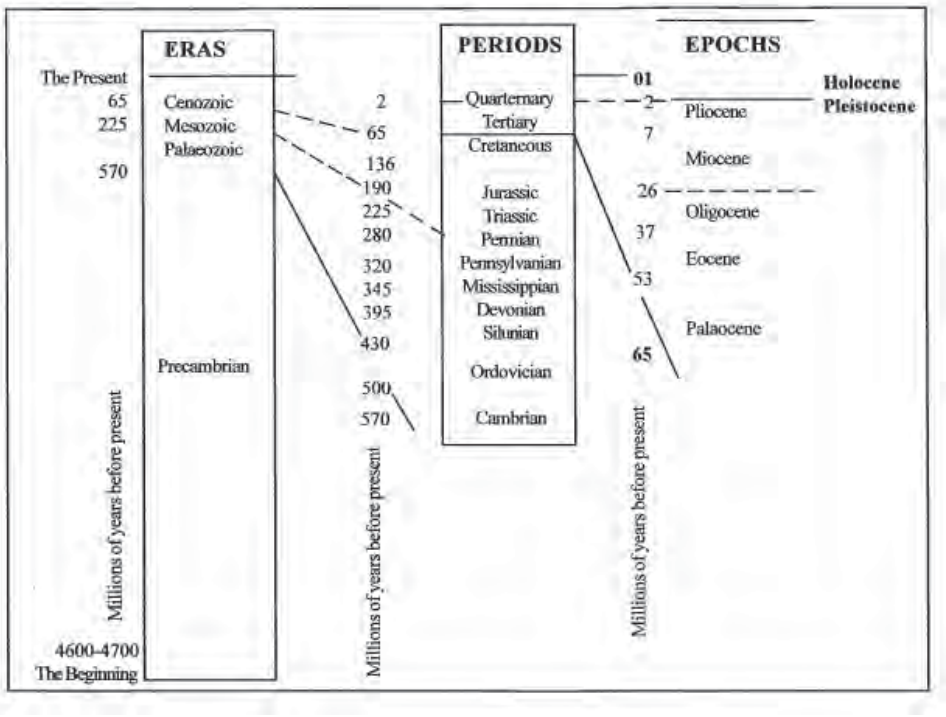

Figure 1-6 Geological time scale. Source: Mc Knights Physical Geography 1990

Questions and Activities

1. Draw an outline map of the world on thick paper and cut out the individual continents.
   Try to refit them together to form Pangaea.

2. Study the map in Figure 1-1 which shows Pangaea:
   a Which is the older ocean – the Atlantic or Pacific?
   b Draw one more map to show how the will look 50 million years from today.

3. a Give an account of how the plates that form the earth's crust move.
   b What do you think will happen if the plates move faster than they do now?

The Tethys Sea

Between 70 to 200 million years ago, a massive body of water called the **Tethys Sea** was said to have spread from as far as Spain in the west to Indo-China in the east. At that time the present Himalayan Mountain System did not exist and the Indian Subcontinent was then located south of the Equator. See Figures 1-1 and 1-3.

At that time, the lithospheric plate carrying the Indian Subcontinent was some 7000 kilometres away in the Southern Hemisphere. In the course of 70 million years, the northern tip of the plate has moved to its present position at the rate of some 5-10 centimetres per year in the first 30 million years and around 5 centimetres per year in the last 40 million years. It is assumed that the main Eurasian Continental Plate has remained in its present location for all these years.

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Table 1-1 Richter and Mercalli scale

Richter Scale		Mercalli Scale	
Magnitude	Effects	Magnitude	Effects
1	Not felt	1	Detected only by instruments
2	Felt by some	2	Felt by sensitive people at rest
3	Felt a little	3	Weak – vibration like passing of lorry, loose objects disturbed little
4	Windows rattle	4	moderate – rattling of dishes, doors and windows, may take up sleepers
5	Windows break	5	Fairly strong – most sleepers wakened, trees and poles disturbed plates broken.
6	Poorly constructed Buildings destroyed, Damaged.	6	Strong – furniture overturned plaster cracked, people may pani
7	Widespread damage, steel bends	7	Very strong- some damage to buildings, chimneys broken
8	Nearly total damage	8	Destructive – much change, walls and chimneys fall
9	Total destruction	9	Very destructive – severe damage to pipes, roads and foundations, landslides occur
		10	Devastating to properti wes
		11	Catastrophic – few buildings survive, great cracks in the ground, pipes and bridges destroyed
		12	Major catastrophe – complete destruction, ground waves occur.

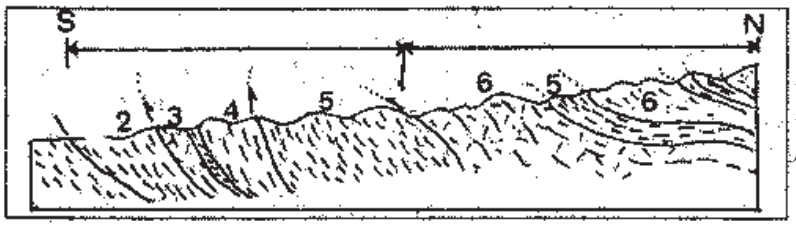

Figure 1-7 Cross Section of the Bhutanese Himalayas showing fault lines and dip of the strata.

As the Indian plate moved closer to the Eurasian plate in the north, the basin of the Tethys Sea became narrower and shallower as its floor was slowly lifted up. As a result, this area which had remained under water was lifted above sea level and the sea water drained out. The first lifting, sometimes called the **thrusting** of the seafloor, took place some 40 million years ago, when the two plates initially collided, The collision between the plates had, and has, both immediate and long term effects. Earthquakes occur immediately following any plate movement whereas the mountain building process takes million of years.

Earthquakes

During the upthrust, the sheer strength of the compression from the north and the south caused the rock strata to fold. As pressure continued to be exerted, the rock strata formed overfolds. Finally, under extreme tension, the rocks cracked where the stress was the greatest. This created a number of **fault lines.** However, the major fault line in the Himalayas occurs where the lithospheric plate carrying the Indian Subcontinent runs northwards under the Eurasian plate. Most of the region's **earthquakes** take place along this fault line as we can see in Figure 1-5. As the two plates pass each other, a sudden release

of Stress (energy) from the locked section of the fault lines causes violent vibrations which is felt througout the region.

The vibration caused by an earthquake is called a **seismic wave** and the strength of the seismic wave determines the **magnitude** of the earthquake. Two types of scales have been devised by seismologists to measure the magnitude of the earthquake. (See table 1.1)

The Himalayas

The upheaval of this region of Asia has taken place in at least three stages since the initial collision of the plates. The last stage occurred about 10 million years ago. The result of this series of upheavals has been the creation of the highest mountain ranges in the world, the **Himalayas**, which in Sanskrit means the **abode of the snow.**

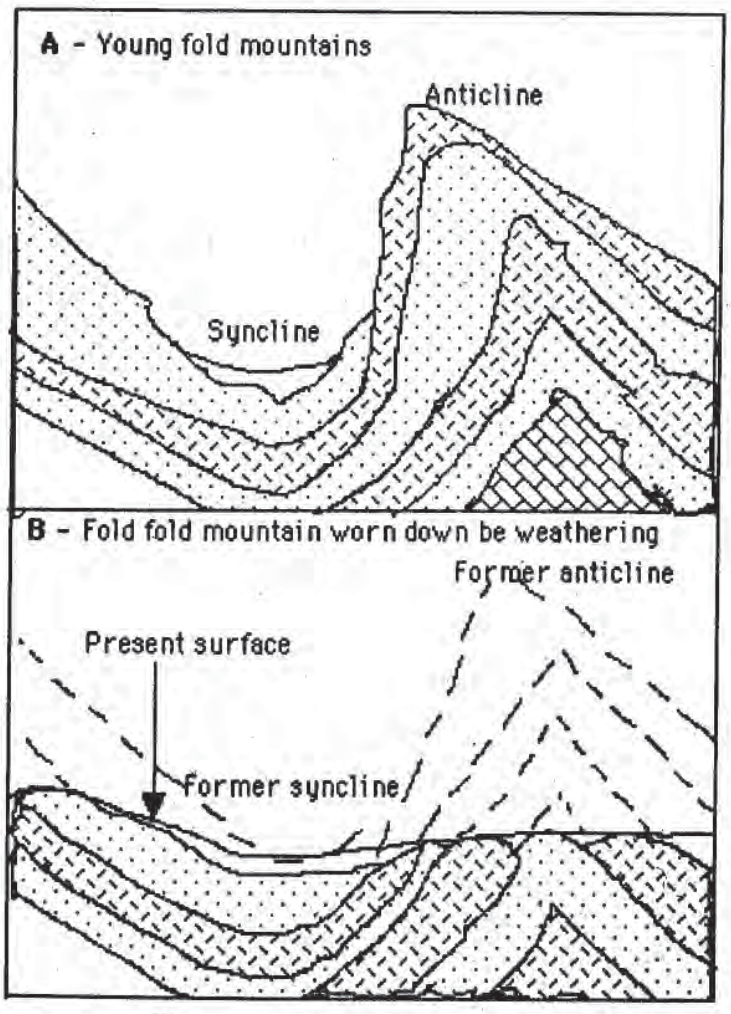

Figure 1-8 a Cross section of young fold mountains showing synclines and anticlines. b. Cross section of old fold mountains showing plain surface worn down by weathering and erosion.

The sedimentary rocks such as limestone and dolomite found on the northern edge of the Himalayas, and in some parts of the Central Himalayan valleys were formed about 60 million years ago under the sea on the continental shelves. Fossils of fish and other marine life have been found in these rocks.

Fossils of the first mammals that existed in India date back only some 45 million years and have a close resemblance to those found in Mongolia. This suggests that these mammals appeared in India only after the collision of the two plates.

Research has also shown that many of the highlands in Asia, particularly in China and Mongolia, are newly created. They were also formed as a result of the collision between India and Eurasia.

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The north-south cross-section of the Bhutanese Himalayas (Figure 1-7) gives a general impression that the **strata** of the rocks have been highly folded. You will notice that major fault lines generally **dip** northwards. The lithospheric plate, while colliding with Asia, is also being submerged into the interior of the earth. The major mountain systems of the world, such as the Andes and the Alps, are also found along the boundary lines of converging plates.

The Himalayas are among the youngest and most recently formed mountains in the world, in geological terms. The **geological time** chart in Figure 1-6 will help you to understand how the planet earth has evolved since its beginning, 4.5 billion years ago. Seventy million years seems a very, very long time in our lives, but geologically it is a relatively short time. If we compare the whole 4.5 billion year history of the world to the length of one day, then 70 million years is equivalent to only one minute of that day.

Fossils and the sedimentary rocks found in the region have helped to confirm the theory which suggests that as a result of the tectonic movement of the earth's crust, the Himalayas grew out of the sea floor. Mountain formation did not stop 10 million years ago, however, as it is a dynamic process. As the tectonic force of the earth continues to push the plates together, the Himalayas continues to get imperceptibly higher day by day.

Landforms

Landforms are the various features of the physical landscape such as hills, plateaux, valleys, mountains and plains. The types of landforms that are found on the surface of the earth are partly due to the geological structure of the rocks underneath. A smooth, horizontally formed rock stratum below the surface is often related to plain areas on the surface. Folded rock strata that result from geological movements often lead to complex surface landforms.

Questions and Activities

1. Make a list of the fold mountain systems in the world. Indicate if they are old fold mountains or young fold mountains.

2. List all the evidences, which support the idea that before the tertiary period, there was a huge sea where the Himalayas now stands.

3.a. Visit a villager or any person who has lived in the area for a long time, and ask how many earthquakes have occurred during his/her life time.

b. Work out the average frequency of earthquakes in the region (use the person's age as the main base).

c. Ask how much destruction was caused by the last earthquake.

d. Estimate the magnitude of the earthquake he/she describes with the help of the scale given in Table 1.1.

Folded Structure and Landforms

You have seen that mountains are formed due to pressure from both sides of converging plates. If the pressure is gentle and even from both sides, the bending of rock strata will be symmetrical. The surface landform will then be arranged alternatively with **synclines** and **anticlines.** But if the compression is uneven, asymmetrical folds will form and the landform on the surface will appear to be a complex mountain system. The cross-section of Bhutan in Figure 1-8a shows that, in general, Bhutan is formed by a series of synclines and anticlines which are in a north-south direction.

Rock Type and Landforms

Sometimes the types of underlying rocks also influence the types of landforms on the surface. This is because rocks vary greatly in their resistance to the processes of weathering and erosion. In Bhutan, the landscape has many mountains and hills that stand upright because the underlying rocks are hard and resistant to weathering and erosion. Such landscapes are usually made up of granites, quartzites, limestones and resistant sandstones. Other types of rocks such as shales, clays, weakly formed sandstones and loose sands are easily worn away by the agents of denudation such as rain, running water, ice and wind. Thus they are often reduced to low-lying valleys and gorges.

The Reshaping of Mountains

Mountains are initially formed by the tectonic forces from within the earth. But the combined forces of denudational agents are responsible for reshaping the surface features through such processes as weathering, erosion and transportation. In fact over a short time frame, these processes are said to be more dominant than the tectonic forces.

For the most part, in Bhutan, the weakly formed sandstones have not been able to resist the forces if denudation and this has produced the many valleys for which the country is famous. Where hard rocks do occur, the land features stand out as mountain ranges, ridges, and hills.

As shown in Figure 1-8b, the older fold mountains are worn down by the impact of erosion and appear to be relatively flat on the surface. Millions of years ago, they were also young mountains and looked like the Himalayas today. The Appalachain mountains of eastern North America and the Scandinavian Highlands are examples of old fold mountains.

Figure 1-9 Hard rocks can resist the forces of denudation longer and form prominent features on the surface of the earth.

Figure 1-10 Running water is a very effective agent for denudation on sloping areas.

Figure 1-11 The tip of Mount Jumolhari in the north-west of Bhutan and a Gola Emtsho between Laya and Lingzhi. Their beauties can also instil fear in the viewers.

Bhutanese Attitude Towards Mountains

Mountains in Bhutan look very beautiful. Their roots are dipped into the unfathomable sea water and their peaks touch the heavens. This is our homeland. There is generally an eastern ridge over which the sun rises and a western ridge behind which the sun sets. The rising and setting of the sun reminds us of the reality in which a life rises in birth and sets at death. The Himalayas provide the support system for the people of Bhutan who depend on the resources in these mountains for their water, food, shelter, wealth and warmth. The enchanting and peaceful mountainsides of Bhutan have always been popular among the Buddhist saints and sages for meditation. Many temples and meditation centres today are located in mountainside retreats where renowned saints and sages had meditated and blessed the sites.

To many Bhutanese, our mountain peaks are the abodes of the protective deities and their names also suggest this. The mighty *Chung-Du* resides in the mountains of Haa, while *Jumo 'Lhari'* is the name of a female deity who resides on that peak. The great glacier peak of *Gangri* at the source of the Mangde Chu is the abode of *Mug Tse,* the local guardian deity of Mangde Valley. Where there are lakes on the mountain plateaus, people consider them as sacred properties of the various deities and therefore untouchable by humans. Any unusual sounds or activities that human make near the lakes or near the summit of the mountain peaks will result in stormy weather accompanied by hail stones, blizzards and foggy weather with very poor visibility.

The legendary dragon is supposed to live in the sacred mountains and occasionally flies across the valley to the other mountains with thundering sounds. It is said that the snow lion and the *yeti* also live near the high mountain peaks. The perennially snow laden peaks symbolise eternity for the present day world of humans. The disappearance of the snows from these peaks will signal the end of the human world.

Such beliefs have made the peaks and the lakes inaccessible to humans, who prefer to keep their distance from them. In places believed to be abodes of deities, they try to maintain silence for fear of bad weather. To a Bhutanese, mountains are a source of inspiration for life and work.

Questions and Activities

1. How significant are the external forces of weathering, compared with the internal tectonic forces in the development of the Himalayas?

2. **a.** Select a section of a valley in your area and describe its shape.
   b. Name the forces that helped to form the valley.
   c. Describe the work done by each of these forces.

3. Visit a few people around the valley where your school is located and find out:
   a. What people think about the mountains in the valley?
   b. What the names are given to each mountain peak?
   c. How the villagers feel about the peaks?
   d. Their views on the lakes in the mountains.

4. Study the Box 1-1 on The Bhutanese and their Mountains:
   a. What is your feeling towards the mountains?
   b. What benefits do we derive from our mountain environment?
   c. Compare the feelings of the people you interviewed in Question 3 above with those described in Box 1-1.

Summary Activities

1 In this chapter, you have learnt about the six key ideas listed in the box in the beginning of this chapter. Do you understand each of these ideas? Write a short paragraph on each idea.

2. Describe the following concepts in your own words (you may look into the text to make sure you have got them right).
   - Continental drift.
   - Mesosaurus
   - Pangaea
   - Gondwanaland
   - Plate tectonics
   - Trench
   - Seismic wave
   - Fossils
   - Dip
   - Synclines
   - Anticlines

3. a. Draw a time chart showing how the Tethys Sea disappeared and how the Himalayas emerged.

   b Provide a reasoned account on the formation of the Bhutan Himalayas.

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Chapter 2

ROCKS AND MINERALS

KEY IDEAS

Rocks
Minerals
Mineral Resources in Bhutan

In other geography text books, you have read about the three main types of rocks found in the earth's crust. This chapter also discusses the thee major types of rocks comprising the earth's crust – igneous, metamorphic and sedimentary rock. However, the main focus of the discussion in this chapter will be the relationship between the rocks and minerals. We shall also study some of the specific characteristics of minerals found in Bhutan and learn their names in Dzongkha and English.

Rocks

As most of our minerals are extracted from rocks, we begin our discussion by examining how rocks are formed. The knowledge of the geological history of the earth's crust helps us to understand the nature of the rocks and where different types of minerals are located.

Igneous Rocks

Igneous rocks originate from molten material found in the upper mantle of the earth. There are two types of igneous rocks – extrusive and intrusive. **Extrusive igneous rocks** are formed on the surface of the earth's crust. The molten material comes to the surface, through vents and volcanoes, and then cools and solidifies, forming rocks such as basalt and volcanic tuff. Sometimes, the molten material cannot come up to the surface, but solidifies within fissures close to the surface of the crust. These rocks, such as granite, andesite and rhyolite are called **intrusive igneous rocks.**

Figure 2-1 Granite rocks are good material for building purposes

Sedimentary Rocks

Sedimentary rocks are those which are formed by the deposition of materials that are broken down from pre-existing rocks, followed by compaction and cementation. Most often the deposition occurs under water. Sedimentary rocks are generally found in layers sometimes called **strata.** The boundaries between the layers are called **bedding planes.**

Over millions of years, the natural agents of denudation erode materials from higher elevations. This material is then transported by running water, wind and ice and is deposited in layers in low lying areas and on the ocean floor. The addition of more sediment exerts pressure on the previously deposited layers. This pressure **compacts** the sediment. Compaction and **cementation** glue the deposited materials together to produce sedimentary rocks, such as

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shale, sandstone, limestone, dolomite and coal. It is mainly in sedimentary rocks that one can find the **fossils** of the animal and plant life which existed millions of years ago. See Box 2-1.

Weathering / Erosion
↓
Transportation
↓
Deposition
↓
Compaction & Cementation
↓
Lithification
↓
Sedimentary Rocks

FORMATION OF FOSSILS
(see figure 2.4)
Fossils are the remains of plants and animals that have been preserved in sedimentary rocks. Preservation of all of the animals or plants is very unusual. Normally, only the remains of the hard parts such as bones and shells, or casts of the animals and plants are found in the fossil.

How are fossils formed?If the dead plants or animals are exposed to scavenging animals, bacterial action, or the elements of weather, they will decay and decompose. Under such conditions, **fossilisation** is not possible. Fossilisation usually takes place under oxygen free conditions where there is a quick burial after death and where the remains are free from bacteria, animal consumption, and weathering. Mud, sands and volcanic ash are said to be the best environments for fossilisation. Although some fossils may be found in metamorphic rocks such as marble, most fossils are destroyed during metamorphism. Sedimentary rocks such as limestones and shales are a common place to find fossils. Fossils are never found in igneous rocks because in the very hot magma nothing can be preserved.

Some fossils are found in the original form of the animals or the plants. This is because the fossils have not undergone much chemical change. Where there is a chemical change in the fossils, the structure will be completely altered although the form will remain similar. Sometimes, the original material may be completely dissolved away, especially in fossils from the Palaeozoic and Mesozoic eras (65-570 millions years ago). In this case, there will be a space in the sediment. Such a space may be filled in by minerals from surrounding rocks brought in by water. Such fossils are very beautiful in appearance, especially if the materials replacing the original ones are silica or iron sulphide. Sometimes, the fossils are chemically decomposed and change into hard rocks such as coal, or are dissolved into petroleum and gas. These are also known as **fossil fuels.**

Fossils provide us with first-hand information on plant and animal life and environmental conditions in those early days. The history of the evolution of many animals and plants is known through the study of fossils. Many different types of fossils can be found in Bhutan, telling us a lot about the animals and plants that existed thousands of years ago.

Box 2.1. Formation of Fossils

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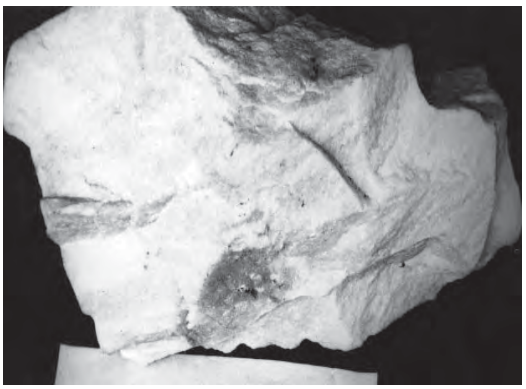

Figure 2-2 Sedimentary rocks with traces of fossils and bedding planes

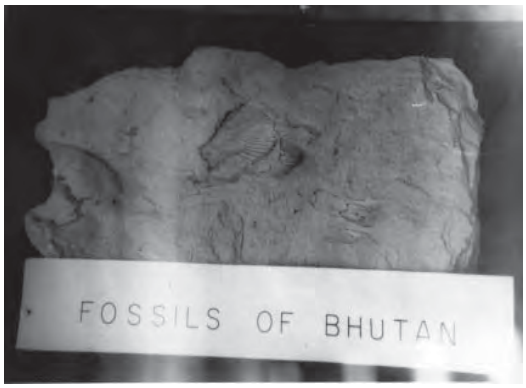

Figure 2-3 Examples of Fossils in limestone in Bhutan

Metamorphic Rocks

Metamorphic rocks are those rocks which have undergone both physical and chemical changes under the influence of pressure and heat. The sources of metamorphic rocks can be either sedimentary or igneous rocks. Slate, quartzite, marbles, schist, gneiss, and graphite are examples of metamorphic rocks. An example of the changing state of rocks through geological times is shown in the flow chart in Figure 2-5.

In reality, very little of the rocks that we find today belong to the original ones that were formed in the beginning of earth's history.

The ever-changing nature of the crust makes the study of rocks very complicated. The task of learning about the origin of rocks and their processes has never been an easy one. See Figure 2-8.

In the Himalayan region, igneous activity, sedimentation, and the metamorphism of rocks are mainly due to mountain building movements. These movements have changed the landscape from a pre-Tertiary low-lying area covered by the Tethys Sea to the highest mountain system in the world. It has also contributed to the occurrence of the precious minerals found in Bhutan and elsewhere in the Himalayas.

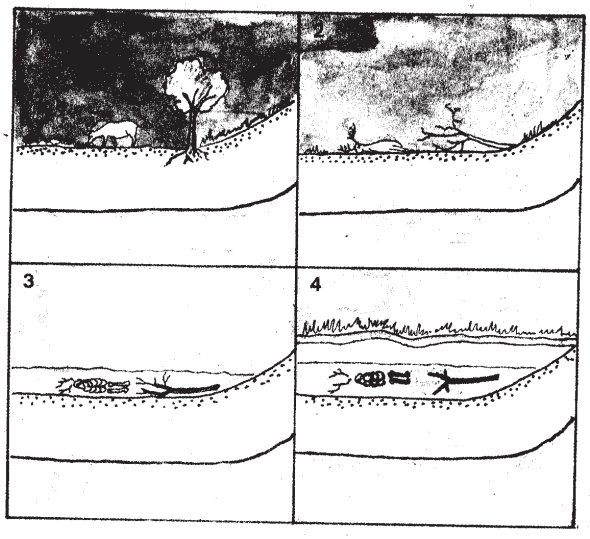

Figure 2-4 Process if fossilization

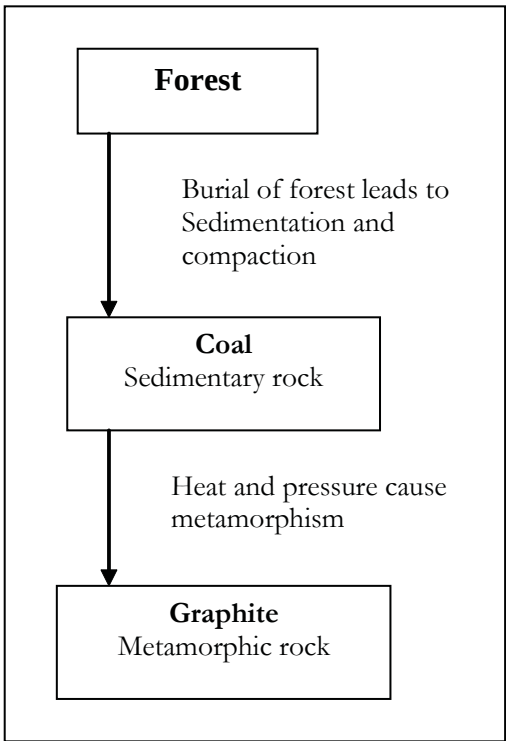

Figure 2-5 Examples of how materials undergo changes through geological periods.

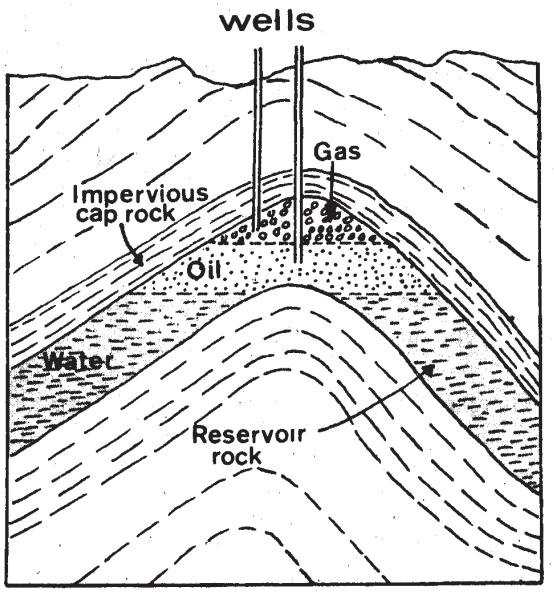

Figure 2-6 Environment under which fossil fuels occur.

Questions and Activities

1. Draw a table as shown below in your note book and find out about three different rocks found in your locality.

Name of Rock	Describe how it appears	Permia bility	Resistance to erosion	Local name	Used for what?

2. Study Figure 2-8.
   a. What is 'geological cycle'?
   b. Explain why most of the rocks present on the earth's surface today were not present when the earth was created.
3. Study Box 2-1 on fossils and Figure 2-4.
   a. List the conditions that are conducive to fossilisation.
   b. List those that will not help fossilisation.
4. Study Figure 2-3.
   a. Describe the way this fossil was formed.
   b. What living organism does it represent?
5. From your physical geography books, find out and describe how one rock changes into another rock. An example is given for you in the section on metamorphic rocks

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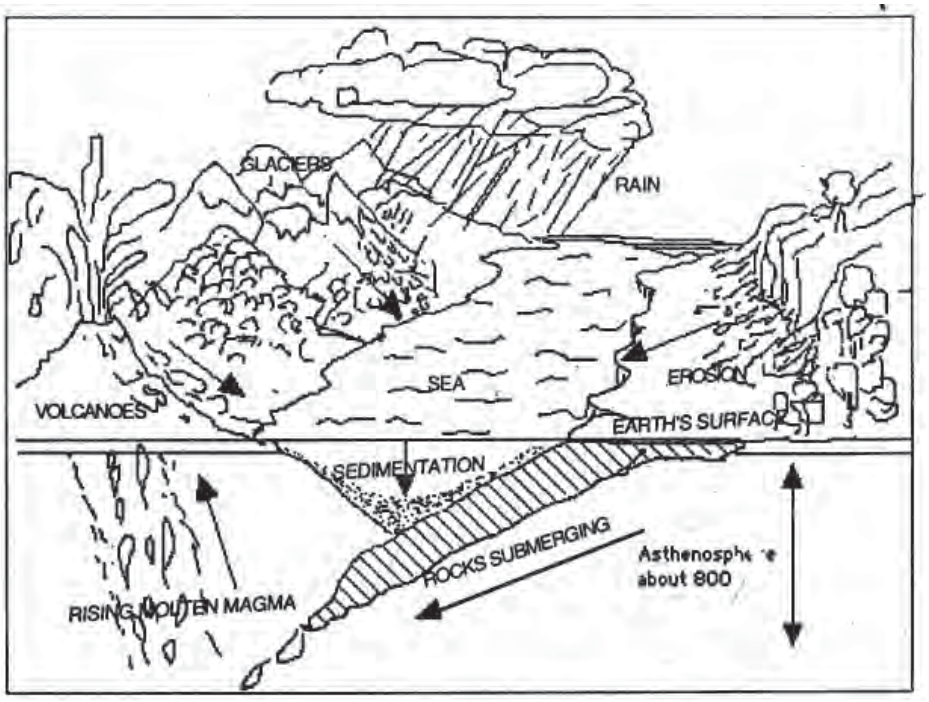
Figure 2-7 Examples of Metamorphic rocks.

Minerals

A mineral is a naturally formed chemical element or compound having a fixed chemical composition, and usually in a characteristic **crystal form.** A crystal form is a regular shape, bounded by plane surfaces which are the outward expression of a regularly repeating internal arrangement of atoms. Minerals are identified by their physical properties such as colour, hardness, cleavage and fracture, or crystal form, or by finding out their chemical composition.

There are thousands of minerals known to occur in the earth's crust but there are only a few hundred which are common, and fewer still which are used in industries.

Figure 2-8 The geological cycle showing how rocks are transformed from one form to the other by plate tectonics, volcanoes, denudation and sedimentation.



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Broadly speaking, the rock forming minerals can be divided into two groups – non-metallic minerals, which are mainly silicates, and ore minerals. It is from the ore minerals that metals are extracted for industrial purposes. For example, iron, copper, lead, zinc, tin and tungsten are extracted from their respective ore minerals found within the rocks. The non-metallic minerals such as coal, gypsum, talc, limestone and dolomite are also important raw materials for many industrial processes.

Some Common Minerals

There are numerous classes of minerals which can be divided into a number of major groups. Examples of the most common minerals in each group are given in Tables 2-1 to 2-5.

Non-Metallic Minerals

These minerals includes silicates, sulphates, chlorides and carbonates, which are given in Table 2-1.

Gemstones

Gemstones are described as precious stones and semi-precious stones. A mineral is considered a gemstone if and only if:

- it is beautiful to look at,
- it is durable or long lasting, and
- it is rare. (See Tables 2-2 and 2-3).

Fuel Minerals

Coal, crude oil, and natural gas are called **fuel minerals**. Coal is used mainly as fuel, both domestically and in industries such as in the manufacturing of cement and iron and steel. Besides petroleum and kerosene, which are commonly used in our daily lives, a host of other petro-chemical products are extracted from crude oil.

Ore Minerals are also called metallic minerals. They are given in Table 2-4.

Native Metals are found in nature in pure forms. Their names are given in table 2-5.

Figure 2-9 Some minerals found in Bhutan

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English Names with Dzongkha names	Chemical Composition
Halite (Rock salt) - རྒྱ་ཚྭ།	Sodium chloride
Gypsum - གཅེར་རྡོ་ཀཱ།	Hydrated calcium sulphate
Limestone - ཐུང་ཀར་རྡོ།	Mostly calcium carbonate
Dolomite - ཐུ་ཀར་རྒྱ་རྩི་ཀཱ།	Calcium-magnesium carbonate
Graphite - གཅེར་ལ་ནག།	Carbon
Mica - རྡོ་ཤེལ་ཙང་།	Hydrous silicates of K, Na, Ca, Fa, Mg etc.
Talc - ཁཱ་མ་གཅེར།	Hydrous silicates of Mg
Feldspar - རྡོ་དཀྱི་གཡོ་མ་གཅེར།	Aluminium silicates of K, Na, Ca, Ba, Fe, etc.
Calcite -	Calcium carbonate
Quartz - ཆུ་རྡོ།	Silica
Fluorite - ཤེལ་ཀུ་ཀ་ཧྲ་ལ་ཐུང་།	Calcium Fluorite

Table 2.1. Non-metallic Minerals

English Names with Dzongkha names	Chemical Composition
Diamond - རྡོ་རྗེ་ཤ་ཡམ།	Carbon
Ruby/sapphire - པད་རཱ་ག།	Aluminium oxide
Emerald (a variety of Beryl) - མཉར་གཤ།	Beryllium aluminium silicate
Topaz - ལྗོག་རྡོ་མེ་ཚེན།	Hydrous aluminium silicate containing fluorite

Table 2.2. Precious stones

English Names with Dzongkha names	Chemical Composition
Turquoise - གཡུ།	Hydrated copper aluminium phosphate
Garnets - པ་ར་རྒ་ཟཧྭ་མ།	Aluminium silicates or Ca, Mg, Fe, Cr, F, Mn.
Amethyst - ཟི་ཀྲ།	Silicon oxide of silica (white, yellow, black, red)
Peridot	Magnesium-iron silicate
Opal - ཨོ་མ་རེ་ཀ་རྡེ་ཚེན།	Hydrated silicon oxide
Moonstone	A variety of feldspar
Onyx - ཀཱ།	Silicon oxide or silica (white, yellow, black, red)
Citrine	Silicon oxide or silica (yellow variety)

Table 2.3 semi-precious stones

English Names with Dzongkha names	Chemical Composition
Galena - ཝ་ཁྱི་ཀ་ཁ་ཤ།	Lead
Chalcopyrite - ཝ་ཁྱི་ཆ་ལ་ཁ་ཀ།	Copper-iron sulphate (fool's gold)
Magnetite - ཁ་ག་ཀ་ཅེར་ཁ་ཁ་ཤེ།	Iron oxide
Sheelite - ཟླ་ག་ཐུ་ཀ་ཅེར་ཀ་ཀཱ།	Calcium tungstate ?
Sphalerite - ཝ་ཁྱི་རྩི་ཚ།	Zinc sulphate
Argentite	Silver sulphide
Cinnabar - མཚལ།	Lead sulphide
Stannite	Copper-iron-tin-sulphide
Cassiterrite - ཁ་ག་ཀ་ཁྱི་ཀ་ཅེར་ཤ་ག།	Tin oxide
Pyrolusite	Manganese oxide

Table 2.4. Ore minerals
Source: Division of Geology and Mines, 1993.

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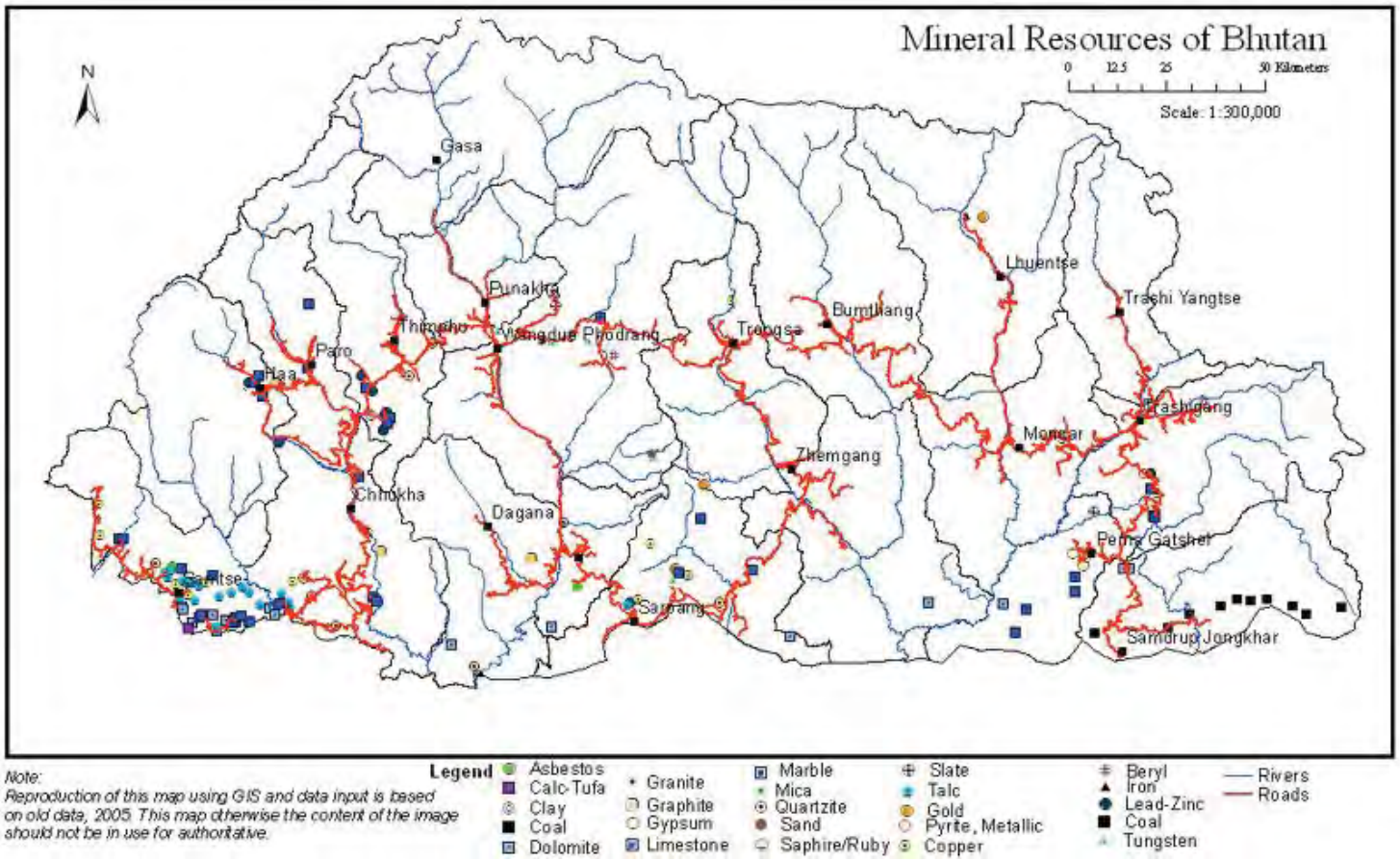

Figure 2-10 Mineral map of Bhutan

Dzongkha Names	English Names
གསེར།	Gold
གསེར་དཀར་པོ།	Platinum
དངུལ་ཆུ།	Mercury
ཟངས།	Copper

Table 2.5. Native minerals

Mineral Resources in Bhutan

We have a one geological organization in our Kingdom today. It is the Department of Geology and Mines in Thimphu. This scientific body carries out geological surveys mainly to prepare and update geological maps of Bhutan. They also try to locate and prove mineral deposits in different parts of the kingdom. Proven mineral deposits may some day give rise to successful mining ventures, boosting the economy of our country.

About fourteen different types of minerals have been found in Bhutan so far. Some of these are already mined, for example limestone, dolomite, gypsum, coal and marble. The Penden Cement Plant at Gomtu uses limestone from the Pagli area in Samtse and gypsum from Kothakpa in Pema Gatshel. The Bhutan Carbide and Chemicals Plant at Pasakha, near Phuntsholing, uses high-grade limestone from Rongri Limestone Mines near Gelephu and also from Hourikhola Limestone Mines near Phuentsholing. The Bhutan Marbles and Minerals Plant at Gidakom, near Thimphu, extracts marbles found in Gidakom and Jeymena area. The quartzite deposit at Tintaley, Samtse, is under operation to supply raw material to the existing ferro-silicon plant of BFAL at Pasakha, near Phuntsholing. Several mini cement plants are expected to be opened in future to use the limestone reserves in the kingdom, which will meet our domestic demands. In addition, Bhutan exports coal, gypsum and dolomite to neighbouring countries such as India, Bangladesh and Nepal.

As you can see from the Mineral Map of Bhutan in Figure 2-10, there are also a few metallic mineral deposits such as copper, lead, zinc and tungsten. At present, these deposits are not mined. A number of factors must be considered before mining the mineral reserves. Mines are very costly to establish and also involve high financial risks for the investors as the market prices of the minerals tend to fluctuate frequently. Mining also requires advanced technological knowledge and skills, labourers and efficient transport systems.

Mining activities have both advantages and disadvantages for the country. While they raise the wealth of a nation and provide job opportunities for the people, the jobs they provide are often hazardous. The environmental well-being of the country should also be considered before mining activity begins.

Questions and Activities

1. Try these two ways of exploring for minerals beside a river:

   a. Put some small particles of river sand in a frying pan (used by villagers to make *zow)*. Add water, then tilt the pan to separate the heavy particles from the lighter ones. Go to a nearby stream and repeat the exercise (be careful about the river currents).

   b. Bury a piece of discarded metal in a sand pit. Using a strong magnet, pass over the sand pit in a series of random paths to locate the piece of metal.

   Carry a strong magnet with you while trekking through the countryside. Pass the magnet over rocks and see whether any of them are attracted to the magnet. Bring back any piece of rock that attracts the magnet and try to identify it with the help of your teacher or a geologist.

2. What difficulties might be encountered in exploiting minerals in future?

Summary Activities

1. Find the following terms in the text and then describe them in your own words.
   - extrusive igneous rocks
   - intrusive igneous rocks
   - sedimentary rock
   - bedding planes
   - fossil fuels
   - metamorphic rock
   - mineral
   - crustal form

2. Copy the diagram in Figure 2-11. Inside the boxes write the names of the types of rocks that could be found in such environments. Show how they are a part of the "Rock Cycle".
3. Describe how the three different types of rocks are formed.

4. Go around your school and identify as many items as you can that are produced from fuel minerals and metallic minerals.

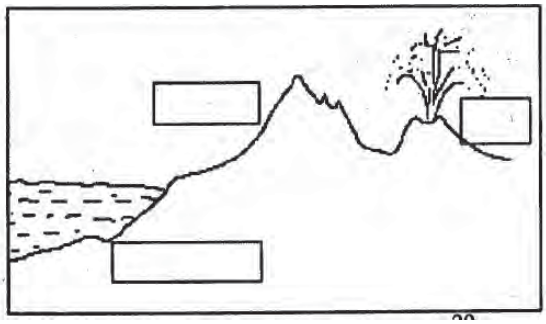

Figure 2-11 Diagram for summary activity Question 2

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Chapter 3

SOILS

In earlier classes, you read about some of the fundamental ideas concerning the composition of soil, soil formation and how soil is useful to humans. In this chapter we will expand on these ideas and describe the different types of soils that occur in mountainous countries such as Bhutan.

What is soil?

Soil is a mixture of weathered rock particles, decaying organic matter, living organisms, mineral salts and **soil water** – the thin film of water that cling to the rock particles.

Soil covers the outer most part of the earth's crust and is characterised by its ability to support living plans.

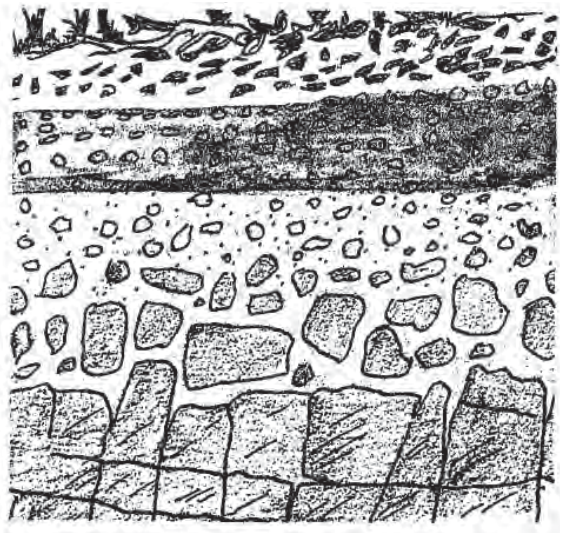

Figure 3-1 Vertical cross section of soil, showing different horizons.

KEY IDEAS

Formation of Soil
Soil Forming Factors
Composition of Soil
Soil Acidity and Alkalinity
Soil Types

This is made possible by the interactions among such different elements as water, sunlight, air, rocks and animal and plant life.

Formation of Soil

Soil is formed by a very slow but continuous disintegration of solid rocks and the decomposition of dead organisms. It is also a result of chemical reactions occurring on the thin layer of the earth's crust where air, water and living organisms meet and interact with each other.

Rock is the **parent material** for soil. Soil is initially formed by the physical and chemical disintegration of rocks. This process of disintegration is called **weathering.** Weathering weakens the solid rocks and causes them to break down into smaller and still smaller fragments.

Figure 3-1 is a **soil profile** in which you can see several defferent layers of the soil. These layers are called **horizons.** The lowest layer is the solid **bedrock,** which is not yet weathered but is likely to become so when the process of soil formation continues its vertical move downwards. The second layer is the **regolith,** which consists of loose boulders covering the solid bedrock below. The true soil is found in the uppermost layer, and consists of unconsolidated materials. This is the ultimate result of weathering.

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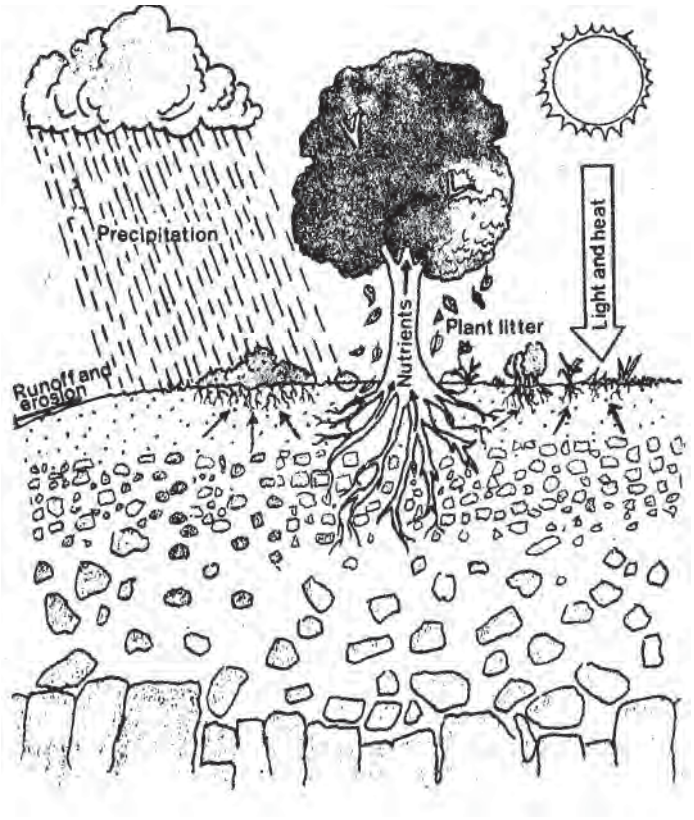

Figure 3-2 Development of soil by the interaction of biological and physical elements.

Figure 3-3 Rocks weathered by the action of water, , ice and wind are parent material for soils.

This loose material contains fine fragments of rocks as well as remains of dead plants and animals. Soil formation is not the end product, but a stage in the long and continuous geological process which is too slow to be noticed in a human lifetime.

Soil-forming Factors

As explained earlier, soil is formed by a combination of factors that interact with one another. These factors are:

- The Geological and Time Factors
- The Climatic Factor
- The Topographical Factor
- The Biological Factor

The Geological and Time Factors

Soil is largely composed of fragmented rocks. Rocks, as parent material for soil, are either solid bedrock or loose sediments that have been transported and deposited from somewhere by the action of wind, running water or ice. In the early stages of its formation, soil bears the characteristics of the parent material from which it has been derived. For instance, a bedrock containing much calcium will result in a calcium-rich soil. A sandy bedrock will form into a highly porous and coarse sandy soil, while a parent material of shale will result in a fine-textured soil.

If the parent material is solid rock, then soil formation takes a very long time. But the process is rapid if the parent material is some kind of loose sediment. On hard rocks, it may take many centuries for a few centimetres of soil to be formed. After thousands of years, however, the original soil is slowly metamorphosed and often all traces of the parent material will disappear. The process of soil formation may be very slow but its degradation is possible within a short period of time. A heavy rain or massive landslide on a mountainside can remove a large portion of good soil which took millions of years to form.

The Climatic Factor

The climate of an area greatly influences the rate of soil development as well as the type of soil that develops in that area. Variations in temperature and humidity affects the rate of both chemical and physical weathering and the rate at which plants grow and organic matter decays.

Hot and wet regions tend to have deep soils that develop quickly. This is because high temperature and humidity help to decay the organic material quickly and increase the rate of new soil development. They also accelerate the growth of plants. The roots of these plants creep into the cracks of the solid rocks underlying the soil, further increasing the rate of weathering.

In the colder and drier regions, such as the high mountain slopes in Bhutan, the organic material decays much more slowly because the rate at which chemical reactions take place is reduced under such conditions. However, due to constant fluctuations in temperature from very hot to low freezing conditions, physical weathering is dominant. This results in the widespread occurrence of regoliths and thin poorly formed soil.

As shown in Figure 3-4, our farmers in northern Bhutan make great efforts in preparing manure using animal wastes, leaves and other foliage. They then apply the manure to their fields to help the soil regain the nutrients it lost through farming. In the lower valleys and in the foothills, where it is relatively hot and wet, farmers do not need to do as much to restore soil fertility.

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Figure 3-4 *Using manure in cold regions of Bhutan to restore soil fertility is a regular activity on the farmlands.*

The Topographical Factor

Topography determines the depth and nature of the topsoil in any particular area. The steepness of the land affects the rate at which erosional agents remove the soil, and helps determine how quickly new soil develops.

Figure 3-5 Slopes influence on soil depth

In flat land areas soil tends to be quite deep. This is because the rate of downward soil formation is greater than the rate of removal from the surface by gravity and running water. On steeper slopes, however, the situation is reversed as surface erosion is relatively rapid while the downward formation of the soil is slower. This explains why the layer of soil is thin and poorly developed in sloping areas.

On the steep slopes in many parts of Bhutan, top soil is washed away by the monsoon rains. In places where vegetation cover is poor, top soil is also exposed to wind erosion.

The Biological Factor

The soil provides an environment for plant growth and a habitat for animals and insects. When the animals and plants die, their remains decompose. Fungi and bacteria feed on the remains of dead plants and animals and actively promote decomposition. Nutrients released from the process enrich the soil. Another result of decomposition is the production of a dark and sticky substance called humus. Humus is very important to the soil as it makes the soil more cohesive and allows it to absorb moisture more readily and thus helps to produce healthier vegetation.

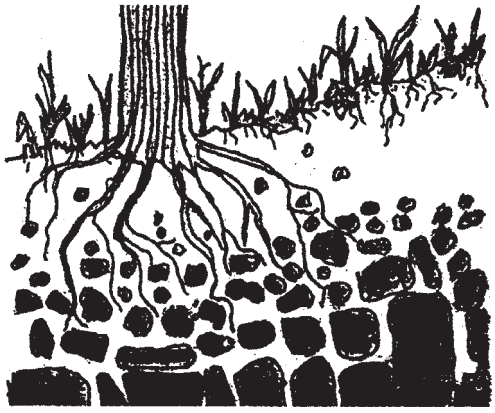

Figure 3-6 Tree roots contribute to soil formation

Plants with large root systems also help to develop soil quality as their roots work their way deep into the soil making pathways through which water and air can travel. Animals of different kinds also influence soil formation. For instance, large animals like cattle and elephants compact the soil with their hooves. And smaller animals like earthworms, mice, moles and rabbits make

holes or burrows which moves the soil up and down, thereby mixing the nutrient-depleted soil with richer soil.

The soil nutrients are continually recycled through plant and animal life and when they die the nutrients go back to the soil and the cycle begins once again.

Questions and Activities

1. What is soil?
2. Study Figures 3-1 to 3-3
   a. Describe the state of rocks in Figures 3-1 and 3-2.
   b. In Figure 3-3, what do you think has caused the break up of rocks and why does the regolith stand out as it does?
3. a. Why is rock considered the parent material?
   b. How do rocks turn into soil?
4. a. With the help of your teacher, select a site along the side of the road where the soil is clearly exposed to a depth of one metre.
   b. Draw a profile of the soil there. Identify the layers of the soil and mark each one with appropriate colours.
   c. Is your profile different from that given in Figure 3-1?
   d. If there is a difference, what are the main differences and why do you think these difference occur?

Figure 3-7 Collection of dry oak leaves in winter is an important part of the annual cycle of farm works.

Composition of Soil

Soil is composed of many different organic and inorganic materials that interact with one another to provide a medium, which supports an immense variety of plants and animals. These materials can be divided into three main groups:

- Minerals
- Organic Matter
- Air and Water

Minerals

The bulk of most soil consists of inorganic matter in very, very small particles. Generally, about half the soil is made of tiny mineral particles called **sand** and **silt.** The mineral content depends on the parent rock from which the soil has been derived. For example, soils that are formed from quartzites contain high amounts of silica.

Plants need minerals to grow and they get these minerals from the soil. Mineral-rich soil is therefore very useful for farming. **Nitrogen, phosphorus** and **potassium** are the minerals most commonly used by plants. They are also depleted more rapidly from the soil. That is why these three components of the soil should be replaced by the farmer so that the next round of crops will not be deprived of nutrients. Sometimes, this is done by using artificial fertilisers.

Organic Materials

Of the total soil volume, some seven percent is composed of a certain fine material, which has its origin in living organisms. Although it is found in very small quantities, the organic matter is a very important component of the soil. Plants and animals in all states of decomposition form the organic matter of the soil. Leaves, twigs and stalks of higher plants that have not yet decomposed are referred to as **litter.**Once decomposed, the litter is changed into humus.

Humus helps to prevent the soil nutrients from being washed away during heavy rains and supports plant growth.

Air and Water

Nearly half of the soil is made up of a network of pores called **interstices.** Air and water enter into the soil through these interstices. The amount of air and water available in a certain soil may vary from one place to another and from time to time. In a wet place or in the rainy season, the percentage of water may be higher than that of air, whereas in a dry place or a dry season it will be the reverse.

You may have noticed on your farms that, when you irrigate a dry rice field, bubbles are formed wherever water seeps in. This is an indication that there was air in the soil and when water enters the escaping air forms bubbles at the surface of the water. The rate at which soil can absorb water is called the **infiltration rate.** This rate depends on two things – the size of the interstices and how much water is already in the soil. Once all the interstices are filled with water we say that the soil has reached the **saturation point.** Infiltration will not take place when the soil is saturated and, therefore, surface run-off occurs. If the soil is constantly saturated, it is said to be **water logged.** This commonly occurs in flat and poorly drained low lying areas.

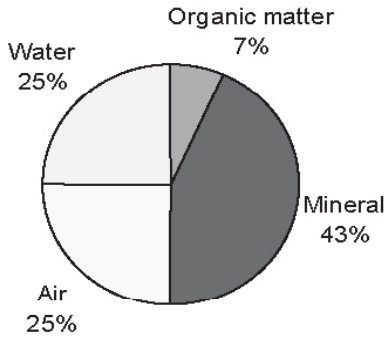

Figure 3.8 Composition of Soil

Soil water helps dissolve soil nutrients which move through small pores in the soil and are then absorbed by plant roots. Water on the surface of the soil is continually lost through evaporation. This process pulls ground water up from the **water table** below. This could be compared to how the kerosene is pulled up through the wick in your lamp. This upward movement of water through soil pores is known as **capillary action.**

Capillary action is only possible if the soil particles are of the right size. If the soil particles are too large, water runs through the soil downwards, carrying the dissolved nutrients, which are then deposited at a lower level. This process is called **leaching,** which results in nutrient-poor soil.

In contrast, if the soil particles are too small, water cannot move through. In such cases, water will either stagnate on the soil surface or run off into streams and rivers. In areas that become water logged, there is a shortage of oxygen in the soil, so organic matter cannot decompose and produce nutrients. Such soils are not fit for crops.

If you look at the soil that is exposed where a motor road has been cut into the side of a slope, you will find that soil colours are different at different depths, as shown in Figure 3-1. These different coloured layers indicate that the soil

has developed a number of horizons. Horizons are formed by water moving up and down in the soil through the processes of **eluviation** and **illuviation**. Eluviation is the leaching of nutrients from the upper horizon and illuviation is the deposition of these nutrients in the lower horizon of the soil profile.

In areas where the soil is fertile, there is a balance between these two movements in the soil. If the balance is disturbed, the soil will become infertile. For example, a rapid clearing of forest cover leaves the topsoil exposed to rainfall, resulting in excessive leaching, surface run-off and topsoil erosion. This can be very serious in areas with steep slopes. That is why we must consider factors such as slope gradients, intensity of rainfall, and composition of the soil before planning to clear a forest area for cultivation.

In many places in the Amazon jungles of South America, cleared forest could not be used continuously for cultivation of crops, as the soil became very poor after the harvest of the initial crops. It is for this reason that our *tseri* lands in Bhutan have to be kept fallow for some years before being used again. This is discussed further in Chapter Eight.

Questions and Activities

1 a What are the three main components of soil?
   b. What are interstices?
   c. How are they helpful to soil?

2 a. What happens during capillary action and leaching?
   b. What is meant by the term "water-logged"?
   c. How do you think we can prevent water logging in soil?

3 What happens if eluviation is more than illuviation?

4 a. Take a large tin and cut the top and bottom out and insert it into the ground as shown in the diagram below.
   b. Get a container with a one litre capacity and a stop watch.
   c. Pour the litre of water into the tin and record how long it takes to be absorbed by the soil.
   d. Try this several times at different sites.
   e. At one site continue to pour litre after litre of water and see how the rate of infiltration changes as the soil reaches the saturation point.
   f. How would you know when the soil has become saturated?

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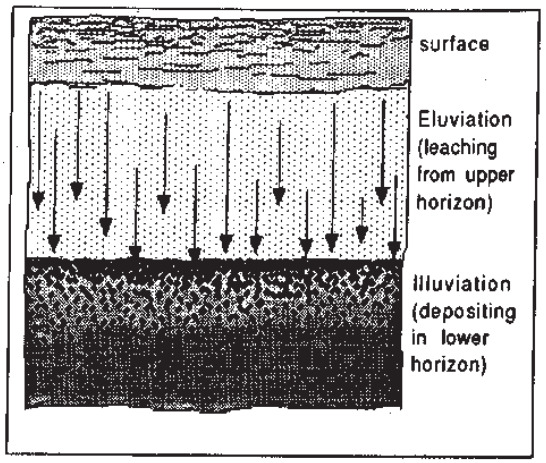

Figure 3-9 Diagram showing the downward movement of soil nutrients.

Acidity and Alkalinity in Soil

Understanding the chemistry of soil is very important for farmers and those engaged in agriculture. As we have discussed above, nutrients can be easily lost through the process of leaching. Agriculturists can determine the **chemical balance** of the soil by measuring its acidity. **Acidity** is measured in terms of the concentration of **hydrogen ions** according to the **pH scale.** A low pH value indicates that a soil is acidic and has a high concentration of hydrogen ions. These ions have replaced the nutrient salts in the soil. Thus, soils with low pH values normally require addition of calcium and potassium to regain their fertility.

On the other hand, soils with high pH values have low concentration of hydrogen ions and are said to be **alkaline.** They are rich in nutrient salts and do not require the addition of fertilisers.

The most productive soils are generally neither acidic nor alkaline and are said to be **neutral**. Neutral soils have a pH value of 7 as shown in the diagram in Figure 3-11.

The chemical behaviour of the soil is closely connected with its physical characteristics. The fine clay particles in the soil become attached to small particles of humus forming a **clay-humus complex,** which has such small particles that chemically they behave like large molecules. This complex plays an essential part in maintaining soil fertility. Nutrient salts necessary for plant growth are dissolved in soil moisture where they dissociate into ions. The clay-humus complex attracts ions particularly the positively charged nutrient salts and holds them by electric attraction as shown in Figure 3-10. In this way, the complex prevents the nutrients from being leached from the soil.

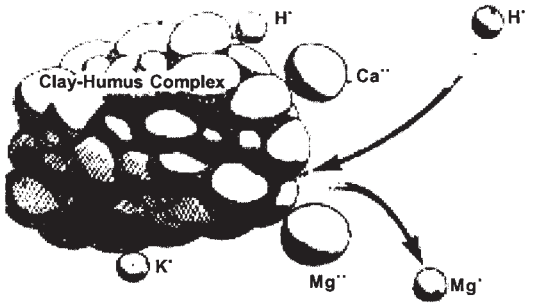

Figure 3-10 The fine inorganic particles and humus in a soil bind together to form the clay-humus complex. On a submicroscopic scale, the particles of the clay-humus complex act like giant molecules with the power to attract ions electrically. The complex performs an important function in a soil by preventing nutrient materials from washing out of the soil. These materials are needed for plant growth. An acid soil contains numerous hydrogen ions that can replace other ions on the surface of the complex, as the diagram shows. Hence an acid soil soon loses much of its content of inorganic nutrients (Z.D. Publishing Co. Cal. 1974)

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Soil Types

Hundreds of varieties of soils have been recognised by soil scientists called **pedologists.** In this section, we will deal with a few types of soils that are found in mountainous countries such as Bhutan. We must remember that very few studies have been done on soils in Bhutan. As such, the information has to be drawn from studies done in other mountainous regions having similar geographical conditions as Bhutan.

Podsolic Soil

Podsolic soil is generally found in areas where the dominant vegetation is coniferous trees. Podsol is a gray soil and is found mainly in temperate regions. This type of soils occurs in areas that have short warm summers and is marked by high leaching rates. Micro-organisms do not thrive in this area, resulting in a slow decomposition of organic matter. In podsolic regions, the coniferous litter decays very slowly and is acidic. There is usually another layer above the soil called the **O horizon**, which is made up of plant litter that has not yet decomposed

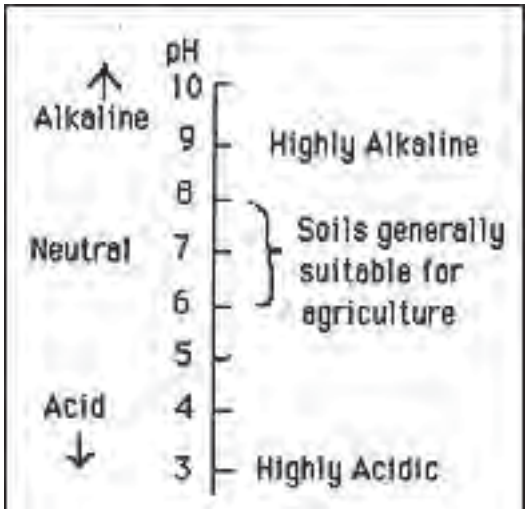

Figure 3-11 A simple pH scale (Z.D. Publishing Co. Cal. 1974)

Such soils are mainly found on the high mountain slopes and surrounding the high altitude valleys in Bhutan. The slopes of the Haa, Paro, Wang, Bumthang valleys and part of Puna Tsang Chu and the upper basins of Dangme Chu are likely to have podsolic soils. Podsols have little agricultural value.

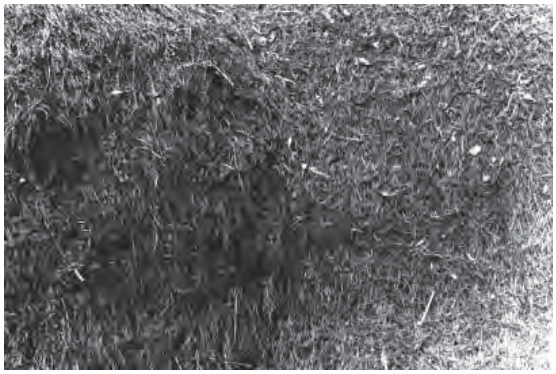

Figure 3-12 Podsolic soil in the temperate climatic zone.

Brown Soil

Brown soils occur extensively in dense deciduous forest areas all over the Himalayas. The soil is rich in humus as a result of sufficient plant litter and other organisms. The humus layer is particularly thick in mature prime forests, which have never been touched by humans. The top soil is usually reddish yellow and is loamy and sandy. Many parts of the central valleys of Bhutan have brown soil. Such soil is very productive in agricultural terms.

Mountain Soils

Mountain soil is found in a very shallow layer especially on steep slopes of high mountain regions. Mountain soil is often mixed with pebbles, gravel and shingle. Its texture varies from loam to sandy loam and it contains little organic matter. This type of soil is formed under harsh conditions and is generally not well developed to be suitable for agriculture.

Red and Black Soils

These soils are found in a few pockets of Bhutan. They are deficient in phosphates, nitrogen, humus and lime. These soils are good for growth of mixed forests of conifers, oaks and scrub trees. They can be seen in parts of the Wang, Shar, Mangde and Tashigang valleys.

The black colour of the soil is due to the presence of humus, while the layer below the top soil can be reddish in colour. Black, white and red clay deposits are found in such areas.

High Altitude Meadow Soil

This soil is usually found on alpine meadows and grasslands at high altitudes all over the Himalayas. Here, precipitation is sometimes in the form of snow, which can lie on the ground for long periods.

The melted water from snow often causes the soils to become water-logged. The soil is thin, fragile, very coarse and easily disturbed and eroded by landslides and **soil creep.** Because of the presence of organic matter from partly decayed grass, its surface is dark. In some places, meadow soil can support varieties of crops, which can tolerate low temperature. Such crops are wheat, buck wheat and barley etc.

Alluvial Soil

When the rivers flow rapidly in their mountain courses, they erode and transport large quantities of silt, loam, and sandy soils. As the river meanders through flat valleys and plain areas, they become very sluggish. At this stage, they begin to deposit even the smallest particles in the load.

The soil deposited in these low lying areas is rich in humus and is very fertile. Agriculture thrives in such regions. The broader valleys of the Inner Himalayas and the foothills are examples of such regions in Bhutan. A very good example can be seen in the rich farmland of the Paro valley (Figure 3-14).

Figure 3-13 Example of red soil found in many parts of the Inner Himalayas

Field Study

a. Make a table such as the one shown below in your note book so you can carry out an actual soil research in your area.

Location	Soil Tyes	Texure Colour	Acid Alkaline	Litter contents
Eg. road side	Sandy	hard/ brown	?	very little

b. Select at least 5 different sites in your valley. Make sure the sites are on different slope gradients. Dig a pit with one flat face and draw a soil profile that highlights the depth and nature of the different layers of the soil at each site.

c. Draw a sketch map locating each of the 5 sites that illustrates the slope and type of surrounding vegetation.

d. From each site, collect a small sample of topsoil to take back to the school lab for analysis.

e. With the help of your chemistry teachers, determine the acidity and alkalinity of the soil you have collected.

f. Use the information you have collected and describe the differences in the soils taken from different sites. Try to explain why these differences exist.

Questions and Activities

1. The activity given below will be helpful in your school gardening and SUPW.
   a. Collect some empty Horlics bottles and cans.
   b. Collect the soils with varying acid and alkaline contents in the containers and label them.
   c. Plant seedlings in the different containers. Water the plants regularly.
   d. Write your observations in a note book and discuss in groups in the classroom how the plants react to acidic and alkaline soil.

Figure 3-14 The fertile valley of Paro

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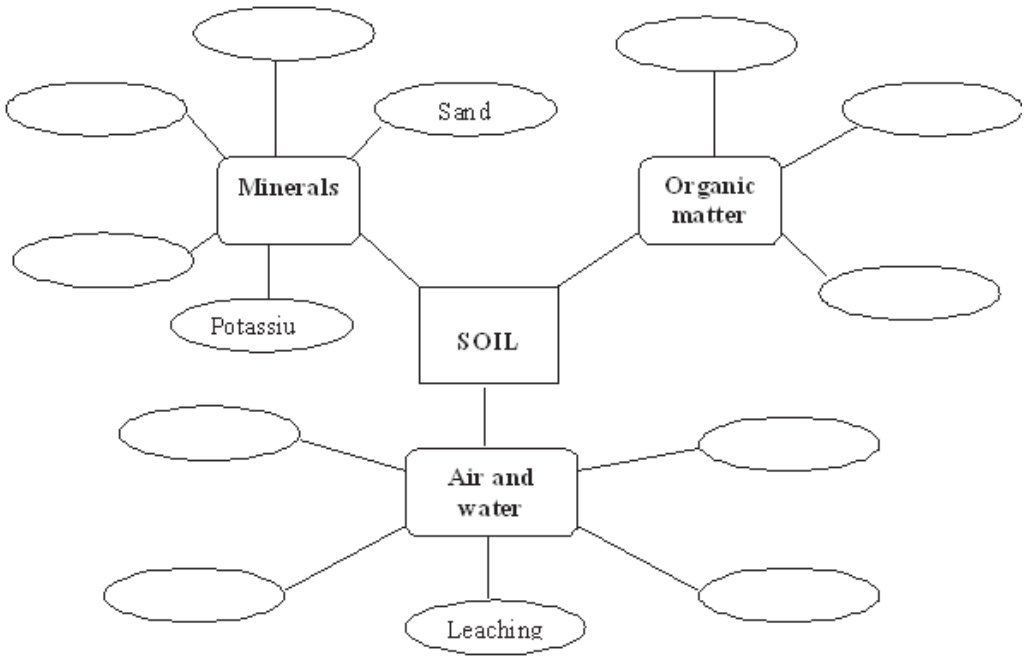
Summary Activities

1. Describe the following new words:
   - Bedrock
   - regolith
   - parent material
   - litter
   - humus
   - water table
   - capillary action
   - infiltration rate
   - saturation point
   - leaching
   - * water-logged
   - * soil horizons
   - * interstices
   - * chemical balance
   - * acidity and alkalinity
   - * clay-humus complex
   - * pedology

2. To summarize the factors that affect soil formation and composition, copy this chart into your note book and label the blanks with appropriate terms



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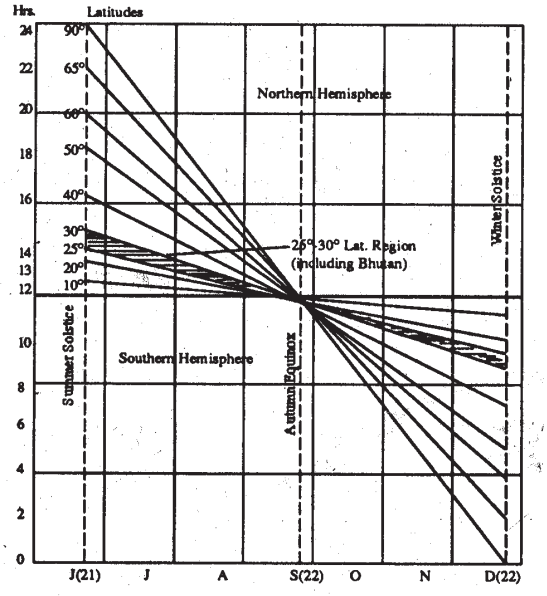
Chapter 4

CLIMATE

In your previous lessons about the climate of the world, you familiarised yourselves with the global pressure and wind systems and the other factors affecting the global climatic pattern. In this chapter, we shall discuss the factors affecting the climate of Bhutan and the different climatic zones that are found within the country.

Bhutan is in the most eastern part of the Himalayan range and it faces the Assam-Bengal Plain of India to the south. Other parts of the Eastern Himalayas include Arunachal Pradesh, Sikkim and the northern part of West Bengal state (all in India) and a part of eastern Nepal. The topographic features of Bhutan and its neighbouring regions present a complex landform. As such, it is difficult to describe a uniform pattern of climate for the entire region.



KEY IDEAS

Factors Affecting Climate

Climatic Zones

Climate and Humans

Although the monsoon is the main factor governing the climate of the Eastern Himalayas, the weather and climatic conditions within the mountains of Bhutan vary greatly from one place to another. This variation is mainly controlled by differences in altitude. As one goes up the mountain sides, it becomes windier. The air is thinner and clearer, and the sun's rays are more intense. On cloudless days, slopes facing the sun will receive intense heat as the thin mountain air does not deflect the sun's rays. But if a patch of cloud passes by and blocks the sun, it can cause an immediate change in the temperature.

We will now discuss the factors that influence the change of weather and climatic conditions in more detail.

Factors Affecting the Climate

Bhutan is geographically a part of the South Asia region and thus the factors that control the regional climate are also the dominant factors controlling the climate of Bhutan. These are:

- Latitude
- Altitude
- Prevailing Wind Direction
- Orientation of Mountain Ranges
- Local Winds
- Vegetation

Figure 4-1 The length of day at different latitudes in the northern hemisphere on 21 June and 22 December (after Strahler and Strahler, 1977)

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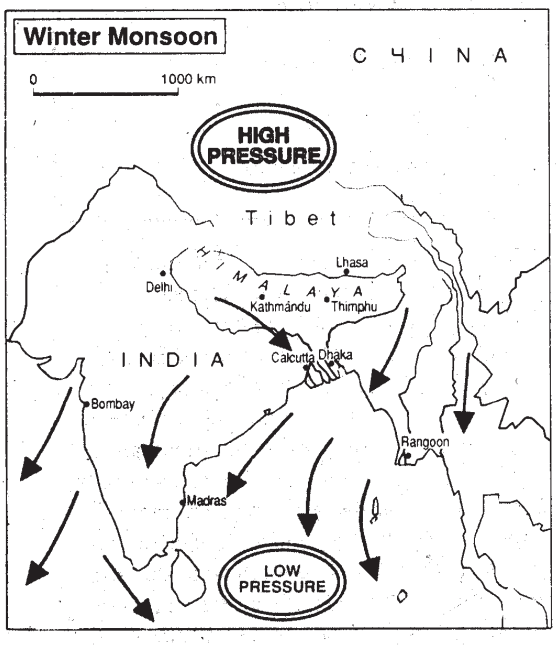

Figure 4-2a Asia map showing NW monsoon winds

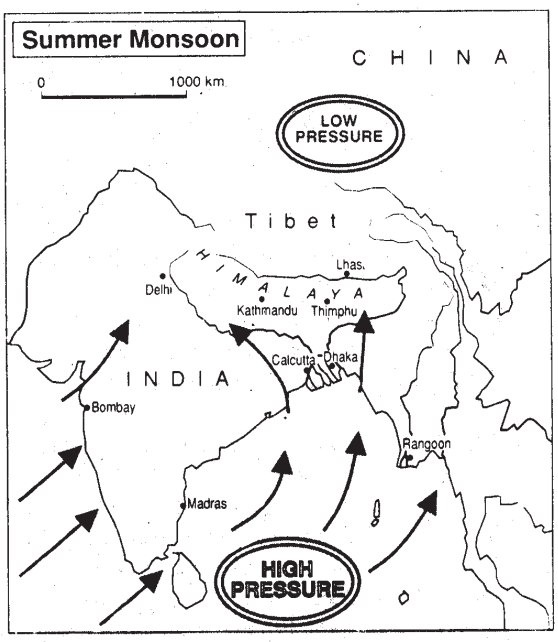

Figure 4-2 b Asia map showing SW monsoon winds

Latitude

The angle of the sun's rays and the length of the days determine the amount of heat energy a place receives. The angle of the sun's rays becomes more oblique as one moves away from the Equator. As a result, the intensity of the sun's rays is much greater in the tropics than it is in places further away from the equator. In summer, the daylight hours get longer as one moves away from the Equator. In winter, the opposite is true and places far away from the Equator have very short days. Thus, the amount of heat received at the land surface is greater in summer than in winter. Around the Equator, the length of a day is relatively constant throughout the year as Figure 4-1 shows. Similarly, there is no seasonal temperature variation.

Bhutan is located to north of the Tropic of Cancer in the Northern Hemisphere at latitude 28 degrees North, leaving it beyond the influence of the perpendicular rays of the sun in the equatorial region. Therefore, it experiences a winter, between December and February, that is colder than those places closer to Equator such as Sri Lanka and Thailand. These countries experiences only a small difference in temperature between summer and winter.

Altitude

Bhutan is a very mountainous country and there is great variation in altitude. The lowest areas are approximately 200 metres above sea level whereas the highest points are more than 7000 metres above sea level. The altitude of a place influences its climate in two major ways. Increases in the elevation causes decrease in the mean annual temperature and an increase in the daily temperature range.

The mean annual temperature decreases with increased altitude because the atmosphere is not heated directly by the incoming **short-wave radiation** of the sun. The earth's surface absorbs

this energy and re-radiates it as heat or **long-wave radiation.** Thus, the atmosphere is actually being "heated" by the earth's surface. This means the further you go above the earth's surface, the cooler the atmospheric temperature becomes.

Elevation also affects the daily temperature range. In the high mountains of Bhutan, the atmosphere is so thin that most of short-wave radiation from the sun reaches the ground surface. In places that are very high, one experiences heat which causes sun burn on clear days. But during cloudless nights, the ground surfaces lose heat more rapidly than lower areas. This is because there is no atmospheric blanket at this altitude to trap the heat which is being emitted from the earth's surface and as a result, the temperature plummets. Thus, the daily temperature range can be very extreme on the mountain tops. In contrast, lower valleys often become widely covered by low clouds during the night. This holds the heat close to the ground surface causing the nights to be considerably warm.

The climatic variation caused by elevation differences is easily seen in Bhutan through the transition of vegetation types. For instance, as one drives from Limithang at the bottom of Kuru Chu Valley to the top of Thrumseng La, one moves from a sub-tropical region producing mangoes to a temperate forest of spruce and fir trees.

Prevailing Wind Direction

The monsoon wind is the main factor governing the seasonal climatic change in Bhutan. You have learnt in previous classes the monsoon winds are caused by seasonal variations in atmospheric pressure over the continent of Asia.

During winter, the temperature in Central Asia drops as the sun's rays become weaker and less effective over that region. As a result, the air becomes heavier and descends, creating a high pressure zone. This heavy mass of cold air then flows southwards into the low pressure zone that develops over the warm water of the Indian Ocean. This north-easterly wind prevails over the region from October to March as shown in Figure 4-2a. The massive barrier of the Himalayas protects Bhutan and the rest of the South Asia region from the full force of this cold dry wind of winter that sweeps down off the Tibetan plateau.

Between June and September the situation is reversed as can be seen in Figure 4-2b. The landlocked interior of Asia heats up much more quickly than the surrounding oceans under the

Figure 4-3 Left, early morning sun hits the east facing slope.

Right, clouds emerging from the valley towards afternoon

strong, summer sun. This creates rising air and an intense zone of low pressure. The wind then slowly changes direction and begins to flow into the centre of Asia. The path is not without obstacles, however. At first the wind hits the mountains of east Myanmar and follows a notherly and then later a westerly course. This is why the Eastern Himalayas are affected by the monsoon much earlier and for a longer duration than the Western Himalayas. In the Western Himalayas the monsoon arrives late and retreats early. Apart from the mountain barriers that stand in the way of advancing wind, the rotation of the earth from west to east also helps the westerly deflection of the monsoon wind.

The southwest monsoon wind is moisture laden as it originates over the warm Indian Ocean. As it runs into the Himalayas, the wind is pushed up over the mountains causing the air to cool and rainfall to occur. This is known as orographic rainfall. The foothills of the Eastern Himalayas is one of the wettest regions in the world, receiving over 2000 mm of rainfall a year.

Figure 4-4 Residues of heavy snow continue to remain for many days on the ubac slopes of central Bhutan.

Orientation of Mountain Ranges

The main Himalayan Mountains lie west to east while the mountain ranges in Bhutan are almost perpendicular to the main range. They look somewhat like the buttress of a tree. As a result, most of the main slopes of the mountains are either east-facing or west facing.

The intensity of temperature varies between east-facing slopes and west-facing slopes. This difference is more evident in the deeper valleys and on the steeper slopes of the Inner Himalayan zones. In many parts of Bhutan, the east-facing slopes get the sun early in the day whereas the west facing slopes remain in shadow until late morning. As figure 4-3 shows, sometimes the morning sun causes evaporation on the eastern slope, which leads to the development of cumulus clouds that spread over the entire valley by afternoon. This means the west facing slopes are often deprived of their sun in the afternoon.

During winter, when the sun's overhead position shifts to the Southern Hemisphere, it appears very low in relation to the mountains. The **ubac**, or north facing slopes, do not receive the heat from the sun and on some slopes snow and ice do not melt for the whole winter. On the other hand, **adret** or south facing slopes in the valley receive sun all year round and have many hours of sunshine each day. Studies done in the European Alps suggest that these slopes are the most popular for permanent settlement.

Local Winds

Mountain landscapes tend to develop their own local wind systems as can be seen in Figure 4-5. Temperature and pressure vary between places at the bottom of a valley and those on the surrounding mountain tops. During the early part of the day, the air above the valley is heated as the high slopes are the first to catch the sun. But, the air at the bottom remains relatively cool due to the fact that all the cold heavy air is drained into the valley during the night and the sun's rays have not yet reached the valley bottom. This difference in temperature creates two different pressure zones within a single valley. The warm

air from the mountain top expands and rises as it is heated. The heavy air from the lower part of the valley then gently moves up the mountain side towards the low pressure area. This upward movement of the air is known as **anabatic wind**. By late afternoon, the situation reverses. The cold and heavy air from the mountain sweeps down the slopes to the low pressure zone in the warmer valley bottom. This is a rather violent movement known as **katabatic winds.** These types of winds are common during spring and autumn. In the foothills they often destroy crops and poorly built houses. Sometimes, thunderstorms can develop, followed by heavy rainfall

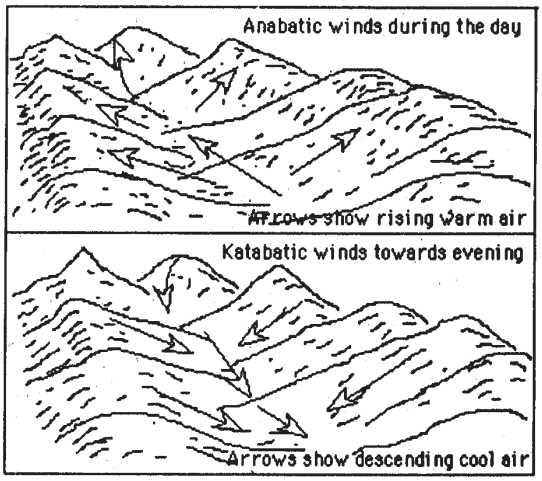

Figure 4-5 Local mountain winds

Figure 4-6 Altocumulus lenticular clouds over mountains, usually formed on the leeward side of the mountains and along the crest of the flowing winds.

Figure 4-7 Trapped smoke in the densely populated town of Thimphu in winter.

At night, the cold heavy air settles at the bottom of the valley. We know that the air close to the ground cools more quickly than the air farther away from the ground surface. By early next morning, while the cold, heavy air still remains on the ground, a layer of comparatively warmer and lighter air will lie above it. This reversal of the normal air temperature gradient in the valley is called a **temperature inversion** and is commonly found in high altitude valleys. This layer of warm air acts as a lid and stops the under lying air from mixing with the rest of the atmosphere.

The trapped smoke from chimneys in the early morning, as shown in Figure 4-7, and the formation of cumulus and altocumulus clouds later in the afternoon are both classic indications of temperature inversions. In heavily populated settlements, such as Kathmandu in Nepal, where industries and extensive use of firewood produce smoke, this becomes a problem to aviation as well as to the health of the people living there.

Another feature of the Himalayan weather is that at higher altitudes, winds, after crossing the higher mountains, form a series of waves on the leeward sides of the mountains. This can be detected from the ground in the form of **altocumulus lenticular clouds** (a series of lens-shaped high clouds). Such types of waves are also hazardous to aviation and aircraft; so better try to keep away from such areas.

Figure 4-8 Cumulo-nimbus clouds, indicating bad weather

Figure 4-9 High cumulous clouds indicating fair weather

Vegetation

Vegetation influences the climate both directly and indirectly. The forest canopy has a great influence on local ground temperatures as it shades the ground from the direct rays of the sun. The forest also absorbs and stores up moisture during the rainy weather and gives off enormous quantities of moisture through a process called **transpiration.** As soon as the moisture leaves the trees, it evaporates as a result of heat from the sun. The combined process of evaporation and transpiration is called **evapotranspiration.**

Vegetation, rivers, lakes and the oceans supply moisture to the atmosphere. Once water vapour in the atmosphere reaches the saturation point, the moisture condenses on dust particles in the air forming water droplets. Many of these droplets will result in fog or clouds. Sometimes, these droplets bump together to form bigger droplets. If the droplets are big enough they fall from the sky as rain.

The presence of fog and clouds affects the ground temperature. Usually, clouds block the outgoing heat energy from the earth's surface and reflect incoming solar energy from the sun. On a cloudy day the ground surface receives only 6 to 45 percent of the incoming solar radiation, whereas during a clear day, as much as 88 percent of the incoming short wave radiation is received at the ground surface. Clouds absorb solar energy during the day and radiate heat during the night, keeping the night temperature warm.

Field Study

Form a group of six students, so you can carry out a study on the relationship between elevation and temperature.

a. Draw a cross section of the valley which you have chosen to study.

b. Each of you will need a thermometer to read the midday temperature at six different altitudes covering as much of the cross section as possible on both sides of the valley. (It is important that all of you read the temperature at the same time, under the same conditions, i.e. in the shade, a metre above the ground surface).

c. Plot your readings on the cross section.

d. Draw a vertical scale beside the cross section that marks the temperature at 1 degree Celsius gradient to show how

Questions and Activities

1. Keep a record of the weather in your area over the next week. Make sure you record the temperature, precipitation, cloud cover and wind variation.
   a Describe the weather variations that have occurred over the week.
   b. Attempt to explain why the weather variations you have noted have occurred.

2. Why do you think temperature inversion is hazardous to aviation and health?

3. **a.** Note as to which part of the day the wind gets stronger in your locality.
   b. What do you think are the causes?
   c. How do such winds affect the life of people in the area?

Climatic Zones

The physical variations such as altitude and orientation of mountains and valleys have created different climatic zones within Bhutan. According to the climatologists, Bhutan can be divided into four different zones:

- Sub-Tropical Monsoon Climate Zone
- Temperate Climate Zone
- Sub-Alpine Climate Zone
- Alpine Climate Zone

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Annual Rainfall in Bhutan

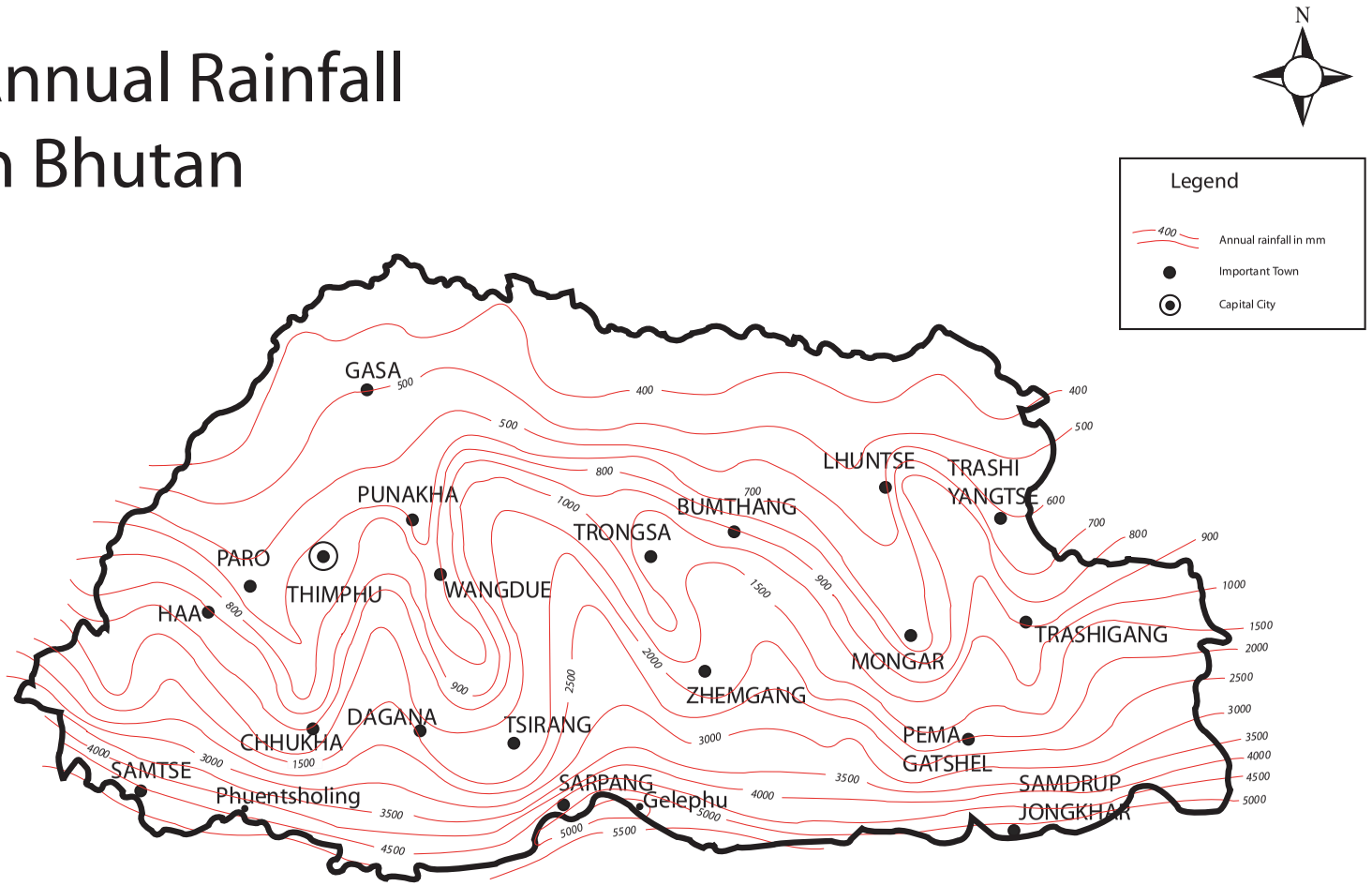

Figure 4-10 Map of Bhutan showing annual rainfall

Sub-Tropical Monsoon Zone

This zone extends in an east-west direction along the southern foothills and stretches into the lower valleys of the Inner Himalayas like fingers of a palm. It lies in the region that is 200 to 2000 metres above sea level. The mean monthly temperature ranges from 15 degrees Celsius in winter to 30 degrees Celsius during summer, while total annual rainfall is usually above 2000 millimetres in the foothills. Temperature and rainfall vary from valley to valley in the interior.

During winters, this zone enjoys cool moderate temperature and relatively dry weather, although there is isolated rainfall when the high mountains above experience snowfall. As the spring approaches, the weather becomes drier and the temperature increases. Early spring is marked by violent stormy winds and hailstones, which often cause damage to houses and crops. During April, May and June the relatively cloud-free sky allows the sun's rays to hit the ground surface, thereby increasing the heat radiation and the temperature. During most nights, the effect of this radiation in combination with the relatively thick atmosphere of the lower altitudes keeps the temperature high, particularly in the low valleys of Puna Tsang Chu, Mangde Chu and Dangme Chu.

The monsoon wind from the Indian Ocean and the Bay of Bengal brings moisture that give rise to cumulo-nimbus clouds, which bring heavy showers of rain. The moisture-laden cloud also keeps the direct sun's rays away from the land surface and keeps the temperature low. Lightning and thunder followed by heavy showers are the common features of weather from mid-June to September. Due to the constant rain, the atmospheric humidity is always high during this season. Moisture and heat contribute to the rapid growth of weeds and creation of wet ground, where mosquitoes breed abundantly. This zone is therefore afflicted by malaria, and people living here must take precautions against possible malaria infection.

Most parts of Samtse, Chukha, Sarbhang and Samdrup Jongkhar Dzongkhags in the foothills and the lower valleys of Thed, Shar, Mangde, Mongar and tashigang Dzongkhags experience this type of climate.

Temperate Zone

The temperate zone lies above the Sub-Tropical zone at an elevation of 2000 to 3000 metres. The average daily temperature during winter varies between 5 and 15 degrees Celsius while the average daily temperature in summer ranges from 15 to 30 degrees Celsius. The total annual rainfall varies from 1500 mm to 2000 mm. Most of the rain comes during the monsoon period from about mid-June to September.

The winter weather in this zone is marked by cold winds, low temperature at night, moderate temperature during the day, cloudiness, light showers, and snowfall. As spring approaches, the landscape is marked by violent winds and relatively dry and clear sky. As a result of long dormant winter, the accumulation of dried grasses and other plant litter increases the risk of forest fires (caused by careless wanderers and herders) in which many valuable trees and wildlife are destroyed.

The monsoon rain in this zone comes at the same time as that of sub-tropical zone, because the source of rain is the southwest wind. Here too, lightning and thunder, cumulo-nimbus clouds and light showers dominate the weather. Rainfall can sometimes continue for several days, causing landslides along the roads. Streams and rivers swell up carrying huge amounts of debris from forests. Deep puddles, thick mud, and landslides along the roads form barriers to transportation.

Figure 4-11 Yaks graze in the sub-alpine region during winter. They move up to the alpine region for summer.

Fog causes poor visibility and creates difficulties for the transport systems of the country, particularly for Druk-Air.

Because of the general north-south orientation of the mountain ranges, monsoon winds reach the Inner Himalayas through the lower valleys, which provide a passage for the moist winds. Usually, rainfall is not evenly distributed all over the valleys. Mountain ranges stand in the way of approaching moist winds, creating windward and leeward sides. The leeward sides of the mountains and the valleys are usually relatively dry and have a distinctively different type of vegetation than the windward sides. During a drive from Thimphu to Wangdi Phodrang one can notice a typical example. The windward side of Dochola is dominated by broad-leaved trees, whereas the drier leeward side (in the Wang valley) is mostly covered by coniferous trees, which require less moisture. See Fig. 4-14.

Paro, Thimphu, higher parts of Shar, Mangde, Tashigang and Mongar valleys, Bumthang and Lhuntse valleys are all in the temperate climatic zone.

Sub-Alpine Zone

Between 3000 metres and 4000 metres above sea level lies the sub-alpine zone.

Here the total annual rainfall varies from 1000 mm to 1500 mm while the mean annual temperature is around 8 degrees Celsius.

The weather in this zone is marked by mist and fog, cold winds and light rain during the short summer and snow in the long winter. Winter becomes intolerable for animals (both domestic and wild) and humans, so they migrate to lower altitude valleys. Yaks and sheep are brought to their winter pasture in the upper parts of the Temperate Zone.

Laya, Lingzhi, Lunana, Gogona, Dur, Merak-Sakteng and Busa-Sephug experience this type of climate.

Alpine Zone

The Apline Zone is over 4000 metres above sea level. Alpine refers to the vegetation or climatic conditions found on the high mountains. Because of very low temperatures and freezing conditions, trees cannot grow here. Instead, mosses and lichen thrive in places where the effect of wind is not very severe. The popular herbal plants of **balu** and **sulu**, used for making incense, are found on the high mountain meadows.

The permanent **snowline** is found at approximately 4800 metres above sea level. Above this line, the snow never melts.

Figure 4-12 Harsh alpine climate is unkind to the growth vegetation in the Greater Himalayan regions.

Snow-laden winds called **blizzards** and occasional snow avalanches occur at this height. This zone does not experience any warm summer season, as even during the summer months it is still extremely cold because of its high elevation.

In this zone are found the high mountain peaks of Jowo Durshing, Daga La, and others in the Inner Himalayan Region and almost all the high mountain peaks which mark the watershed along Bhutan's northern boundary with the Tibetan Plateau. Jumo Lhari, Jiwuchu Drake, Masa Gang, Gangkar Puensum, and Jowo Durshing are covered with snow throughout the year and are known in **Zhungkha** as **Kyalpai Gang** (meaning perennial snow peaks).

Figure 4-13 Stunted alpine vegetation in areas where germination is possible

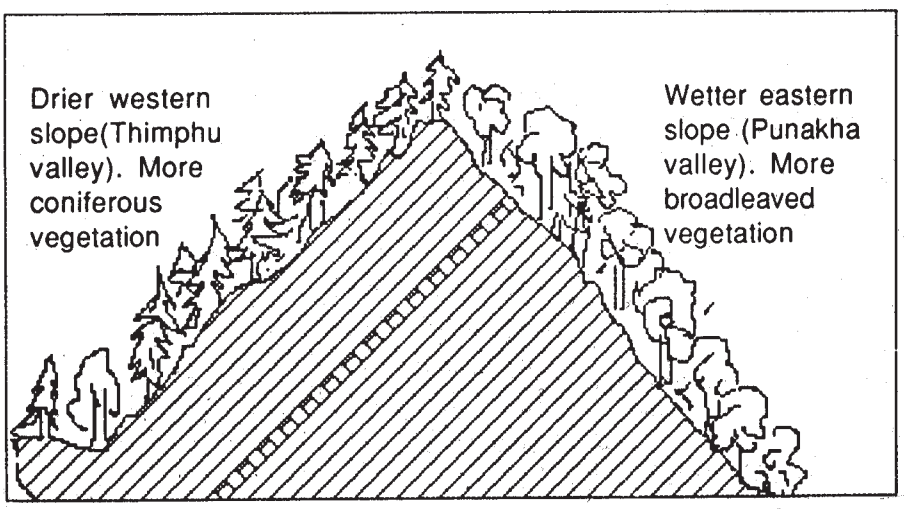

Figure 4-14 Diagram showing vegetation on two sides of Docho La.

Climate and Humans

The settlement pattern and work habits of humans are greatly influenced by such natural conditions as slope of the land, altitude, temperature and rainfall. Extreme conditions of these factors tend to have a negative influence on the settlement patterns and work habits of the people. For example, settlement may not occur in a place which has extremely high temperatures or excessive rainfall. A place with cold weather or very dry conditions also does not attract settlers.

A gance at the population map of Bhutan will indicate that settlement have been determined by the physical and climatic conditions. The alpine zone is hardly touched by humans and the sub-alpine zone is sparsely populated. As you travel around the country, you will observe that settlements have generally occurred in relatively flat areas, where climatic conditions are moderate. The highest settlement in Bhutan is Lunana at 3500 metres above sea level. Here, humans and their domestic animals can only stay for part of the year as they have to escape the harsh winter.

In many parts of the world, humans have claimed their victory over the limitations imposed by nature. Yet, adaptation to nature are still part of great effort humans make for survival. As such, they have adopted various methods to battle against the dictates of natural conditions. These include modifications to architectural designs for buildings and the invention of methods and equipment designed to heat and cool their dwellings and vehicles.

Many birds and animals respond to climatic changes by migration. Others avoid the cold winter by sleeping through it, using up the fat they stored in their bodies during the summer. Some animals, such as the snow leopard, which does not like hot places, prefer to stay on high mountain sides throughout winter, well insulated by their thick fur which keeps them warm.

Climate is also a very important factor in determining the growth of trees and other plants. We can see for ourselves how different types of trees and plants have responded to the different climatic conditions in different parts of the country. It is sometimes through the knowledge of types of vegetation that our farmers interpret the types of climate and altitudes of new potential farm sites. The next chapter will deal with vegetation.

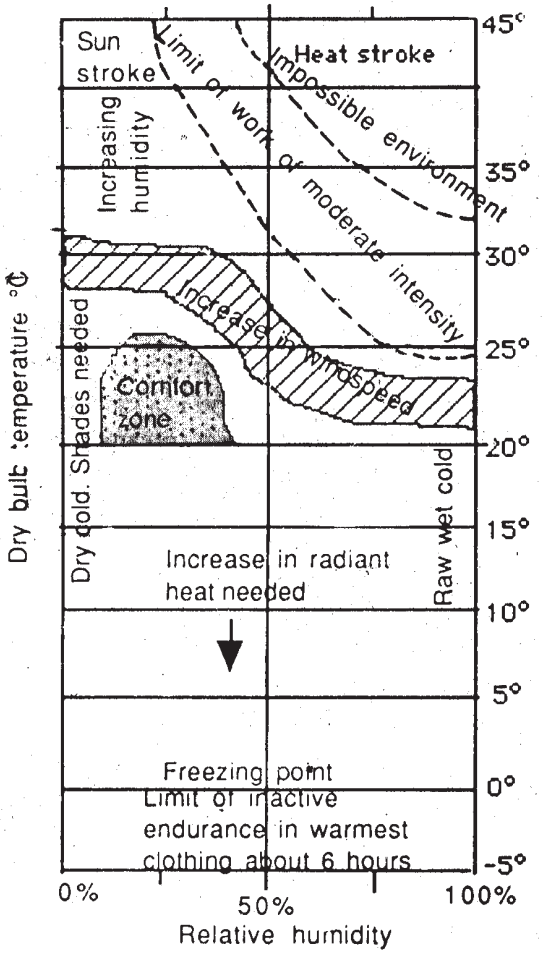

Figure 4-15 Kopen's climatic comfort zone

Questions and Activities

1.

a Under which of the 4 climatic regions does your area fall?

b Give sufficient reasons to support your answer.

2. How do animals and birds respond to climatic changes?

3. Study figure 4-15.

a How do you compare your place of study with the comfort zone?

b What would people do to make their living tolerable if their settlements fall outside this comfort zone?

c In which parts of Bhutan do you think such a comfort zone naturally occurs?

4 Study the temperature and rainfall of 2 stations given in Table 4-1, and answer the following questions:

a For each station, calculate the mean annual temperature.

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b Calculate the total annual rainfall for each station.

c Calculate the temperature range for the month of November for both stations.

d Draw a graph for each station that shows the monthly variations in rainfall, maximum temperatures and minimum temperatures.

e Which station is at the highest altitude? Give reasons for your answer.

f One of the stations is Gasa and one is Sibsoo. Which of them is represented by the data in station B?

g What types of vegetation would you expect to find in station A?

h What agricultural activities would be predominant in station B?

Summary Activities

1. Describe the following important terms in your own words.
   - Monsoon wind
   - Prevailing wind
   - Anabatic winds
   - Katabatic winds
   - Altocumulus clouds
   - Lenticular clouds
   - Ubac
   - Adret
   - Temperature inversion
   - Orographic rainfall

2.

a If the Himalayas did not exist, how would this influence the climatic conditions of Bhutan?

b How would this affect the life, vegetation and agriculture in South Asia?

Stations		J	F	M	A	M	J	J	A	S	O	N	D
A	Max. T. °C	11	12	14	16	16	19	19	17	19	17	12	11
	Min. T. °C	-3	-2	3	6	9	12	13	13	12	5	-5	-2
B	Max. T. °C	2121	26	24	27	28	28	29	27	25	24	22	
	Min. T. °C	12	15	19	19	20	24	24	24	23	20	17	15
	Rain mm	17	30	79	290	364	828	841	458	434	151	6	9

Table 4-1 Temperature and rainfall of 2 stations in Bhutan.

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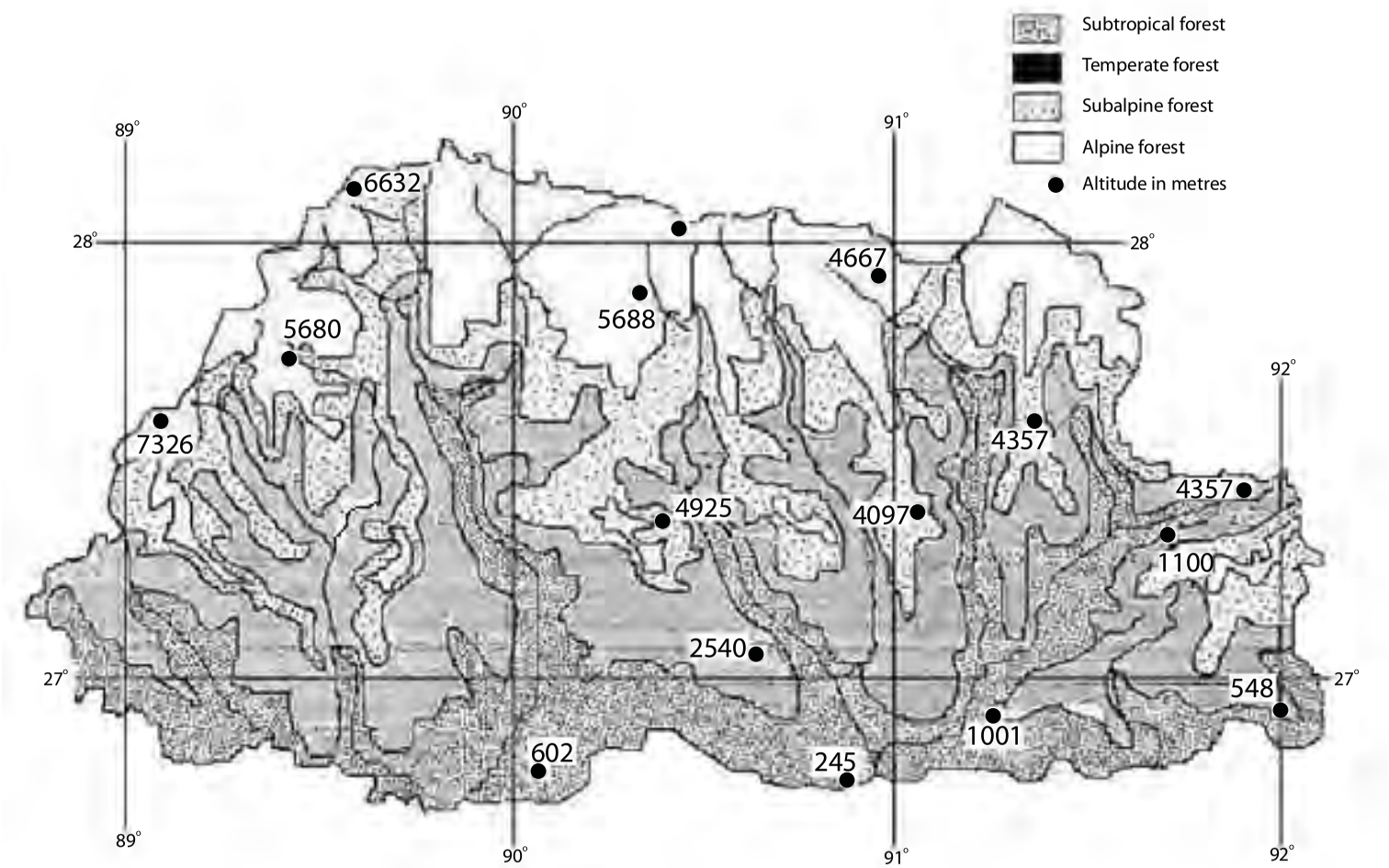

Figure 5-1 Map of Bhutan showing vegetation zones

Chapter 5

FORESTS AND WILDLIFE

KEY IDEAS

Sub-Tropical Forest
Temperate Forest
Sub-Alpine Forest
Alpine Forest
Wildlife, Forest and People

You have already studied in your previous classes about the forests in Bhutan and how important they are in our mountainous country. We have looked at them in terms of their influence on water resources, soil protection, wildlife protection and the very survival of our future generations. In this chapter we shall learn a bit more about forests. We will look particularly at the types of forests that are found at different altitudes and the wildlife that lives within them. We will also discuss why forests are important to humans, and how human activities affect the forests. The table below shows the coverage of Forest in Bhutan

VEGETATION	PERCENT
Conife Forest	26.5
Boardleaf Forest	37.7
Forest Plantation	0.2
Scrub Forest	8.1
Total	72.5

Physical and climatic variations have given Bhutan not only an abundant forest cover but also a rich variety of tree types. Below, we shall look at the types of vegetation that prevail within the country.

Sub-Tropical Forest

True tropical rain forests do not exist in Bhutan because such forests are largely evergreen and require continuous rainfall throughout the year. The hot region in Bhutan does not receive continuous rainfall as it has a marked dry winter season and mostly receives its rainfall in the wet monsoon season. Although many tropical types of vegetation are present, they are somewhat different from those that are found in the tropical region itself. We will discuss the three different categories of the sub-tropical forests below.

Hot Wet Forest

In Bhutan, the sub-tropical forests along the foothills may be broadly referred to as **hot wet forest.** Dense jungles are found on the valley slopes and river banks. Here the mean annual rainfall is more than 2000 millimetres and the growth of plants and trees during the monsoon is rapid. Sal forest occurs as scattered trees in some areas such as Sibsoo, Samtse, Phuentsholing, Kalikhola, Sarpang and throughout the other low altitude areas where the elevation is between 200 and 500 metres above sea level. The forest floor is covered with thick undergrowth.

Local Names	English Names
Sissoo	Sissoo
ཚོན་།	Cane
ཨཕག་ཤིང་།	Bamboo
Khair	Acacia
Gamari	--
Siris	Kokko
ཤུ་ཀུཡཱཧཱ།	--
Saur	Birch
ཐཡ་ཀུ་ཤིང་།	Fig
ཇོར་ཀོ་ཤིང་།	Walnut
ཐལཕ་ལོ་ཤིང་།	Oak

Table 5-1 Common trees in the hot wet zone

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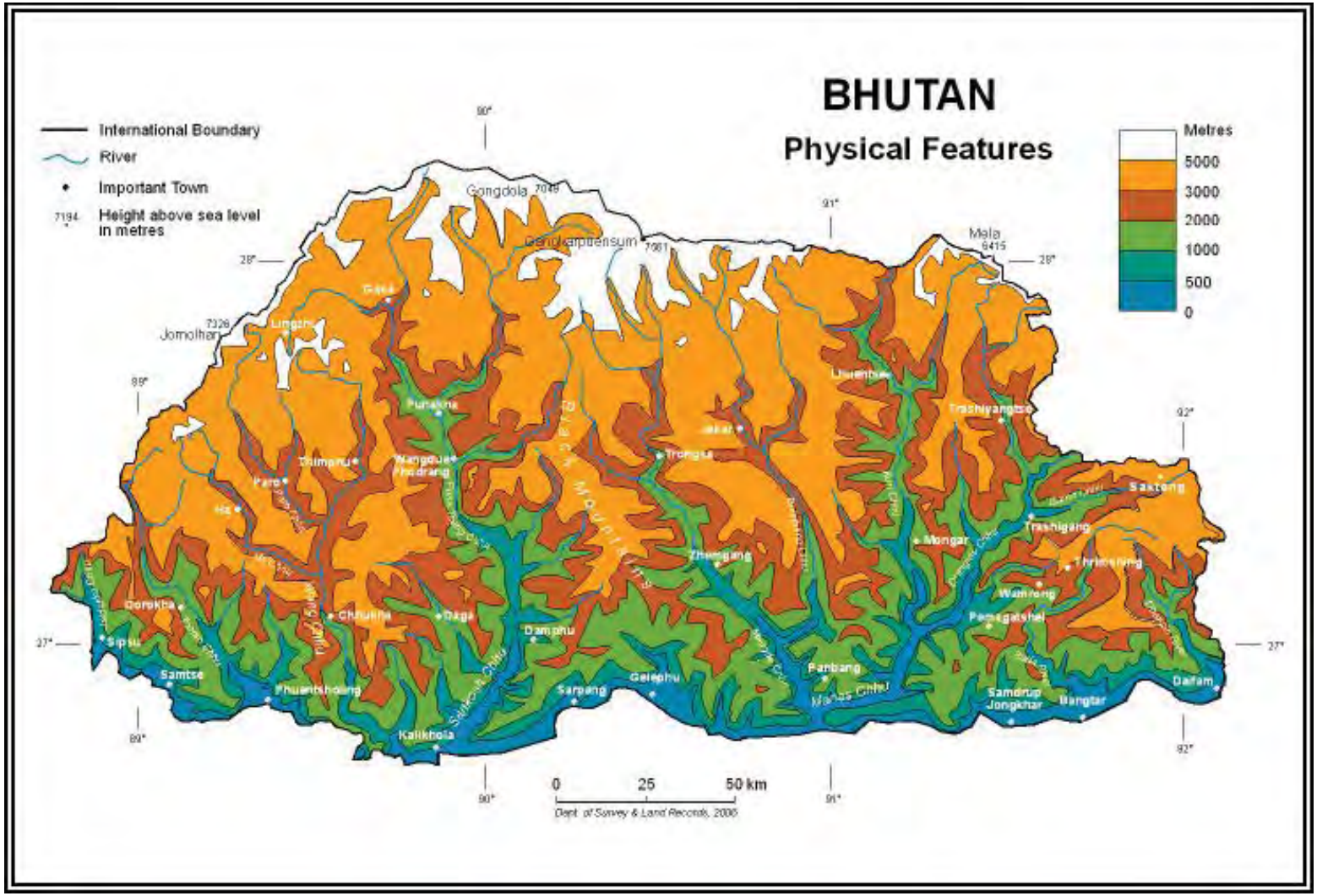

Figure 5-2 Physical Map of Bhutan (New Edition: 2006), Source: Dept. of Survey and Land Records, Ministry of Agriculture.

Figure 5-2 *Hot wet forest of the sub-tropical region in the southern foothills*

Figure 5-3 *Broad leaved forests in a sub-tropical zone. Notice the deciduous trees.*

Warm Broad-Leaved Forest

Warm broad-leaved forest is also a type of sub-tropical forest, but it occurs at higher altitudes where there is less rainfall. The forest contains a mixture of evergreen and deciduous broad-leaved trees. The transition to this type of vegetation from the hot wet forest is gradual. The broad-leaved forests occur in the deeper valleys of the Kholong Chu, to the south of Tashi Yangtse and outstanding examples are found in the hills to the north of Geylegphug and Deothang and in the Zhongar Chu valley. This forest type also occurs in many other parts of southern Bhutan where the elevation is greater than 1000 metres but lower than 2000 metres.

Chirpine Forest (They Tong)

Another types of sub-tropical forest, the **Chirpine forest,** occurs in areas that have elevations between 900 and 2000 metres. This is a low-altitude xerophilous forest found in deep dry valleys of Bhutan. Parts of Puna Tsang Chu, Mangde Chu, Kuru Chu and Dangme Chu valleys have thin but extensive chirpine forests. These valleys have a very long dry season during which forest fires are common. The chirpines are more resistant to forest fire than many other trees, and as such they are the dominant trees in this region. This area receive only a little rain which usually occurs in the monsoon season.

The pines are tapped for turpentine and the timber is used for building houses. Other varieties of trees found in this belt are birch, chestnut and horse-show-nut. In the Mongar and Tashigang valleys, the chirpine forest has an abundant undergrowth of lemon grass. Lemon grass is boiled, distilled and the oil extracts are either expoted to India or to the third countries for manufacturing soap, shampoo, perfume and air freshener. Locally, Bio Bhutan, a private company has started bottling oil extracts in collaboration with local communities and is sold as insect repellents. It is also rich in vitamin A. The raw liquid extracted from lemon grass is also used to cure ringworm.

Temperate Forest

The temperate forest is found in the cooler areas above the sub-tropical region. It is characterised by broad-leaved trees in the lower region and coniferous trees at the higher elevations. In Bhutan it is divided into four sub-categories, discussed below.

Cool Broad-Leaved Forest

The **cool broad-leaved forest** occupies the region that occurs between 2000 and 2900 metres above sea level. In this region, two types of forests are found in response to variations in the amount of rainfall. The drier types contain a dominance of deciduous oak species. The mountain sides of

Mangde and Mongar valleys are areas where drier broad-leaved forests can be found. In the wetter region mixed forests are found in which **epiphytic plants** are also common. A good example of this type of forest can be seen between Sengor and Limethang in Mongar.

Figure 5-4 Chirpine forest in the dry valleys of Tashigang with lemon grass undergrowth

Chapter 5 See page 49of the textbook

Dzongkha/Local Names	English Names
ཀླད་ཤིང་	Larches
ཤུ་ཁག་མ།	Maple
ཅག་པ་ཤིང་	Betula/Birch
ཚོ་ག་ཤིང་	Wild Chestnut
བང་ག་ཤིང་	Horse-shoe nut
རོམ་ཤིང་	-
ཇུ་མ་ཤིང་	Alder
ཤིང་ཚལ།	Cinnamon
བདལ་ཤིང་	Daphne
ཚེལ་ཤིང་	Oak

Table 5-2 Common trees in the cool broadleaved forests.

Figure 5-5 Blue pine and oak forests in temperate region. Our high consumption of wood is responsible for the damage done to this precious forests.

Blue Pine Forest

The **blue pine forest** is found at a height of 2100 to 3100 metres. Valleys with relatively little rainfall have this kind of vegetation, such as the Inner Himalayan valleys of Ha, Paro, Wang and Bumthang. Besides blue pine, there are some other species of trees in this zone among which the poplar, *thonp shing, bji shing,* and *sissi shing* are the most common.

Spruce (She Shing) and Hemlock (Ba-Shing) Forest

In Bhutan, the **spruce and hemlock** trees dominate the mountain-cloud forest zone which is characterised, as the name suggests, by wet, misty conditions. This zone is found at an elevation of 2400 to 3300 metres on the main mountain ridges throughout the central and northern parts of the country. Shrubby and arborescent rhododendrons are frequently found in this region along with a number of other trees such as maple, larch, oak, birch and hemlock.

Fir Forest (Dung Shing)

The **fir forest** is a characteristics of the highest forested ridges throughout Bhutan. The dense canopy provides a humid environment in which rhododendrons, shrubs, and herbal plants flourish. The altitudinal distribution of this zone is 3100 to

3800 metres. At the **tree line** which occurs around 3600-3800 metres, the firs become stunted and junipers and smaller rhododendrons constitute the main types of vegetation at this height.

Figure 5-6 Spruce and Hemlock

Dzongkha/Local Names	English Names
རྩེད་སྡུ་ཤིང་།	Blue Pine
ཟུག་ཤ་ཤིང་།	Birch
ཛན་དན་ཤིང་།	Cyprus
ཤུག་ཤ་ཤིང་།	Juniper
གཟར་ཤིང་།	Larch
ལེ་ཤིང་།	Spruce
དཀར་ཤིང་།	Poplar
ཨེ་རེ་ཨེ་རི།	Rhododendron
ཐྲ་ཤིང་།	Hemlock
གཤུང་ཤིང་།	Fir

Figure 5-7 Rhododendron and Fir

Sub-Alpine Vegetation

In the **sub-alpine region** we find shrubby vegetation that occurs above the tree-line throughout the northern and central Bhutan. This zone lies at an altitude of 3200 to 4700 metres above sea level. No detailed meteorological data is available about this vegetation zone. All the same, the region is floristically rich and contains many plants which are much prized in horticulture. The common types of vegetation found at this height are **juniper and rhododendron shrubs.**

Figure 5-8 Rhododendron shrubs at high altitudes

Alpine Vegetation

Alpine vegetation which is very **xerophytic** in nature, clings to the ground surface and is found above 4000 metres on the highest mountains. It is widespread in the northern parts of the country and on the higher ridges of central Bhutan such as those of the Jowo Durshing Ranges. The plant life found here is very similar to that found in the steppe region of the Tibetan Plateau.

Questions and Activities

1 Study the photographs in figure 5-2 and answer these questions:
 a Describe the characteristics of the vegetation you see in this picture.
 b In which season do you think this photograph was taken?
 c List the similarities and differences between the trees in this photograph and the tree in your own area.

2 Study figure 5-4
 a Why are chirpine trees to be *xerophytic* in nature?
 b Why are other kinds of vegetation not able to thrive well in this region?

3 Study figure 5-8
 a Why do you think the plants in the picture are so small?
 b Estimate the approximate altitude of the site shown in the photograph. Give a few reasons why you think this is the altitude of the site.

4 Work together as a class to collect as many types of tree leaves as possible. Identify the trees with the help of people from the local area. If you have identification books in your library, these may be very helpful as well. For every leaf in the collection, write a short description about the tree from which it comes.

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Wildlife

Rich and unexploited forest covers nearly two-thirds of Bhutan's total land area. This provides a diverse habitat for a wide variety of wild animals such as tigers, leopard, wild buffalo, bison and several species of deer. Wild tuskers find an ideal stomping ground in the foothills of the kingdom. The rare golden langur is found around the Manas river both on the Indian and the Bhutanese side. On the Bhutanese side, golden langurs are found in the Royal Manas National Park and also in the lower parts of Trongsa and Zhemgang dzongkhags. Takin, the national animal of Bhutan is found in the northern region, particularly in Jigme Dorji National Park. In winters, they move down to Damji and Gathana areas of Gasa while in the summers, they graze in the alpine meadows of Tsharijathang. Takin, called the Bhutan Takin, is found exclusively in Bhutan. The red panda which lives mainly on bamboo, is also found in this area.

In an effort to preserve Bhutan's diverse natural environment, 9 national parks and wildlife reserves have been established in the kingdom with reprentatives of all the eco systems that are present in the country. They account for 26 percent of the total geographical area of Bhutan. In addition, another 9 percent of the total geographical area is set aside as biological corridors to allow free movement of animals, birds and reptiles from one reserve to another.

The Royal Manas National Park covers an area of over 821 square kilometres in the south-eastern part of country. In this humid sub-tropical environment, elephants, buffaloes, golden langurs, wild boar, pythons, tigers, bison, rhinos and deer thrive.

The Jigme Dorji National Park covers most of the high alpine environment of the northern region. Blue sheep, musk deer, bear and leopards can all be found in this sanctuary.

Besides providing habitat for wild animals, these parts and reserves are also home to an amazing variety of bird life. In the foothills we find egrets, cormorants, parakeets, woodpeckers and hornbills. Higher up in the mountains live the colourful sunbirds, tits, flycatchers, the Himalayan pheasant, with its glorious feathers, and the very rare black necked crane.

The following regulations are in force to protect the wildlife in Bhutan.

- Hunting – shooting, setting traps, and snares – is forbidden in Bhutan.
- Animals, other than the endangered species, which cause damage to crops and property can be killed by the farmers within the boundaries of their registered farmland or property.
- Endangered species cannot be killed even if they destroy crops and property. They should just be chased away.
- The products of wild animals such as skins, bones, musks, horn, or any other trophies originating from wildlife, are the property of the Royal Government. Any individual who has acquired or possesses such trophies should surrender them to the government.
- Capturing and rearing of wild animals of any species is considered an offence.
- Fishing is permitted, but you must have a valid licence. However, fishing is not allowed at all during the breeding season between November and March of every year and on religious days.

Box 5-1 Rules and regulations on hunting in Bhutan . Source: Department of Forestry, 1992

Figure 5-9 Assorted Wildlife: Part of Bhutan's pristine environment

Figure 5-10 Red Panda, a native of the Inner Himalayan forest.

Figure 5-11 Black necked crane – a rare bird of Bhutan.

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Forests and the People

Humans depend on forests for many of their basic needs. Forests provide firewood, lumber to build our houses and charcoal for our industries. But as we cut the trees down, the continuity of the forest is upset through the process of **deforestation.**

Deforestation has far reaching effects on the environment. Our country is situated in a mountainous terrain, which has a delicate ecological balance. The slopes of these mountains are much susceptible to erosion than flatter regions.

When trees are removed, the topsoil is exposed to the influence of rain, wind and running water. This can cause severe soil erosion and heavy landslides on the mountain slopes. Sometimes, people believe that where forests are abundant, the soil is rich. But this is not always true, as trees can also grow in bare rocky areas. Forested areas do not always have good soils. Soils in cleared forest areas often become infertile within a very short time and are then abandoned by farmers.

Living trees are composed of carbon atoms and also absorb carbon dioxide as they grow. Removal and burning of trees causes the level of carbon dioxide in the atmosphere to increase. Such activities will leave the forest with fewer trees to re-absorb the gas. This increase in the proportion of carbon dioxide in the atmosphere will disturb the atmospheric heat balance.

Carbon dioxide is one of the gases in the atmosphere that is referred to as a **green house gas.** This is because the gas acts like the glass roof of a green house. It allows the shortwave radiation from the sun to pass through it but traps the long wave heat radiation being emitted from the earth's surface. If too much of the outgoing heat is trapped by the atmosphere, it will cause **global warming.** This phenomenon is known as the **green house effect** and will be discussed in more detail in chapter 12.

The destruction of forests by humans also adversely affects the wildlife. The forest is the natural home of almost all wild animals. When the forested area is reduced in size it means these animals are deprived of their natural habitat. Preservation of wildlife has now become an important activity in many countries of the world.

Figure 5-12 In Bhutan, people and nature have lived in harmony for ages. The responsibility of continuing this sustainable relationship falls on our generation.

It is now generally accepted that every different species of a plant or an animal has its own important role to play in maintaining the ecological balance of the world as a whole. Every living thing is a part of the ecosystem that maintain the correct percentage of oxygen in the atmosphere, moderates the climate and recycles the essential soil nutrients.

Natural forests and wildlife also provide us with a variety of things that are important to our everyday life such as food, medicine, fuel, fibre, waxes, dyes, industrial raw materials, oils and lubricants.

People find the natural unspoilt environment very refreshing and often choose to spend their holidays visiting or trekking through these areas of scenic beauty. Imagine yourself smelling the aroma of wild flowers, watching the magnificent magnolia and rhododendron on the mountain sides, or the trout swimming through the clear river water. Reflect on the immense pleasure you derive from such an experience.

In the Buddhist faith, all living beings have souls. It is morally wrong for humans to cause harm to other living souls. This belief, that wild creatures have as much of a right to survive as humans, is now being held by many non-Buddhists as well. The Royal Government reflects this belief in its rules and regulations regarding the protection of wildlife as outlined in Box 5-1.

In 1991, a forestry survey showed 56 percent of Bhutan was covered by forest, whereas in 1984 it was more than 64 percent. That means that nearly 1 percent of the forest cover is being removed from our mountain sides every year. If we continue in this way, we will lose all our forests from the mountains. All that will remain of Bhutan will be a series of massive landslides. The green mountain slopes will become barren, ugly and unproductive. What can we do to prevent this from happening?

Questions and Activities

1 Contact a local forest officer and gather the following information:
   a A list of wild animals, birds and reptiles found in your local area.
   b Underline or highlight the names of the endangered species in Bhutan.
   c Why are they called endangered species?
2 Ask a farmer in a nearby village the following questions:
   a What wild pests does he or she have on the farm?
   b What difficulties is the farmer facing in keeping the regulations of the Royal Government on disposing wild pests?
   c How much does he/she know about the government regulations in wild life?
   d From your investigation, have you found any species of wildlife that are both endangered and also pests to the farmers?

Summary Activities

1 Describe the following terms in your own words.

- Montane
- arborescent
- xerophytic/xerophilous
- endangered species
- green house effect

2 Using the information from the part of the text sub-titled "Forests and the People", work out a scheme for making the people in your village aware of the importance of conserving the forests. Be creative, you could make posters, write a drama, or tape a radio broadcast for the BBS.

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Chapter 6

RIVERS AND THEIR EROSIONAL WORK

KEY IDEAS

Sources
Stages of a River
Features Created by Rivers in Bhutan
Rivers as a Natural Resource

The surface of the earth is constantly changing due to two competing processes. The tectonic forces create new shapes on its surface, while the agents of denudation reshape it by removing materials from one place and transporting it to another. The results of these processes are very evident in the young Himalayas of Bhutan.

As the Indian and the Eurasian plates continue to push towards each other the mountains continue to grow. The steep slopes provide great energy to the glaciers and running water as they cut and erode the land surface.

As we discussed in chapter 1 of this text, the movements of the tectonic plates and the resulting changes to the shape of the earth's surface takes place very gradually. However, the agents of denudation can drastically change a landscape in only a few hours. For instance, a brief rainfall can totally change the local scenery as surface runoff cuts new gullies and the additional weight added to the soil by the water starts landslides on the steeper slopes.

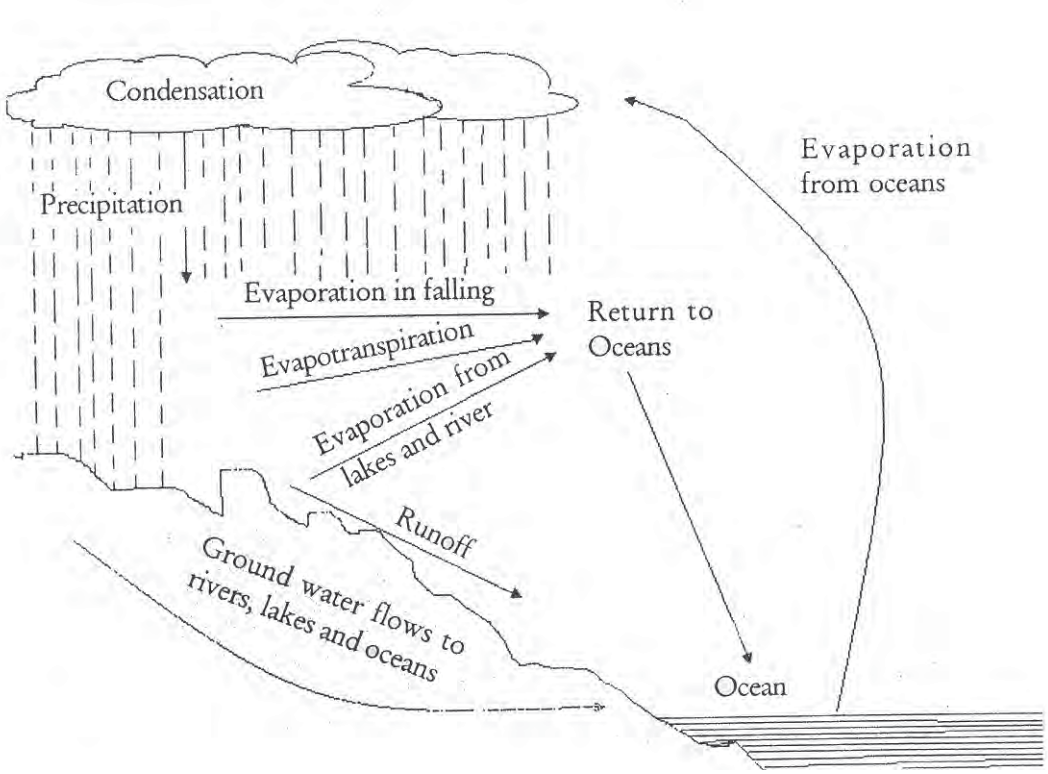

Figure 6-1 Hydrological Cycle

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From reading other geography texts, you know that running water, or **fluvial action,** is an important agent of denudation. In Bhutan, it is one of the most important agents shaping the landscape. In this chapter, we shall look at the following topics related to rivers and their work.

- Where do rivers originate?
- What landforms are created by rivers in their different stages?
- What sort if erosional work do rivers do in Bhutan?

Where do rivers come from?

Hydrological Cycle

Figure 6-1 shows that a river is a part of the hydrological cycle. Heat energy from the sun warms up the surface of the vast Indian Ocean, causing evaporation and increasing the amount of moisture in the air. As the air is forced over the Himalayas it cools and as a result cannot hold as much water as it did at the lower elevations. This causes the humidity of the air to reach 100 percent and condensation takes place. As a result of the condensation, clouds are formed and orographic rainfall occurs. The rain runs off the surface of the Himalayan slopes and then feeds the numerous rivers that flow back to the Indian Ocean to complete the cycle.

Springs

The location of springs is influenced by two factors – depth of the water table and the structure of the rocks under the earth's surface.

Much of the rain that falls on the earth's surface soaks into the ground. At some level below the surface, the water table is maintained. The soil beneath the water table is always saturated. However, the depth of the saturated zone fluctuates in response to changes in the seasons. When the water table rises to meet the surface of the ground a **spring** results.

Variations in rock permeability also influence the formation of springs. If the water that has infiltrated into the ground meets a layer of impermeable rock, it flows over its surface in the Springs form where the surface of the impermeable rock intersects with the surface of the ground. The water coming out of these springs then flows over the surface to form **streams** and **rivers.**

River	J	F	M	A	M	J	J	A	S	O	N	D
A	6.9	6.5	6.5	7.2	10.1	30.2	42.4	63.3	63.0	19.6	13.5	10.9
B	180.5	145.0	157.7	184.6	270.1	288.7	1120.6	1377.0	1057.9	469.5	259.5	176.6
C	97.1	96.5	109.5	146.4	299.0	623.2	597.7	707.3	508.2	238.0	124.0	110.3

Rivers: A = Wangchu recorded at Thimphu. (in cubic metres per second)
B = Puna Tsang Chu recorded at Dubani. (in cubic metres per second)
C = Kuru Chu recorded at Kuru Zampa. (in cubic metes per second)

Table 6-1 Average flow of three rivers – 1989 – 1991
Source: Department of Power, 1992

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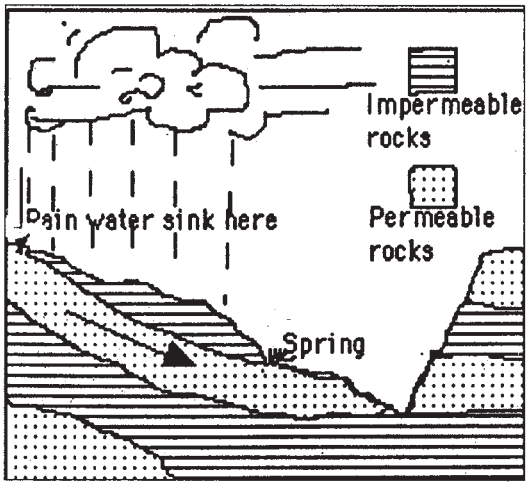

Figure 6-2 Diagram showing how a spring occurs

A stream is joined by many other smaller streams to become a river. Most of the rivers and streams in Bhutan begin from springs on the mountains and hillsides. Some of these springs are seasonal and exist only during or just after the monsoon season.

There are a number of other sources for rivers in addition to springs. Some rivers have **lakes** and **glaciers** as their sources, such as the Mo Chu, which starts from Lingzhi Tsho and Pa Chu which begins from the Jumo Lhari source. The monsoon rain is collected through rills and gullies which gives rise to seasonal streams and adds to the flow of the main rivers.

Drainage Basins

As the river flows down the mountain it is joined by smaller streams which are called **tributaries.** Many of the tributaries dry up during the dry season as they are a result of the monsoon rain. The number of streams increase dramatically during the monsoon. The area of land which supplied a river and its tributaries with water is called its **drainage basin.** The highland separating one drainage basin from another marks the **watershed.** A drainage basin covers the entire area that contributes water to a river system from its sources to its mouth. Because Bhutan is a relatively small, landlocked country, the drainage basins of many of its rivers are not all found completely within its geographical boundaries. Drainage basins are usually nested one inside another. For instance, most of Bhutan's rivers are tributaries of the mighty river of Brahmaputra, known to us as **Chumo Riti,** which flows into the Bay of Bengal. Thus their drainage basins form a part of the much larger basin of the Brahmaputra.

Figure 6-3 The Wang Chu drainage basin

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Stages of a River

The impact of a river on the physical landscape of the country is better understood if one considers the different stages of the river. For many years geomorphologists have divided rivers into three stages – youthful, mature, and old.

Youthful Stage

A river flows through narrow valleys and drops from great heights in its **youthful stage.** It is usually very active, energetic and fast-flowing. Most erosional work is carried out by rivers that are in this stage. Here the river flows very quickly and **vertical erosion** dominates as the river bed is deepened. However, it also erodes the banks of the river through the process of **lateral erosion,** creating deep narrow valleys. The erosional work of the river is largely done by the **load** it transports. The sand and rocks which make up the load of the river are often referred to as the river's erosional **tools.** We shall discuss the physical features produced by rivers in their youthful stage later in this chapter.

Mature Stage

As the river leaves the mountains and hills of Bhutan, it attains a **mature stage.** Although the speed of the river is reduced, the volume of water is greater here as many tributaries have joined the main stream. It deposits the heaviest part of its **load** such as boulders and rocks. It still continues to carry small pieces of gravel, silt and mud brought down from the mountains. Using this remaining load as tools, the river now causes more lateral erosion than vertical erosion and, in effect, widens its course.

As the velocity of the river decreases it begins to weave from one side to another in a snake-like movement. It creates bends that are called **meanders.** The current is the strongest on the outside edge of these bends and so most of the erosion takes place there. This often creates steep banked **river cliffs.** River cliffs created by this process can be seen along the broader river valleys of Bhutan, such as the Pa Chu, the Wang Chu and the Chamkhar Chu. These rivers meander for some distance through relatively flat valleys in the Inner Himalayas before they begin to rush down again through narrow gorges.

Figure 6-4 A river in its youthful stage.

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Figure 6-5 River cliff, meanders, alluvial deposits.

Old Stage

We do not see the old stage of the rivers within the boundary of Bhutan because by this time they are hundreds of kilometres away in the flat, delta region of India and Bangladesh. There, because the rivers are flowing through areas that are very flat, the velocity of the water decreases. They no longer have the strength to erode either sideways or downwards. The silt and mud they have been carrying from their upper courses is deposited on the bed of the rivers. During the monsoon season, when rain and melting snow increase the volume of water in the rivers, they overflow and flood the lowlands nearby. The sand, mud and small stones are dropped along the river bank and are piled up to form high river walls called **levees.**

Sometimes, the neck of the meanders are cut through, especially during the rainy season when the volume of water in the river increases drastically, causing a brief renewal of erosional activity. The length of the river is thus shortened and a residue of the previous course is left behind. These "cut off bends" form the crescent-shaped lakes that are often found along side the main river in flat areas. These lakes are called **oxbow lakes.** When the water in these lakes dries up, the rich silt in them allows grass to grow well and the former lakes become good grazing land for cattle as well as good farmland for cultivation.

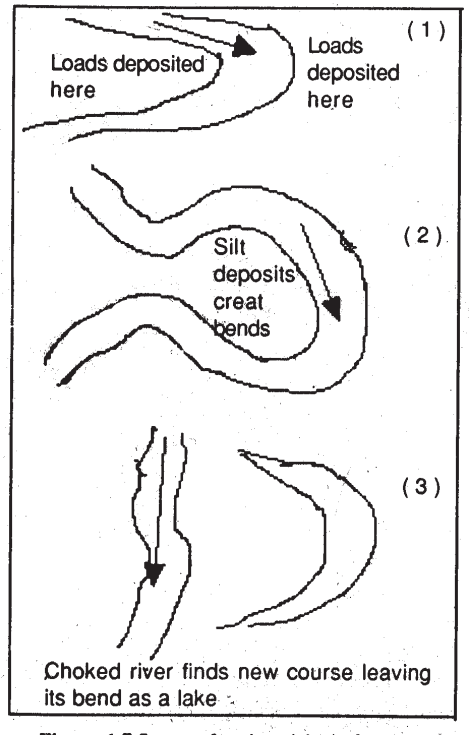

Figure 6-7 Stages of ox-bow lake in formation

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Figure 6-6 Meandering river and interlocking spurs.

Questions and Activities

1 a Using the information in Table 6-1, draw bar graphs to illustrate the variations in flow in these three rivers throughout their annual cycle.

b Describe the shape of these graphs in words.

c In which month does each river have its peak flow? For each river calculate the percentage increase in its flow between the time of lowest flow and the time of peak flow.

2 a If possible, visit a river that is in its youthful stage and a river which occupies a flat valley.

b Describe the differences you see between the two rivers.

3 a Draw a sketch map of a valley you know well. Include the location of all the streams.

b Mark P on the streams that are permanent and S on those that are seasonal.

c Count the number of streams in the valley and calculate the percentage of those are seasonal streams.

d Which of these streams come from springs and which come directly from rain water?

4 Take a 1 litre sample of water from any stream in a glass jar. Let the water settle and then make a list in your note book of everything that you can see in the jar. Use a magnifying glass or a microscope to look at the contents of the jar more closely.

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Figure 6-8 a Waterfall at Gaselo near Wangdiphodrang

b Waterfall at Namning in Mongar valley.

Figure 6-9 Gravels and boulders deposited by a stream forming rock fans indicates the sudden drop in the velocity of the river.

The Work of Rivers in Bhutan

Most of the rivers in Bhutan are considered to be in their youthful stage as they are very active and erosional features are common sights. We now turn our attention to describing the various features made by the rivers of Bhutan. The most common features are waterfalls, interlocking spurs, gorges, and alluvial fans.

Rock Fans and Flash Floods

The tributaries of many rivers drain down steep, narrow valleys. During the course of their journey, these small streams carry much silt and sand. During the floods, that occur mostly in the monsoon season, they also transport boulders.

As the streams join the main rivers, their velocity drops drastically as does their ability to transport their load. As a result, this material is deposited at the confluence point where they join the main river and features called **rock fans** are formed. Over the years, soil develops on these fans while the main river bed continues to be lowered due to erosion. These fan-shaped areas then become suitable for farming as shown in Figures 6-9 and 6-10.

Flash Floods occur when the volume of water in a stream increases dramatically over a very short period of time. During the rainy season surface run off from the steeply sloped catchment area quickly joins the main stream causing a rapid increase in

its volume and speed. Loss of vegetation in the up-stream areas is one of the major causes of flash floods as the infiltration rate of soil is reduced, increasing the surface run off.

Waterfalls

Rapids and waterfalls are common features in many parts of Bhutan. Generally, waterfalls are formed when a river flows over different kinds of bedrock. Some rocks such as granite are very hard, while rocks like limestone and sandstone are soft. The river wears away the softer rock much faster than the harder rock. When a river flows over an area which is made up alternately of hard and soft rocks, the softer rocks are worn away faster, resulting in waterfalls. If the rocks lie across the course of the river in bands as shown in Figure 6-8, **cataracts** or **rapids** are formed. As the softer rocks wear away, the steepness becomes larger and so does the waterfall.

Sometimes, the waterfalls found in Bhutan are also formed as a result of the higher eroding capacity of larger adjoining rivers. The main valleys cut down much deeper than the smaller valleys created by streams coming in from the sides. In such cases, the water in the tributaries falls from great heights before joining the main stream. Examples of such falls can be seen along the courses of the Wang Chu and Mangde Chu. The force of the falling water, and the small debris that it carries, wear away and cut out a hollow at the bottom of the fall known as a **plunge pool.** Notice the plunge pool in Figure 6-8a.

Valleys and Interlocking Spurs

For the most part, rivers in Bhutan flow through a mountainous region with great force and therefore their impact is greater than if they flowed on a level plain. Usually, the source of a river lies at or near the crest of a mountain range and the river descends the steep slopes at great speed. The force of the water cuts out rocks and soil along the river's course. Rivers use these rocks and other debris as tools to carry out vertical corrosion. The result of this action is the formation of **V-shaped** valleys. Where the bedrock is hard, lateral corrosion is less pronounced, and the result is steep-sided valleys, called **gorges.**

Figure 6-10 Alluvial fans created by streams used as rice fields in Tashigang valley.

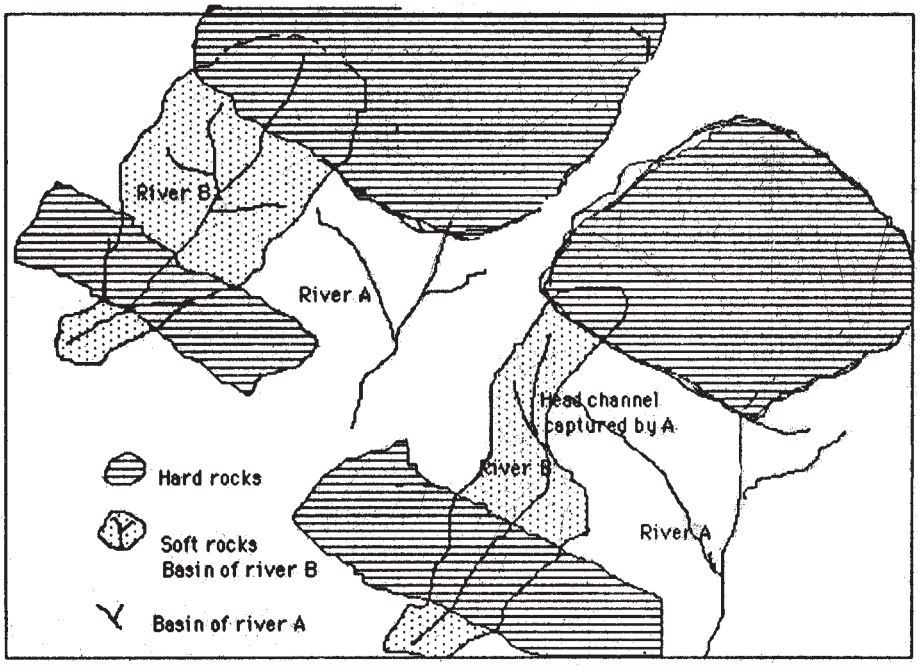

Figure 6-11 River capture

Figure 6-12 Boulders transported by streams during flash floods in the Dagana region.

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Where the bedrock is relatively soft, lateral corrosion has been more ecute and the resultant landform is a broader valley such as the one in Paro.

As the river makes its way to flatter ground it weaves from side to side, resulting in the alternate undercutting of high ground. Parts of the high ground remains projected above the river bed. If we view such a valley from one end, a series of spurs can be seen. As Figure 6-6 illustrates, these spurs interlock with each other like a zipper. Thus they are referred to as **interlocking spurs.** Interlocking spurs are common features in the Bhutanese landscape.

River Capture

Sometimes a river can erode all the way through the crest of a mountain and capture the head of another river in the neighbouring valley. For instance, river **A** flows through a valley with steep gradient and river **B** flows in the opposite direction on the other side of the divide. River **A** is more forceful and **backcuts** the slope faster then river **B**. After many years of erosion, a **gap** is formed in the divide between the two drainage basins. The head of the valley of river **B** is **captured** by river **A.** River **B** is then said to have been **"beheaded"** as this area will no longer provide water to its former valley. The water will now flow into river **A** which runs in the opposite direction to river **B**. This whole process is referred to as **river capture** and is illustrated in Figure 6-11.

Rivers as a Natural Resource

The greatest bulk of the world's water, as Table 6-2 shows, is found in the oceans and is thus salt water. Fresh water comprises less than 3 percent of the total water supply for the world. In Bhutan, all of our water that flows into our rivers is fresh water as it comes from surface runoff, glaciers and ground water.

Table 6-2 The water resources of the earth

Form of Water	Percentage
Oceans	97.20
Glaciers	2.00
Fresh water lakes	0.12
Ground water	0.50
Soil water	0.10
Saline lakes	0.01
Streams, atmospheric moisture, plant water	0.003
Total	**100.00**

Source: McKnight's Physical Geography (1984-1990)

People in Bhutan are blessed with a good supply of fresh water. We use the water from our rivers to quench our thirst, irrigate our fields and wash our clothes. But we also use the water to produce power to grind our flour and, more importantly, to produce hydro electricity.

Bhutanese rivers flow from great heights, and have great potential energy. It is estimated that our rivers could provide more than 20,000 megawatts of hydroelectric power if they were fully exploited. This vast source of renewable energy is less likely to run out because the generating capacity of its rivers can never be exhausted. Hydro electricity will be discussed in detail in Chapter 10.

We owe the continuous flow of water in our rivers to the extensive vegetation cover provided by our forests. Without vegetation cover, the water brought by the monsoon rain would run off the surface of the land, carrying valuable topsoil with it. If all the rain water runs off the surface, it causes **sheet erosion**.

Sheet erosion results from poor farming practises and over grazing. This will accelerate the removal of fine top soil, leaving behind coarse and infertile soil, which has no value for cultivation. Erosion in the same place will cause the development of deep **gullies.**

If little water is available to sink into the ground, the ground water reserve will not be resupplied and the water table will remain well below the surface. Without sufficient groundwater, there will be little water to feed the springs that supply the base flow to the rivers. We will then suffer from severe drought and lack a fresh water supply during the dry seasons. Dry mountain slopes cannot support the growth of vegetation, and this will then affect the supply of precious wood and timber for our domestic and commercial uses. Lack of water will also greatly hamper all farming activities and power generation.

Field Study

Knowing how to find the volume of flow of a river is a skill needed by many professionals in Bhutan. Before you can build a hydel, a water supply system for a town, or an irrigation channel, you must know how much water is flowing in the river. In the following exercise, you can learn how to do this.

a Choose a small stream near your school, take a long string, a metre stick, a stop watch and a note book with you.
b Put the string across your stream suspended between two sticks.
c Record the depth of the channel every ten or twenty centimetres along the string, as shown in the diagram in Figure 6-13.
d From this record, you will be able to calculate the cross sectional area of the stream when you get back to school. You will need a piece of graph paper and perhaps the help of your Maths teacher.
e Now you want to measure how fast the water is flowing. To do this, measure a distance of ten metres down stream, and mark this point with a marker.
f Have your friend or partner stand at this point with the stop watch. You should now take the small piece of wood and throw it into the middle of the stream, at the same time tell your friend to start the watch. When the wood passes the 10 metre point, stop the watch.
g You can now calculate the speed of the water in metres per second, by dividing the distance by the number of seconds.
h Now you can calculate the volume of flow of the stream like this:

Velocity of the water X Cross Sectional Area (d above). Your answer should be in cubic metres per second.

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Summary Activities

1 Write a definition for each of the following terms in your own words:

- Watershed
- drainage basin
- load of the river
- river capture
- spur
- gorge
- meander
- river cliff
- rapids

2 Explain in your own words the relationship between vegetation and the hydrologic cycle. Illustrate your answer with a diagram and

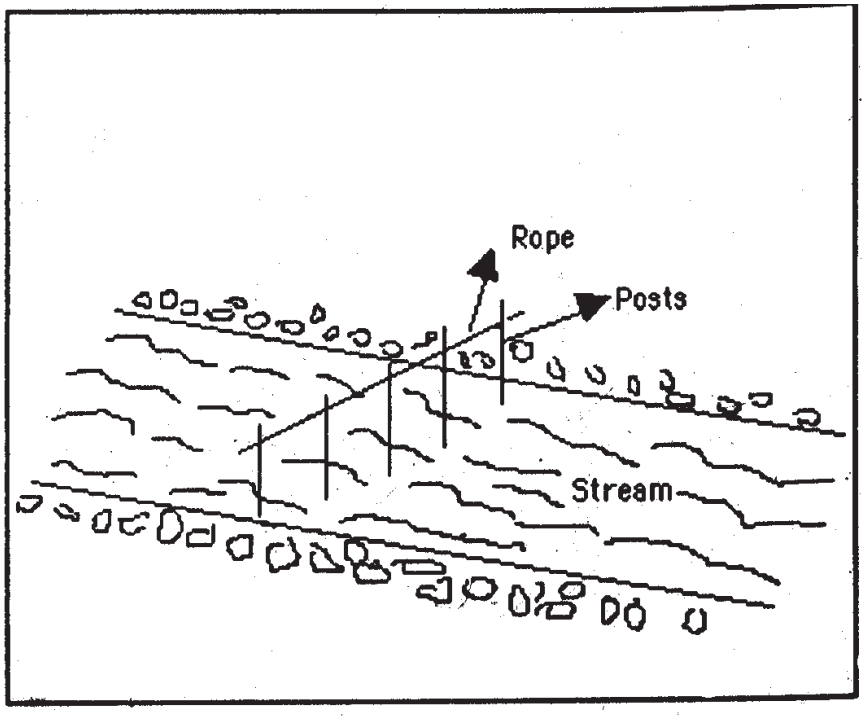

Figure 6-13 Cross section of a stream showing how to measure the depth

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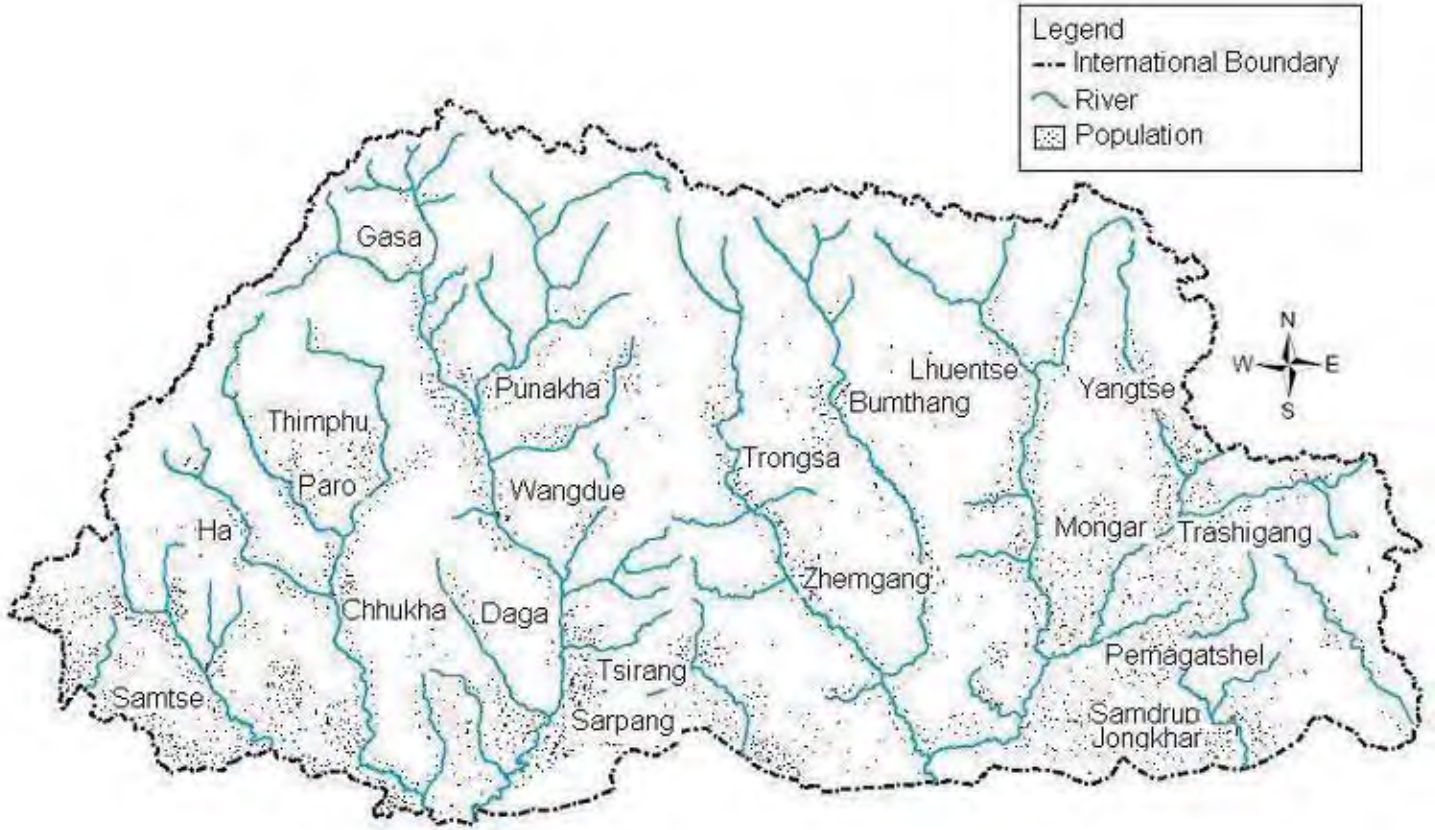

Map of Bhutan showing Population Distribution

Chapter 7

RURAL AND URBAN SETTLEMENTS

KEY IDEAS

Patterns of Settlements
Growth of Towns
Urbanization in Bhutan
Hierarchy of Settlements
Problems of Urbanization

In class VIII, you learned about the distribution of population in Bhutan. You discovered that people are not evenly spread across the country. This probably made you ask the question "Why are people concentrated in particular locations?" In this chapter, we will learn more about the patterns of rural and urban settlements and how they occur.

As you travel across the country, you will notice certain patterns in the way farming and settlement have occurred in the kingdom. The relatively gentle hillsides, flatter valley bottoms and terraces on the mountain slopes are commonly selected for building farms and houses. You will normally come across two different patterns of settlements, nucleated and dispersed, although a linear pattern of settlement is also appearing in the landscape.

Patterns of Settlements

Nucleated Settlement

A **nucleated** clustered settlement is one in which people live in houses clustered together surrounded by cultivated lands. The nucleated settlements are normally found in the northern, central, north western and north eastern parts of the country. Farmers live in a close community from where they travel to their farms in the morning, returning to the villages at night. Occasionally they do not return to their homes but instead stay in sheds near the fields to guard their crops from wild animals.

It is interesting to note that most of the rural nucleated settlements are also found in regions where the winter can be quite harsh. In fact, in the past many of these settlements were occupied only in warm summer seasons and left almost vacant in winter as their occupants migrated seasonally to take advantages of the better winter climate at the lower altitudes. Until the 1960s, most people from the Wang valley moved to Punakha valley during the cold winter and returned to spend the summer in the relatively cool valley of Wang. Seasonal migration still occurs in some parts of Bhutan in such places as the Shar and Mangde valleys. However, the practice is not as extensive as it was in the past.

Figure 7-1 A nucleated settlement in Ura in Bumthang Dzongkhag

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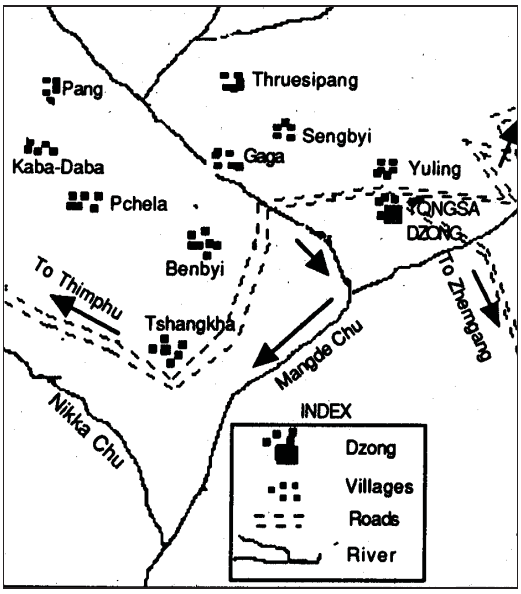

Figure 7-2 Sketch map of nucleated settlements in Tongsa Dzongkhag

Figure 7-3 A traditional house being constructed. Most families spend a large portion of their income to build a house.

In the nucleated settlements, people traditionally build 2-3 storey houses. The ground floor is usually meant for the livestock. This is done for three reasons:

- to protect the animals from rain and cold specially during winter.
- To keep away predators such as leopards, wolves, tigers and bears.
- To collect dung for preparing manure for the fields.

A fourth reason could be the economic use of space and labour. By making 2-3 storeyed houses, both property and animals can be kept under one roof instead of making different shelters. This means the labour and expense involved in acquiring and maintaining roofing shingles can be greatly reduced. This practice is particularly common in high altitude areas. A good example of this practice can be seen in Paro and Bumthang.

Nowadays, people realise the health hazards related to keeping livestock in their houses. They build separate shelters for their animals. The Government is also encouraging people to build two storeyed houses rather than three storeyed ones. As can be seen in Figure 7-3, to build a traditional house, a great amount of timber is required.

Dispersed Settlement

In some parts of the country such as the southern regions and some parts of Kheng and the eastern region, people build houses on isolated farmsteads which may not be actually very far from the next neighbour. But each individual house is built at a sufficiently good distance from one another so that the houses are spread over a large area instead of being clustered together in a close community. The pattern that appears on the landscape can be called dispersed or scattered settlement. In these parts of the country, people live in simple houses

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which are usually one or two storeyed and require less timber. The materials used for building houses are mainly bamboo, stones and mud. The main walls are made of stones while partition walls are made of woven bamboo on which red mud plaster is applied. Wild banana and thatching grass are commonly used for roofing. Many people grow thatching grass on their own land.

In the dispersed settlements, farmers build sheds in the farmstead close to their houses where animals are kept at night during the summer monsoon. In these areas, winter is not so cold that the animals need to be kept in enclosures. They can be kept just under one roof during the rainy monsoon. During other seasons they take the herds to the forest pastures, just as the farmers do in the northern and central regions. In the zones where the settlement is more scattered, the winter is not as cold and harsh as in the northern part of the country. In the dispersed settlements, seasonal migration is normally not practised.

Almost every village must have a temple which serves both as the religious centre for the community and as a school where a few children are taught the Buddhist texts and rituals. Some villages have more than one temple. Now, some new features have been added to the village, such as primary school or a community school, a basic health unit, an agricultural extension unit and a veterinary service unit for the livestock. Many villages also have motorable road and electricity.

Figure 7-4 Above, dispersed settlement in Pema Gatshel, and below, in Chapcha.

Figure 7-5 Above, general type of houses in the north, and below, in the southern region.

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Linear Settlements

A new settlement pattern has appeared on the Bhutanese landscape in recent years. The motor roads throughout the country have made it easier for many of our country people to travel outside their villages to trade and procure household goods. Gradually, people have begun to settle down close to the motorable road.

At first, they built small temporary huts at the terminal points on the roadside. Gradually, they began to use these points as permanent settlements and more people joined them to increase the number of houses along the roads. They also began to cultivate land along the roadside. Some have put up restaurants and shops to serve both travellers and inhabitants in and around the area. This trend slowly gave rise to a linear pattern of settlement as can be seen in Figures 7-7 and 7-8. Although there are only a few linear settlements at present, they are likely to become a prominent settlement pattern in the future.

A general view of the entire country will also present a predominantly linear settlement pattern. This is because the mountain ranges in between the valleys have been an important factor in determining the pattern of settlement in Bhutan.

Figure 7-7 The new settlement along the motor roads

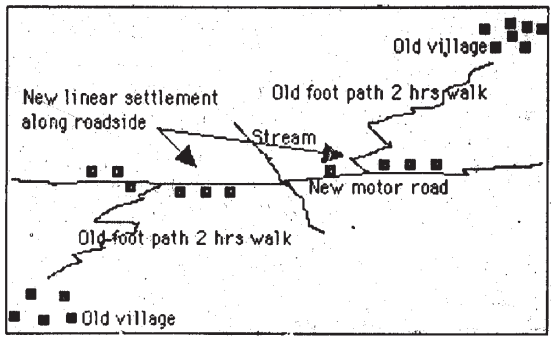

Figure 7-8 Sketch map of linear settlement

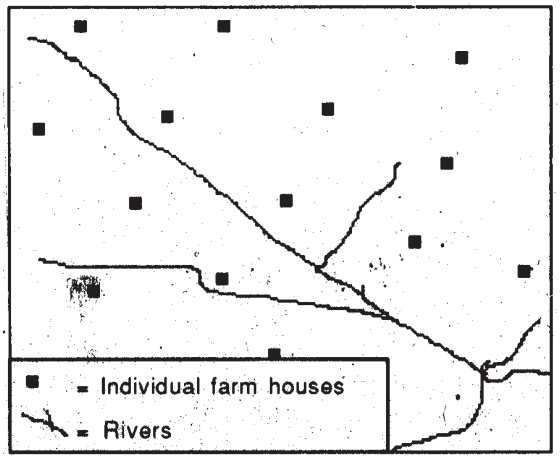

Figure 7-6 Sketch map of a dispersed settlement

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Field Study

Choose a village that you would like to study in detail and collect the following information. After you collect the information, write a descriptive account of the settlement you have studied. Illustrate your account with graphs, maps, pie-diagram and drawings.

You may collect the information using the following format:

1 Number of houses

3 storey	2 storey	1 storey	Hutments

2 Distance or travel time from the nearest road in terms of kilometres/hours.

3 Whether clustered or scattered.

4 What types of land use?
Dry Cultivation Wet Vegetable Forest Cover
Cultivation Gardening

5 How many people are there?

Age Group	Male	Female
0-5	?	?
6-10	?	?
11-15	?	?
etc.		

6 What do people grow on their farms?

Questions and Activities

1.a Find out for yourself why people keep animals in the ground floor of their houses

b Why would keeping animals in the lower floor of the houses be hazardous to health?

2 As a class make a display that shows the variation in house construction techniques throughout the country. Interview people from different regions to find out as much as possible about how the houses are constructed in their region and why they are built in that manner. Make sure your display is well illustrated with drawings and models.

3 Make a list of the advantages and disadvantages of both nucleated and dispersed settlements.

4 Study Figures 7-7 and 7-8. Make another list of the advantages of such settlements. Discuss this in your class.

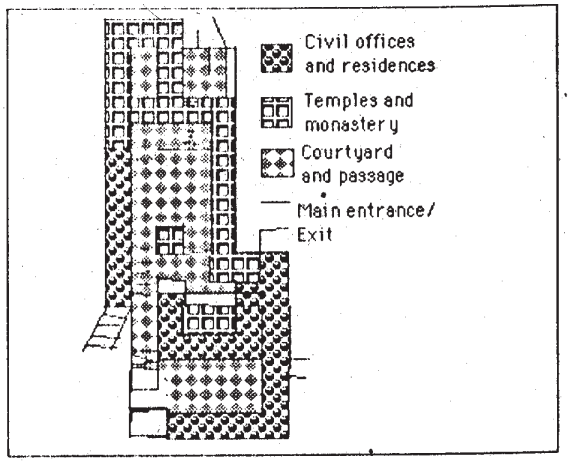

Figure 7-9 Sketch Map of a Dzong Showing the functional Zone.

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Figure 7-10 Dzongs have been the nuclei points around which towns developed.

The Growth of Towns

The Dzongs

Dzongs have been the centre of administration and religious studies for many centuries in Bhutan and they are still places of great importance today. In the past, the dzongs served as the functional point for almost all the services provided to the people, as is the case today. Some parts of the dzongs were devoted to monastic studies, temples of different saints, teachers and deities; while some were used for civil functions such as administrative offices, courts of justice, official residences, storage, granaries and kitchens. In times of bad harvest, people were given grain from the granaries.

During festivals, people from the villages came to the dzongs to participate in and witness the rituals and dances and to receive blessings. At such times, traders sold cloth, soap and other essential items to the crowd, as this was the only chance a trader had of getting a large group of customers all in one place. Apart from these occasional gatherings, the dzongs were occupied by a few officials and their assistants as well as the monks and their helpers. The traders also travelled to different dzongs and monasteries where festivals were to take place. At other times of the year they were only peddlers, visiting individual houses and bartering their goods for cereals and other necessary items available in the villages.

Large gatherings such as those at festivals, which a villager did not get to see very often, were called **Mi-Thron.** The term **mi-throm** is almost synonymous with urban crowd in modern times. Other than this, Bhutan has had no experiences of urban development in the past. In this section, we will study the development of towns in our country during the last 30 or 40 years.

Urbanisation

'Urbanisation' refers to a process whereby people from rural areas move to urban centres and the traditional society is transformed. The nature of the work people do, and the way the people live is drastically changed. On moving to a town, the predominantly agricultural workforce must take up employment in the service or manufacturing industries. Unlike the rural areas, urban landscapes are usually characterised by crowds of people, tall concrete buildings concentrated in small areas, and a criss-cross of streets and shopping centres offering a wide variety of tempting goods and services.

The change over time in the percentage of the population living in towns is called the **rate of urbanisation.** During the past 200 years, the number of people living in towns has increased dramatically throughout the world. During the 19th century, only 1 person out of every 40 people lived in a town, but by the year 2000, it is estimated that nearly half the world's population will live in towns. More than 60 countries in the world presently have over 50 percent of their population living in urban centres.

Urbanisation in Bhutan

Urbanisation in Bhutan is a recent phenomenon. Until in 1960s, there was no place that had the characteristics of an urban area, such as multi-storeyed buildings, streets, restaurants, shops, hotels, hospitals and schools. During the last 30 years, the rate of urbanisation in Bhutan has been rapid.

There are three important factors which have affected the establishment and growth of the urban centres in Bhutan.

1. Site and situation of the place.
2. Increased service facilities
3. Growth of trade and transport

The dzongs were already ideally located as they were easily accessible by tracks from different parts of the valley. They were also built where networks of mule tracks from other valleys converged. Therefore, the government administrative offices were established inside the dzongs. In the 1960s, when the Royal Government began to expand developmental programmes in the kingdom, employment within administrative offices increased, resulting in the growth of population living in and around the dzongs. Residential colonies developed for those employed in the administrative offices. Towns grew up either around or very near to the dzongs. Towns and cities that develop as a result of administrative functions are called **administrative towns.** Almost all the dzongkhag administrative centres come under this category.

The employees needed health services, education facilities, road transport, and shopping centres from where they could buy food and other necessary items. Gradually, the areas of settlement grew and included all these new services. More people migrated to settle in the towns as there were opportunities for jobs in the service sectors. Hotels sprang up to provide accommodation for travellers, and banks were set up for monetary transactions. As the population density increased over the years, the size of settlement expanded outward to bring a greater area of land under the township. Thimphu has typically grown from a few farming villages in the 1960s to its present size.

Table 7-1 shows how the number of restaurants and lodging centres in Thimphu increased during the 1980s. Thimphu has become an important centre for visitors from abroad as well as from different parts of the kingdom.

Table 7-1 Number of Restaurants, Hotels and Guest Houses in Thimphu since 1980.
Source: Ministry of Trade and Industry, 1992

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Year	Restaurants	Hotels/Guest Houses
1980	14	3
1985	23	16
1990	48	38
192(sept)	72	56

Table 7-1 Number of Restaurants, Hotels and Guest Houses in Thimphu since 1980
SOurce: Ministry of Trade and Industry, 1992

Not all towns develop due to employment in administrative offices. Different towns perform different functions, depending upon their location. Phuntsholing is located near the border between India and Bhutan. It serves as connecting point between the two countries and as such is an ideal place for the promotion of trade. So, it has become a **trade town.** Geylegphug and Samdrup Jongkhar are also trade towns.

In places where natural resources are found in sufficient quantities, industries spring up to manufacture goods, using the resources. Gedu, on the Phuntsholing-Thimphu highway, is a typical **industrial town.** Several colonies of concentrated population are also found in Chukha. These developed as a result of the Chukha Hydel Power Project during the 1980s. Sometimes educational centres such as monasteries, schools, and training institutions give rise to small **educational towns** to serve the needs of the staff and students. Kanglung which serves Sherubtse College is an example of this type of town.

The Growth of Thimphu

Thimphu is situated in a narrow valley on the banks of the Wang Chu. From Dechensholing in the north to Simtokha in the south it stretches about 11 kilometres and is no more than one kilometre wide.

Figure 7-11 Part of Thimphu valley – left, in 1966 and right, in 2006

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The development of Thimphu as a town is very recent. Before, Thimphu valley consisted of terraced fields, where people mainly cultivated rice. During the construction of Tashichoedzong, which took about 9 years (1961-1969), the main shopping centre (some 25 shops in all) was located near Dechen Zam. This area is now used as a driving test ground. Most of the labourers lived in hutments in and around Tashichoedzong and Mutigthang area.

Only after the construction was completed in 1969 did the focus turn towards town development. The old farmers had left for Punakha, their winter residence, and discontinued their seasonal migration. In 1960, there were as many as 13 villages of which now only 2 remain, and these are also slowly being replaced by new urban buildings. Figures 7-11 and 7-12 clearly show the changes Thimphu has undergone during the last thirty years.

When the town began to emerge in its present location in 1970, there were no detailed plans to guide the location of roads and streets, residences and office buildings. People began to construct houses wherever they found convenient and as directed by the stars according to astrologers.

A planned development programme for Thimphu was initiated in 1985 when the National Urban Development Commission (now merged with the Public Works Division) was established. It drew up detailed plans for the future expansion of Thimphu, designating particular areas for specific functions.

Functional Zones of Thimphu

The interior of most towns and cities of the world can be divided into distinct functional zones. Each one may be defined by the specific role it plays in the daily activities of the people living or working there. As mentioned above, towns people need places to work, to live with their families, to buy goods, and places for the children to play. These activities will influence different uses of the town area as listed below:

- Central Business District (CBD)
- Residential areas
- Industrial areas
- Shopping centres
- Recreational areas

Generally, the CBD is the centrally located zone and is characterised by tall buildings, big shopping complexes and administrative offices. This zone has easy access from any part of the city and therefore many people will set up business here. Because of this, the price of land is also the highest here. As one moves away from the CBD, the price of land declines.

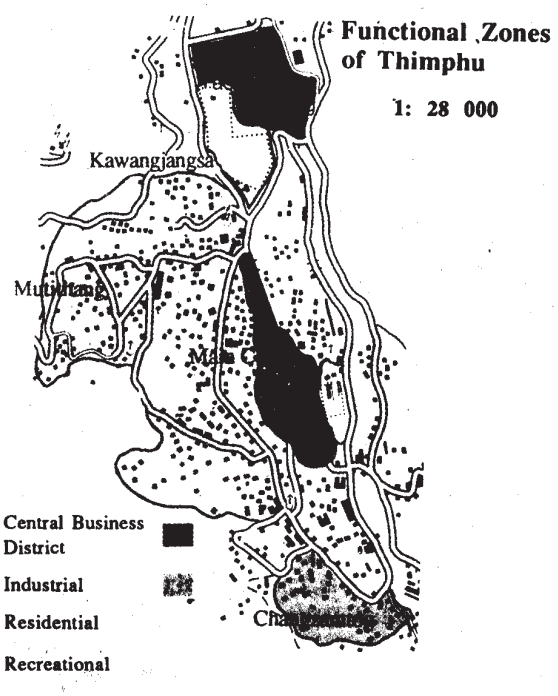

Figure 7-12 Map of Thimphu showing functional zones

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Figure 7-13 A part of CBD in Thimphu

In Thimphu there are really two Central Business Districts. The administrative area in and around Tashichoedzong and the commercial district in the area around the clock tower. We can distinguish them as the Central Business Districts as they are the areas where most of the taller buildings, managerial offices and bigger shopping complexes are located. You will learn why it is so in the section on Central Place Theory. Can you identify the residential zone, recreational zone and industrial zone in the map in Figure 7-12?

In a well planned city or town the industrial zone is usually located at some distance from the residential area and in a place where the prevailing winds and river currents will not carry the pollution from the industrial site into the residential zone. Do you think that the industrial area in Thimphu is suitably located? Do the questions and activities 1-4 in the box before going on to the Hierarchy of settlements.

Hierarchy of Settlements

A settlement will grow at a location where there are advantages such as prospects for economic growth and good transport facilities. Over the course of time, some settlements will grow bigger while others will remain small. In each country, there will be a hierarchy of settlements with one or two large cities, some towns and many villages. The annual statistical yearbook shows population size in the different towns in Bhutan. Can you find out which is the largest town?

Central Place

The idea of the central place was first put forward by the German Geographer, Walter Christaller, in 1993 in his Central Place Theory. In this, he attempted to explain the relationship between the size, function and distribution of towns and cities. (This idea is further explained in Box 7-1).

A settlement which provides goods and services is called a **central place.** Each settlement is a central place, but the goods and services provided will be different at different central places. By nature, people are very economic in their expenditure, so they tend to travel a short distance for certain goods and services. For example, people usually buy goods like salt, rice, tea and sugar from places located close to them, but travel to a bigger place farther away to buy goods for which they pay higher prices such as jewellery, computers and television sets, for instance .

In this way, each hierarchy of settlement supplies a different **order of goods.** Smaller places offer more general and **lower order** goods with a small range of choice whereas bigger places offer more specialised, **high order** goods with a greater range of choices. If you are a resident of Dechencholing, you buy low order goods such as tea and sugar at the local shops whereas you travel to Thimphu to buy clothes, radios and other high order goods. Each central place thus serves a catchment area. Low order places, such as Dechencholing have a small catchment area, and high order places, such as Thimphu have a much larger catchment area.

In the case of some very specialised goods and services, Thimphu's catchment is made up of the entire kingdom. For example, the district hospital in different parts of the country treat patients suffering from common diseases. But specialised surgical treatment, which is a higher order service, is only available in Thimphu at the Jigme Dorji Wangchuk National Referral Hospital. Thus, people with serious illnesses have to travel to Thimphu from all parts of Bhutan. See Table 7-2.

Questions and Activities

1 Write a short account of the Dzongs as centres of Mi-Throm as you see it today. Why do people come to the Dzongs?

2 Study Table 7-1.
Make a list of the factors that will cause rapid Urbanisation in the country.

3 Write an account of the development of a town in the country other than Thimphu. You should look at its past history.
- a How it developed?
- b Who initiated it?
- c How many people and houses were there in the beginning and how many are there now?
- d What did people mainly do and what do they do now?
- e Where did they come form?
- f. What kind of town is it? (you should be able to determine this by looking at the main occupation of the people living there).
- g Draw a sketch map of the town and mark the functional zones in it using different shades and make sure to include legend on the map.

4 Study figures 7-11 and 7-12. Whar are some of the difficulties that have affected the smooth development of Thimphu into a coherent town?

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Dzongkhag	No.	Dzongkhag	No.
Gasa	-	S.Jongkhar	08
Lhuntse	01	Haa	11
Yangtse	01	Samtse	13
Sarbhang	03	Tashigang	15
Tsigang	03	Tongsa	17
Zhemgang	04	Punakha	32
Dagana	05	W. Phodrang	40
Mongar	06	Chukha	45
Bumthang	07	Paro	60
P.Gatshel	08		

Table 7-2 Number of patients who travelled to Hospital in Thimphu for surgical treatment between June 1991 and June 1992.
(Source: Thimphu General Hospital, 1992.)

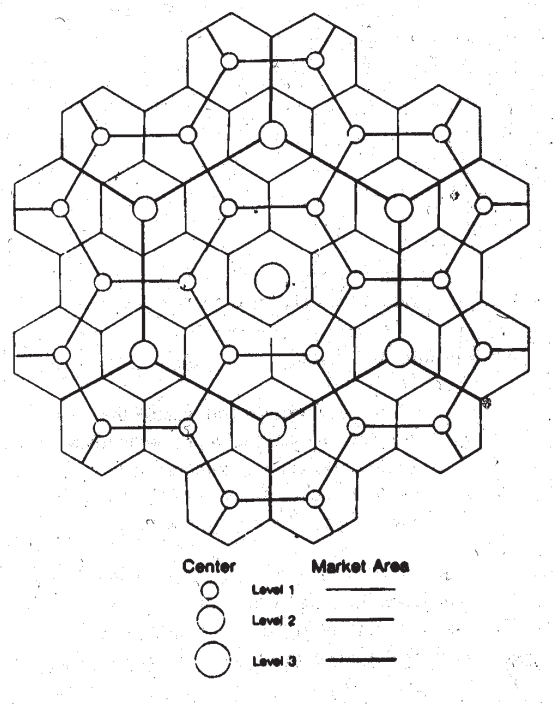

Figure 7-14 Development of market areas in Christaller's theory

Central Place Theory

A **central place** is a market area which serves a certain number of people and settlements. It is normally located in the centre of a settlement or group of small settlements. Christaller put forward this theory to explain the functions, influence and distribution of settlements. He explained that each central place has an influence over certain surrounding settlements known as its **catchment area.** The sphere of influence depends on two factors:

a) threshold population; and
b) the range of goods and services.

Threshold population defines the minimum number of people needed to support a central place for it to operate with sufficient profit. If a place does not have enough influence, its functions will collapse and it cannot run as a central place. For instance, a barber must have enough heads to serve in the catchment area to be able to pay his rent, cover the expenses and to make a little profit. Below a certain number of people, he cannot run his saloon.

The range of goods and services will determine the distance people will travel. People normally visit the nearest place, which provides the goods and services they need. This means that the central place will be visited by people from a circular area, as shown in figure 7-15.

While working on this theory, Christaller assumed that:

a) all settlements are on a uniformly level area;
b) the density of population is equal everywhere; and

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c) transport services and cost of travelling will be the same in any direction.

In reality, these assumptions do not usually hold true. One will never find a hierarchy of settlements exactly the same as the one explained by Christaller. However, the theory does provide us with some insight into the pattern we see as we look at the distribution of towns and cities throughout the country.

Box 7-1 Central Place Theory of Walter Christaller

Questions and Activities

1
   a Divide into groups and discuss the possible reasons that make some towns more important than others.
   b Why are goods and services important in deciding the hierarchy of settlements?

2 Draw a sketch map of any dzongkhag and indicate by different colours the towns or villages that offer higher order goods and services and those which offer lower order goods and services.

3 Study Table 7-2:
   a On an outline map of Bhutan, draw arrows that show from where the patients have travelled to Thimphu for specialised surgical treatment.
   b How can you determine Thimphu's catchment area?
   c Do a similar exercise on education services. Find out how far students travel from home to go to the local primary school.

4 Pick two shops from the local area – one that sells soap and salt and another shop that sells brocade *toegos* or cassette players. Ask the shop keepers how far people travel to purchase these different types of goods. Can you tell which item is the highest order good? Why?

5 Explain to what extent Christaller's theory applies in your area? Ask the shoppers why they travel to certain places for purchasing their goods.

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Problems of Urbanisation

Urban settlement has many advantages. It provides opportunities for new jobs, good transport facilities, accessibility to a wide variety of goods and entertainment and high quality education and health services. However, these advantages are linked with numerous problems, which urban centres in Bhutan will experience as they grow.

Urban Sprawl

The first problem, among many, is that of **urban sprawl.** As population increases, built up areas tend to spread out onto the farming lands and beyond, thus more areas are brought under urban settlement. In many parts of the western world, urban sprawl is a very serious problem and to combat this, governments have created **green belt zones** around the outside of cities. A green belt is an area on the outer edge of the city in which it is illegal to build. It is thus left as forest or farmland. It is also a boundary beyond which the city does not expand.

Social Problems

In order to limit the horizontal expansion of a city, the building of blocks of apartment towers is encouraged and motoways inside the city are built to ease the flow of traffic. This has led to more problems. People living in tower blocks feel lonely and suffer from mental stress. Improving the traffic system encourages more vehicles to use the roads. This leads to greater pollution and increased frequency of accidents which makes the traffic situation even worse. High buildings and traffic problems have started to appear in Thimphu in recent years.

Housing Problems

Urban centres attract migrants from the village. Thus, more people will be added to the urban population. The centre will not be able to provide jobs for every person who comes to live in it so there will be unemployment. Lack of employment and proper earnings create hooliganism and mental stress in many people. Since people without proper jobs cannot afford proper housing, ugly towns of illegal, temporary sheds made of tin, mats and torn cloth emerge in some places. These are called **squatter settlements.** They usually have no proper supply of electricity, drinking water or sanitation. They are the source of epidemics. In the process of urbanisation, land becomes very expensive, which only the rich people can afford. Poorer people will be slowly pushed out of urban areas or will be compelled to live in squatter settlements.

Figure 7-15 Left, garbage collection pit in Thimphu; Right, squatter settlement.

Economic Problems

An increase in urban population with no improvement in the number of job opportunities will mean that many people will have little or no income. Those who have little income will not be able to pay their taxes to the urban development authority, such as the City Corporation of Thimphu or Phuntsholing. Because many people cannot pay taxes, the corporation will not have enough money to provide basic services such as clean water supply, electricity, garbage disposal, health programmes, education and transport services. Without the government's support, the city corporations would be very short of resources.

Waste Disposal

The solid waste which is produced daily by the households of a town or city must be disposed off properly. A safe place is required for dumping this waste; it cannot be just removed from one place and dumped in another. As the number of urban households increase, the volume of solid waste will also increase.

At present, Thimphu produces as much as 16 to 18 tonnes of solid waste a week. Tins, plastic bottles, glass bottles and cigarette foils are some of the non-degradable solid waste.

Location	F.C. Count for 100 ml of water
Chari Zampa	nil
Pangri Zampa	20/100 ml
Dechencholing Zampa	320/100
Bridge near India House	160/100
Dechen Zampa	240/100
Near Chang Limithang	4080/100
Sama Zingkhar	4480/100

Table 7-3 Pollution Survey of Wang Chu (Faecal Coli Count per 100 ml.)
Source: RSPN, Thimphu, 1992.

Figure 7-16 Sewage let out to the Wangchhu near vegetable market in Thimphu from the Public latrine.

Studies have shown that big tins will take hundreds of years to degrade while cigarette foils will take tens of years. During this long period, considerable damage can be done to the environment.

Water Supply

Despite the fact that many parts of Thimphu suffer from a shortage of drinking water, a survey calculated that the volume of water at the source was adequate for Thimphu's needs. Many houses in Thimphu get continuous water supply whereas some get it only at certain hours each day. People may leave the taps open after they have used the water. This wastage causes water shortages for others.

Where the population is concentrated in small areas, diseases, especially those caused by untreated water, are likely to spread rapidly. Urban centres experience the threat of water borne diseases more often than rural areas. Some of the water borne diseases that are spread in Bhutan are cholera, typhoid and diarrhoea. These water borne diseases are a result of increased pollution of the water sources by humans. To prevent these diseases, water must be chlorinated and boiled before consumption.

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Sewage

Human excreta is a bio-degradable material and it does not cause any problem as long as the population is small and scattered. However, it becomes a threat to health and hygiene when human population increases, and particularly when the population is concentrated in a small area. It is also a problem when humans deposit their waste near the sources of drinking water.

There are many sewage tanks built near residential houses and office buildings in the town. But the tanks become full, and even overflow at times. Thimphu needs to work on a system for transporting and then treating the human wastes before they are released into the Wang Chu. Untreated sewage released directly into the river will also affect the river ecosystem. The quality of the water in the Wang Chu will become poorer, threatening the life of people living downstream.

A pollution survey of the Wang Chu carried out by the students of Thimphu schools n 1992, showed that where more people live, pollution in the river is higher. Table 7-3 shows the Faecal Coli count from Chari Zam to Sama Zingkhar in Wang valley. Faecal Coli are a group of harmful bacteria that come from human faeces and if the concentration in one millilitre of water is found to be over 10, then the water is considered polluted and unfit for consumption.

The growth of Thimphu during the last 30 years indicates that urbanisation is proceeding rapidly in Bhutan. In many countries, urban growth is criticised as undesirable and the cause of many problems, yet little is done to encourage people to stay in the rural areas. Until living in rural areas is made attractive, the influx of population into urban centres is difficult to check.

Questions and Activities

1 a Make a list of the advantages that attract the rural population to urban centres.
  b Make another list of the disadvantages of life in rural areas which push people out of the small villages and towards the urban centres.
2 What consequences will Bhutan face as a result of urban sprawl in about 30 years from now?
3 List the social problems from which city dwellers may suffer.
4 Study Table 7-3 and Figure 7-18. Explain the relationship between the population distribution and the F.C. count?
5 a How do people contribute to the increase of sanitation problems in their living places?
  b What steps could best reduce such problems?

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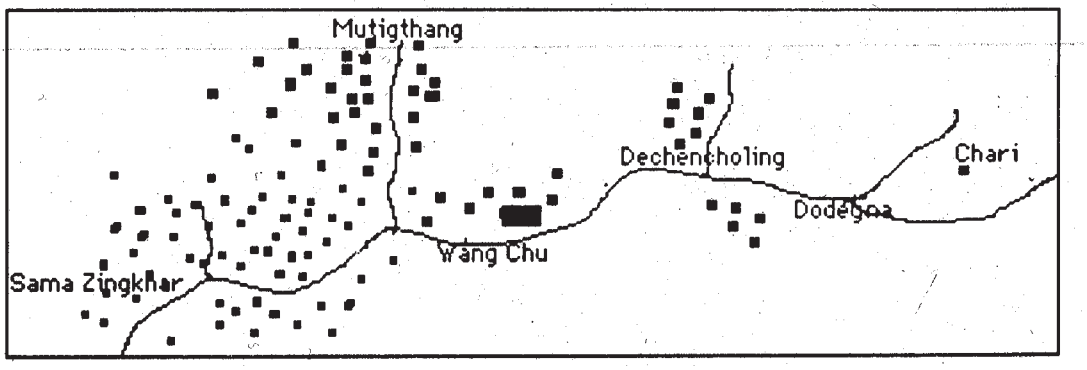


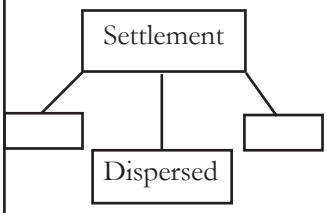
Figure 7-17 Map of Thimphu valley showing population distribution and water sample site during RSPN pollution survey in 1992.

Summary Activities

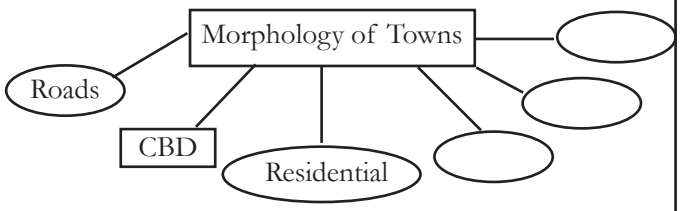
1 In your own words describe the following terms from the text:
- linear settlements
- rate of urbanisation
- central place
- order of goods
- green belt
- squatter settlement
- sewage

2 Copy the charts below into your note books and complete them by filling the blanks with appropriate information.

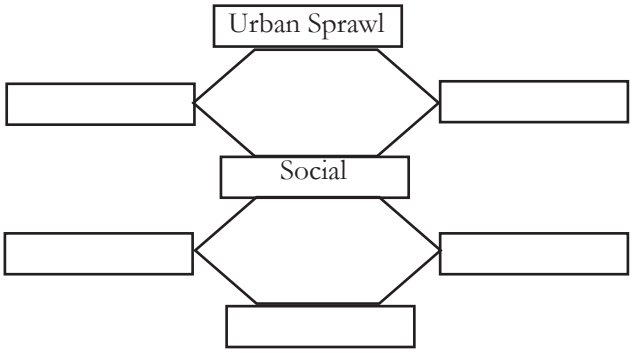
(a) Patterns of Settlementss



(b) Urbanisation



(c) Problems of Urbanization



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Chapter 8

"Interdependence Philosophy – Defend Our Environment as we will be Dependent On Environment for Generations".

"Full Circle: Nurture nature, Nature nurtures".

AGRICULTURE

(Agro-ecological zonations and Farming Practices)

KEY IDEAS

- Farming Systems and Production Systems
- Agro-ecological zonations
- Cropping Pattern & Agricultural Practices
- Challenges to farming

Background

Farming: from Subsistence to Commercialization

Farming in Bhutan will continue to remain one very important mainstay of our economy and employment as almost 69.1% (*Population & Housing Census of Bhutan, 2005*) of the rural population depends on agriculture as a source of livelihood, employment and income. Realizing this fact as far back as the very first plan period in 1961, agricultural development policies and programs evolved focusing on sustainable use of renewable resources embracing environmental conservation and bio-diversity protection. Sustainable Land Management Program is one very good example which focuses on conserving and promoting the production potential of our land through proper land management systems including various erosion control methods. Adoption of new technologies (*such as high yielding varieties of crops and animals; use of quality crop seeds; good feed and fodder seed varieties; fertilizers and agro-chemicals for controlling insect pests and diseases; health care for animals and so on*) for increasing yield and quality, both from crops and livestock is another case in point for increasing their production potentials.

Such production programs are combined with aggressive approach for providing access and market for the produce; and enhancing the capacities of the producers through providing information and training.

Such a proactive developmental thrust in the arena of agriculture have significantly enhanced the pace and process of evolution of our farming practices. Thus enabling the process of the emergence of an active market oriented farming from a subsistence farming.

In the past, farming is a way of life and livelihood for many farming populations in rural Bhutan. Farming practices followed were rather a culture inherited from generations and thus were woven into the fabrics of tradition with religious events like conducting offering ceremonies for appeasing local deities for bountiful harvest rather than adoption of scientific interventions. Bartering of goods (livestock products like butter, cheese and meat; and agricultural products like rice, maize, wheat, chili and so on) and services

were a common practice forming a major part of the farm business then.

With the commencement of planned development in 1961 and particularly after the creation of Ministry of Agriculture in 1985 (Dept. of Agriculture existed since the 1960s), farming embracing crop production and livestock rearing received much impetus. New crop varieties and new breeds of animals (cattle, pig, horse, poultry, and sheep) were introduced. Highly subsidized inputs like crop seeds, fertilizers, agro-chemicals, animal breeds, fodder seeds and health care of animals including medication and vaccination were provided. At the same time, under the aegis of Ministry of Agriculture, research and extension for the development and delivery of new technologies received much thrust. To promote, support and enhance production, both from animals and crops, the Ministry of Agriculture established research Centers, Extension system and support services (like Agriculture Machinery Center; Irrigation Division; National Soil Service Center; National Plant Protection Center; National Post Harvest Center).

As a result farming evolved from subsistence to a semi-commercial level. Some of the growing export figures for horticultural commodities are presented in table 1. The emergence of some economically viable semi-commercial scale ventures are some strong indicators. They include:

1. Horticulture crops like apple, citrus, potato;

2. Livestock Production farms like private piggery & poultry; diary farming;

3. Processing units like agro-processing units; and Diary processing units; and

4. Establishment of post harvest facilities.

The development of access and market, both External and Internal market networks like the vegetable markets; FCB (Food Corporation of Bhutan) auction yards have led to enhanced trade and commerce between and within districts; and with export market. Cash crop production and sale grew exponentially across the country indicating the emergence of a market based economy.

The overall contribution of the RNR sector (agriculture, livestock and forestry) to the GDP is about 38 %. Of this, about 50 % comes from Agriculture; 20 % from Livestock and 30 % from Forestry (Policy Objectives & Strategies – Arable Agriculture Sub-sector; 9FYP document, 2002-2007).

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Commodity	Volume (tonnes)		Value ('000 Nu.)	
	2003	2004	2003	2004
1. Apple	4,841.84 (25.41)	3122.97 (57.65)	53,352.31 (588.54)	43,528.06 (967.60)
2. Citrus (Mandrin Oranges, Lime and Lemons)	14,524.89 (81.62)	19,574.59 (94.90)	142,942.03 (488.22)	220,058.50 (852.62)
3. Other Fruits	0.35	1.22 (1628.66)	6.54 (11187.75)	5.35 (10730.72)
4. Potatoes	17911.29 (2565)	17,662.13 (2580.51)	71,948.06 (7491.04)	112,957.09 (10,094.00)
5. Spices (1997 – 2003)	1037.98 (222.97)	1,153.36 (266.94) *886.42	65949.44 (9,930.38)	96,106.76 (12,291.86) *83,814.90
6. Vegetables (1997 – 2003)	224.94 (5867.57)	961.67 (7,848.40) * -6,886.73	8861.56 (37,868.91)	8,794.56 (49,887.55) *41,092.99

Table 8.1: Export figures for Horticulture commodities

Source: Bhutan Trade Statistics, 2003; compiled by Agri. Marketing Dibvision, MoA
Note: Figures in the bracket are import figures
* - Trade balance figures

Looking at the farming practices and the technologies adopted by our farming community; and the comparative advantage that our production environment offers, especially for some organic products, there is a huge opportunity for improving the level contribution to the GDP made by the RNR sector.

The other aspect is the possibility of combining adoption of high yielding crop varieties /animal breeds with improved crop / animal husbandry methods, for improving the yield significantly. Similarly, there is a huge potential for improving the utilization of forest resources, both timber and non-timber products by implementing the forest management plans effectively.

1. The Landscape and Prospectives

Bhutan is situated in the eastern Himalayas at a longitude range of 88°.7' E – 92°. 15'E and latitude range of 26°.7' N – 28°.4' N (Source: Agro-Met Division, CoRRB, MoA from GIS *reconnaissance*). Therefore, Bhutan is compressed within a latitude range of about 2 degrees which translates into approximately about 172 km aerial distance from north to south and a longitude range of about 4 degrees that measures about 336 km from east to west (Source: Cadastral Information Division, DSLR, MoA). Within this latitude range altitude varies from 200msl to 7500msl at an average (Source: Atlas of Bhutan (1997), LUPP, PPD, MoA).

The mountainous ecosystem with its great variations in altitude explains the great

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diversity in climatic conditions. As a result we have climatic conditions ranging from hot and humid subtropical conditions in the south to tundric conditions with perpetual snow and ice in the high Himalayas. Such unique ecological conditions have given the Himalayan region a great diversity in both flora and fauna. For Bhutan, in terms of agricultural production, it means a fantastic opportunity for harnessing the comparative advantage of producing crops which can only be produced under such special ecological conditions. Bhutan with its highly conserved and protected bio-diversity and environment, it has great potential for producing high value crops, such as medicinal and aromatic plants ([MA]Ruta – *Sassurea lappa*; [A]Honglen – *Picrorhiza kurroa;* [A]Pangpoi – *Nardostacheys jatamansi;* [A]Lemon grass – *Cymbopogan citratus*;[M]Pipiling – *Piper pepiloidus;* [M]Jatig – *Swertia chirayita;* [M]Yatsra Guenboop – *Cordyceps sinensis);* vegetable seeds (cabbage, cauliflower, broccoli, potato) and wild flowers like orchids and Rhododendrons, under organic and natural conditions.

(Note: MA – Medicinal & Aromatic; A – Aromatic; M- Medicinal.)

2. National Biological Asset Endowment

Internationally, Bhutan is recognized as one of the hot spots of biodiversity. For Bhutan this means it is blessed with great diversity of flora and fauna, which many countries have exploited before knowing the consequences. This translates directly into environmental health which can be viewed as one of the indicators of human health since the water we drink, the air we breathe and the quality of food we eat is reflected in our environmental health. Therefore, recognizing and appreciating the value of the great diversity that Bhutan is blessed with, it has adopted "Middle Path" developmental philosophy, i.e., balancing economic return with conservation of environment and cultural heritages.

Bhutan's biological endowment of flora and fauna includes: 7500 species of vascular plants including 46 recorded species of rhododendrons; over 700 species of birds; and more than 165 species of mammals (Vision and Strategy, Nature Conservation Division, 2003; Dept. of Forestry Services, MoA). To safeguard and promote this diversity, under the nature conservation program, of the total land area of 40077 Sq. Km, the Royal Government have set aside 26.23% (10,513 Sq. Km) under protected areas system and 9 % (3607 Sq. Km) under biological corridors (Vision and Strategy for the Nature Conservation Division, 2003). Additionally, the Royal Government has also declared that Bhutan will maintain 60 % of the total area under forest cover at all times to come (Vision 2020). These commitments of the Royal Government will directly ensure the preservation, protection and promotion of the bio-diversity. As a result, the environmental health will be ensured that will not only provide aesthetic beauty for generations, but it will contribute significantly to the goal of Gross National Happiness as good natural wealth will impacts positively on the spiritual well being.

Farming System

(*Land Use Types and Predominant Production Systems*)

A farming system may be defined as a unique arrangement of *farming enterprises* (for instance, live stock rearing, crop cultivation, and utilization of natural resources like forest products) that a household manages according to *well-defined practices in response to the physical, biological, and socio-economic environments* and in accordance with the household goals, preferences and resources.

A farming system may be simply defined as managing the *farm resources* in a profitable and sustainable way under the *given conditions* by a farm household. It is a unit operating in a healthy manner at all times.

In Bhutan, the farming system is highly integrated, subsistence oriented mixed farming system that is typically characterized by the presence of three main components that includes crops, livestock and forest resource use. Hence, the name mixed farming system. However, the farming system also includes the farm household and the Environment under which the house hold functions. These include, the socio-cultural and administrative (policy and institutional support) environment; and the bio-physical environment like the land scape, soil, climatic conditions. All these factors contribute into making the total of the farming system.

At the farm level, within our mixed farming system, forest features as an integral part. It connects livestock to crops through providing fodder and leaf litters as bedding materials for cattle. The bedding materials when decomposed are used as manure for crops. Timbers, fuel wood and non-timber forest products (NTFP) (like bamboo, mushrooms, medicinal plants and so on) are other resources that the farming communities utilize from forest. Water resources required at the farm, both for drinking and irrigation purposes are also intricately connected to the sustainable utilization of the forest resources.

Within a farming system we could observe more than one production system operating. For instance, a household in warm temperate zone will operate on wet land, dry land, and orchard; and rear livestock and utilize forest resources.

Based on the land use types, which means how the land is being used for purpose that is being used, we have identified six production systems.

Land use types		Area (Km^2)	% Area
Forest		29045	72.5
Pasture		1564	3.9
Horticulture (Orchad/ Plantation)		58	0.1
Agriculture (7.7%)	Wet land	388	1.0
	Dry land	977	2.4
	Tseri	883	2.2
	Mixed Cultivation	840	2.1

Table 8.2: Land area under different land use types (About 15.7% (6289 Km^2) of the total area is occupied by settlement and land that are not under use like under snow/ glaciers, rocks, water spreads, marshy areas, and landslips/ erosion.) Source: Atlas of Bhutan (1997), LUPP, PPD, MoA

For instance, the paddy lands that are irrigated and/ which remains flooded for most part of paddy growing season falls under Wet Land Production System (WPS). While those land

types that are rain fed or irrigated, but does not remain flooded falls under Dry Land Production System (DPS). On the other hand we have Pastoral Production System (PPS) where rearing of livestock predominates with huge area under pasture. Then we have Tseri Production System (TPS) (that is similar to shifting cultivation). It is also referred to as "Slash and Burn System" where people slash, clear and burn bushes and young trees after a period of fallow (anywhere from 3 to 12 years) and cultivate from a year up to 2 to 3 years.

Sl. No.	Production Systems
1	Pastoral
2	Forest
3	Wet land
4	Dry Land
5	Orchard/Plantation
6	Tseri

Table 8.3. Different Production Systems. Source: Doctorial thesis, Dr. Kinlay Dorjee, PPD, MoA (1995)

Another production system which is gaining importance is the Orchard/Plantation Production System (OPS) as a source of cash income to our farmers. Then, the Forest Production System (FPS) forms one integral part of our mixed farming system that contributes fodder to the livestock, fuel and timber to the farm household and nutrient source to our crops as decomposed farmyard manure (FYM) in the form of leaf litters. It also provides NTFPs that contributes to the nutritional and income needs.

In our farming system, which is mixed, we could have a combination of production systems with predominance of one or few production systems. We will first consider the agro-ecological zones and within each zone then look at the prevailing production systems as influenced by the climatic conditions. Within the production system we could also look at the agricultural practices followed and the differences that we can observe.

Agro-Ecologiocal Zonations (AEZ) and Farming Practices

Based on altitude, rainfall and temperature six main agro-ecological zones, from north to south have been distinguished. They are as presented in table 3.

Within an AEZ, predominance of a particular type of a Production System is determined by the agro-ecological conditions and topographic features. As we look into the various AEZ and the production systems therein, it will be much clearer.

Alpine zone (0) (see table 8.4): In this zone, Pastoral Production System dominates with yak rearing as the main source of livelihood to the semi-nomadic people living in that zone. Crop production is limited to high altitude barley, buckwheat, mustard and few vegetables including radish; turnip; cabbage and cauliflower; and potato. The herders either barter or sell their yak products like butter, cheese and meat to people in lower areas from where they take cereals and essential household items. Typical areas include Laya & Lunana, Gasa; Merak & Sakting, Trashigang; and Soe, Naro & Linshi, Thimphu.

Cool temperate zones(1) (see table 8.4): Here, livestock rearing with pastoral production system is still dominant. Farmers rear both cattle and yaks besides other livestock types

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like sheep and horses. Cattle graze the pastures in summer and yaks in winter. Much more agriculture is practiced here than in the alpine zone. Buckwheat, barley, mustard and wheat are traditional crops grown in this zone and potato and apple to some extent has become an important cash crop in more recent years. These crops are grown on Kamshing (dry land), which forms the DPS. Buckwheat and mustard are also grown on Pangshing, a form of shifting cultivation where crops are cultivated after fallow periods ranging from two to ten years. Most of these lands are used for grazing during their fallow period and some of the areas have been brought under improved pastures. Typical areas include Haa; Bumthang and Gasa.

Agro-ecological Zone	Altitude Range (m.a.s.l)	Annual Rainfall (mm)	Air Temperature		
			Max ^{0}C	Min ^{0}C	Mean ^{0}C
0. Alpine	3600-4600	<650	12.0	-0.9	5.5
1. Cool Temperate	2600-3600	650-850	22.3	0.1	9.9
2. Warm Temperate	1800-2600	650-850	26.3	0.1	12.5
3. Dry Subtropical	1200-1800	850-1200	28.7	3.1	17.2
4. Humid Subtropical	600-1200	1200-2500	33.0	4.6	19.5
5. Wet Subtropical	150-600	2500-5500	34.6	11.6	23.6

Table 8.4. Agro-ecological zones of Bhutan.

Source: Doctorial Thesis; Dr. Kinlay Dorjee, PPD, MoA (1995)

Agro - ecological Zonation	Dzongkhags
0	Bumthang; Gasa; Lhuntse; Trashi Yangtse; Thimphu, Haa; Paro; Wangdue Phodrang
1	Bumthang; Thimphu; Paro; Haa; Gasa; Trashi Yangtse; Trashigang; and Wangdue Phodrang
2A	Haa; Paro; Thimphu; Wangdue Phodrang; and Trongsa.
2B	Trashigang; Lhuntse; Mongar and Trashi Yangtse.
3A	Punakha; Wangdue Phodrang; Trongsa; and Chukha.
3B	Trashi Yangtse; Trashigang; Lhuntse; and Mongar.
4	Zhemgang; Tsirang; Trashigang; Pema Gatsel; Samtse; Sarpang; and Chukha
5	Samtse; Sarpang; Samdrup Jongkhar; and Chukha.

Table 8.5: Dzongkhag classification according to AEZ

Source: MoA/ISNAR, 1992
It is, however, not easy to delineate the distribution of these agro-ecological zones across the dzongkhags (districts). In some dzongkhags, for instance Paro in the west and Trashigang in the east, a range of agro-ecological zones can be encountered.

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Warm temperate zone(2) (see table 8.4): is the most productive parts of the country. A wide range of crops is grown from paddy in irrigated areas to barley and potatoes on dry land. Fruit production like apples, pears and peaches have also picked up in this zone as well as cultivation of vegetables like cabbage, cauliflower, chili, broccoli, tomatoes and many others for the market.

While livestock continue to be the main source of drought power and manure, farmers in this zone are also increasingly using farm machinery and chemical fertilizers.

Typical areas include Paro, Thimphu; parts of Mongar and Trashi Yangtse.

Dry sub-tropical zone(3) (see table 8.4): Here, maize is the most common cereal followed by millets and pulses. Tseri, a form of slash and burn, is widely practiced in this zone as well. In more recent years, cultivation of fruits and vegetables are also gaining importance depending on the availability of water or precipitation. Lemon grass harvesting has become a very important source of income to the farmers living in this agro-ecological zone. Cattle rearing are also common with free ranching in the forest as a predominant form of herding. Farmers also rear pigs and poultry on a much larger scale than in the higher agro-ecological zones.
Typical areas include Punakha; Wangdue Phodrang; Trashi Yangtse; Trashigang; Lhuntse; and Mongar.

Humid sub-tropical zones(4) (see table 8.4): Here, there is a gradual increase in the wetland areas with increased paddy production is noticed. Citrus cultivation, predominantly mandarin orange is the main cash crop with cardamom in the lower foot hills. Mustard, wheat, pulses and vegetables are grown in rotation with rice on some of the more fertile and warmer areas that have also easy access to markets. Cattle rearing are also common features as fodder is available in abundance.

Typical areas include Tsirang; Trashigang; Pema Gatsel; Samtse; Sarpang; and Chukha.

Wet Sub-tropical Zones(5) (see table 8.4): Here, paddy is the main cereal crop with a number of tropical fruits like mandarin orange, mango, pineapple, banana, guava that are grown in this belt. Areca nut is also grown in this belt as cash crop. Where irrigation is possible, vegetables are also grown in autumn or early spring. Livestock including cattle, sheep and goats are common in this belt due to the availability of fodder.

In all the AEZs, use of forest products like non-timber forest products (NTFP) (like mushrooms, ferns, bamboo, *Pat-tsa & Dambro,* bamboo shoots), fodder, timber and leaf litter is a common feature.

Crops and Cropping Patterns

1. Crops

The crops that are grown could be broadly grouped into 4 categories. Namely:

a. Cereal crops: paddy, maize, wheat, barley, millets, and oats
b. Legumes & Oil Seeds: Peas, beans, mustard
c. Vegetables: Potato, chili, ginger, brassicas, tomatoes, squash, green leaves
d. Fruit trees: Apple, Citrus, Areca nut, mango, stone fruits, banana

Among the cereals rice and maize are the most important crops. Potato and chili dominates as a cash crop vegetable for our farmers. Among the fruit trees, Citrus is grown widely in the sub-tropical climatic conditions while apple predominates in the temperate regions.

The present level of crop yield obtained are much below the production potential of the crop and achieveable levels. Rice and Wheat are very good examples. In case of rice, over the years yield per hactre had increased, however, it is still below 3 MT/ha. While the world average is above 3 MT and many countries have much higher yields as shown in table 8.6.

Crop Category	**Crop**	**Area (Ha)**	**Production (MT)**	**Yield (T/ ha)**
Cereals	Paddy	18860.32	54325	2.9
	Maize	21837.25	90566	4.1
	Barley	1130.36	1424	1.3
	Wheat	3070.04	4191	1.4
Oil Seeds	Mustard	1823.08	1767	1.0
Vegetables	Potato	3423.08	47403	13.8
	Chili	815..38	3190	4.0
	Ginger	1423.89	6225	4.4
	Radish	963.17	5628	5.8
	Others	336.03	5597	1.7
Fruit Crops	Total number	Total Bearing	Production (MT)	Yield (Kg/ trees)
Apple	386959	246,082	5917	24
Citrus	1831312	983407	31915	32
Areca nut	705470	168014	3419	20
Others	3540000	1500000	44755	30

Table 8.6: Area, Production and Yield of major crops
Source: Agriculture Statistics, 2004

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Wheat is much the same. Therefore, there is a potential to increase yield by increasing the levels of inputs (quality seeds and fertilizers) and adopting production technologies that will increse crop yields, like timely irrigation, maintaining proper plant density, management of insect pests, diseases & weeds, choice of high yielding varieties (HYV) and so on. When we look at the Argiculture Practices as practiced in Bhutan we will try to reflect upon the adoption of production technologies and then look at the opportunities for increasing the yields.

Table 7: Asia and the Pacific rice production, yield and area (1997) and their growth rates, 1987-1997

Country	Production (P) (`000 tonnes)	Area (A) (`000 ha)	Yield (Y) (kg/ha)	1987-1997 growth rate (%)		
				P	A	Y
Australia	1 352	164	8 244	6.2	4.5	1.6
Bangladesh	28 183	10 177	2 769	1.1	-0.4	0.7
Bhutan	50	30	1 667	-0.2	0.1	-0.2
China	198 471	31 348	6 331	1.0	-0.7	1.6
India	123 012	42 200	2 915	2.6	0.5	2.1
Japan	12 531	1 953	6 416	-	-0.5	0.5
Korea, Dem. People's Rep.	2 347	611	3 841	-5.1	-1.7	-3.3
Malaysia	1 970	655	3 008	1.6	0.1	1.5
Myanmar	189 000	6 070	3 064	4.0	3.3	0.6
Nepal	3 711	1 511	2 455	1.3	0.5	0.9
Pakistan	6 546	2 316	2 827	3.3	1.2	2.1
Philippines	11 269	3 840	2 933	2.7	1.8	1.0
Sri Lanka	2 610	660	3 954	1.3	-	1.3
Thailand	21 280	9 932	2 143	1.3	0.2	1.1
Viet Nam	26 397	7 021	3 760	5.5	2.4	3.1
Others	65155	16976	25425	-	-	-
Total	523 784	133 696	3 918	1.8	0.4	1.4
Rest of world	49 479	16 115	3 070	2.0	0.3	1.7
World total	573 263	149 811	3 827	1.8	0.4	1.4

Source: FAO-RAP Publication 1998/21.

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Region/Country	Average yield (t/ha)	Remarks
1. North America	2.54	The Average yield of the region and the average yield of the countries higher than 3t/ha are given except in case of USA, India and Bhutan. As could be observed wherever wheat is the staple crop, the average yield is much higher – particularly in western europe. This also indicates that if production technologies (good nutrition management through adequate fertilization and irrigation; insect pests, diseases and weeds control; maintaining good plant population per unit area and so on) are applied there is a big yield gap that could be taken advantage of.
a. Mexico	4.1	
b. USA	2.5	
2. South America	2.3	
3. Western Europe	5.5	
a. United Kingdom	7.5	
b. Netherlands	8.6	
4. Eastern Europe	2.9	
5. North Africa	1.9	
a. Egypt	5.3	
6. East & South Africa	2.2	
a. Zimbabwe	4.9	
7. Oceania	3.8	
a. New Zealand	6.0	
8. West Asia	1.6	
9. East Asia	2.4	
a. China	3.5	
b. Japan	3.6	
10. South Asia	1.7	
a. India	2.4	
b. Bhutan	1.4	

Table 8: Wheat Average Yield (t/ha)
Source: Wheat in the World - b.c.curtis

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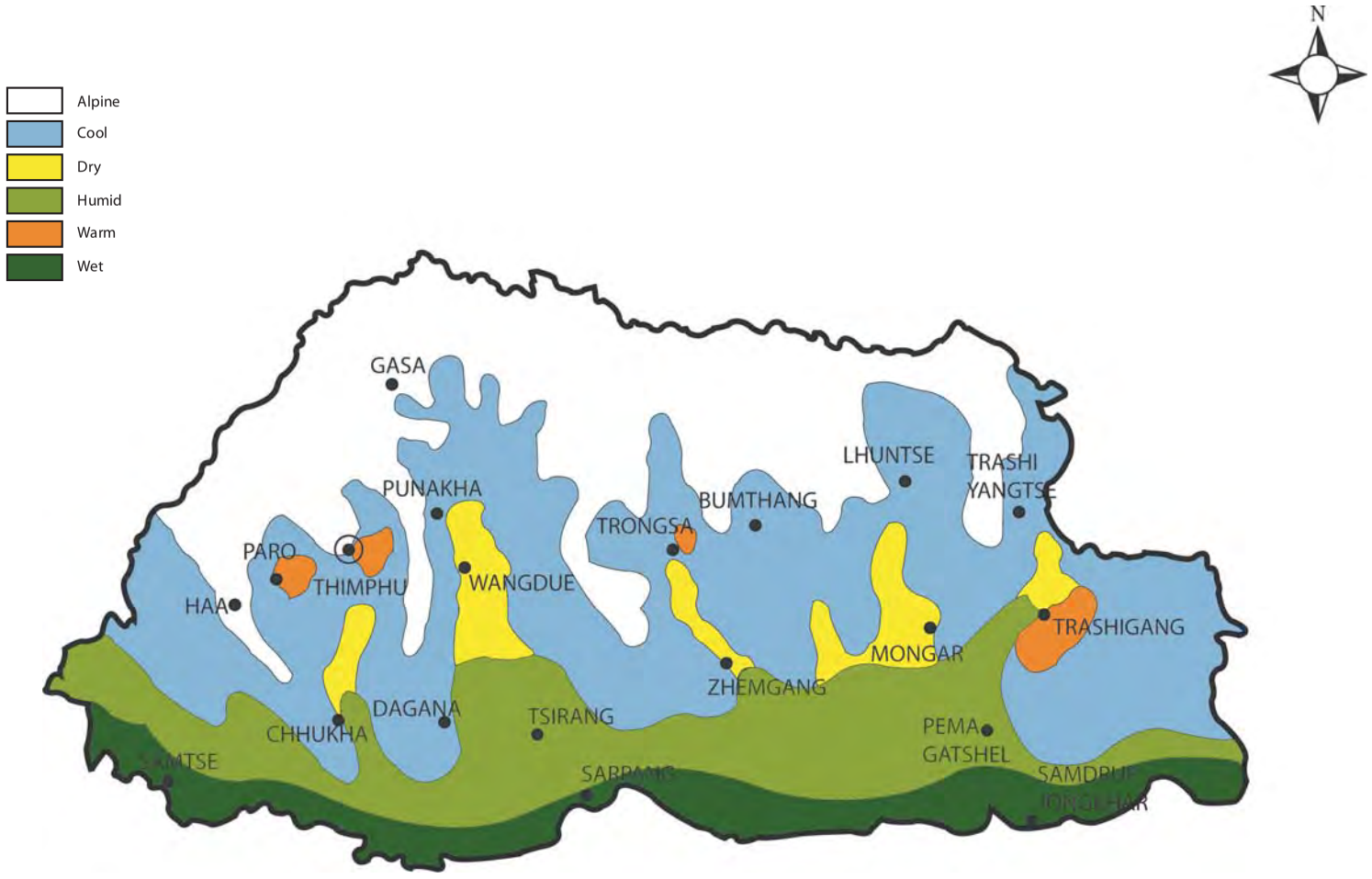

Figure 8.1: Agro-ecological Zones of Bhutan
Source: Adapted from MoA/ISNAR, 1992

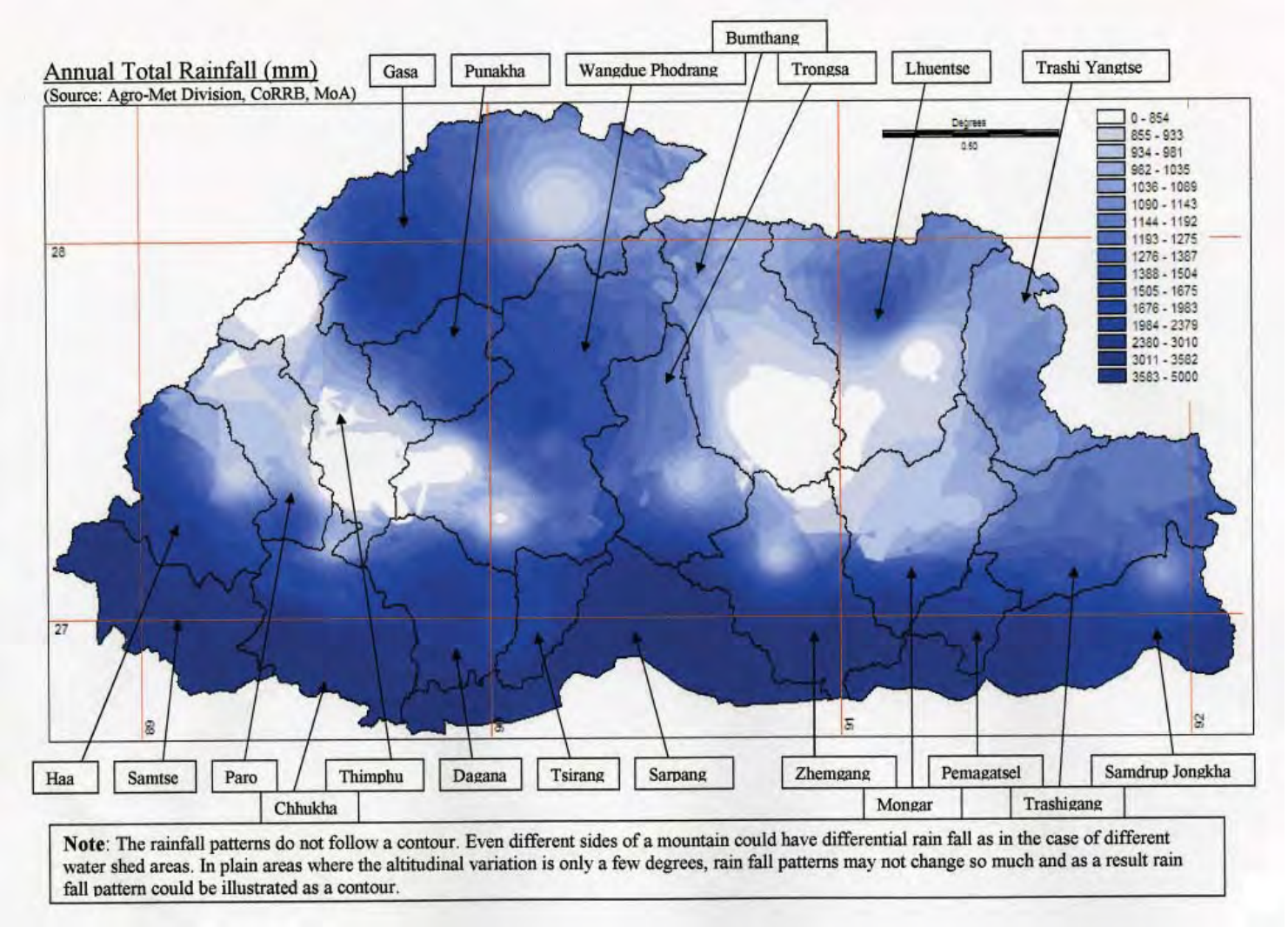

Table 8.2: Annual Total Rinfall (mm)

b.Cropping Pattern

Cropping pattern could be defined as distribution or cultivation of crop in time and space.

For example: **In time -** one crop following another spread over time – e.g.: growing vegetables after rice; **In space -** as a monocrop, i.e., one crop over a given area – e.g.: Maize over vast area; or as mixed/companion -crop, i.e., more than one crop in a given area – e.g.: Maize inter-rows sown with potato or legumes.

It is simply an arrangement or pattern of growing crops with an objective of maximizing the producing potential from a unit area of land. It is indeed a land utilization plan for harnessing maximum benefit.

In the arable agriculture sector we have two predominant production systems – the dry land production system and the wetland production system. We will look at the prevalent cropping patterns in these two land use types. One is rice based cropping pattern where rice is the main crop for wet land production system.

The other one is the maize based cropping pattern where maize is the main crop for the dry land production system. We will not deal with the cropping patterns under Tseri and Orchard/Plantation production system under arable agriculture.

The other types of rice based cropping pattern include:

1. For High Altitude areas
   a. Rice – Vegetables
   b. *Rice – Potato
   c. Rice - Fallow
2. For Mid – altitude areas
   a. Rice – Mustard
   b. Rice – Rice
   c. Rice – Vegetables
   d. *Rice – Chili
   e. Rice - Fallow
3. For Low altitude areas
   a. Rice – Rice
   b. Rice – Grain Wheat
   c. *Rice – Green manuring legume
   d. Rice - Fallow

(- Potato, chili and Green manuring legumes are pre-rice crops)*

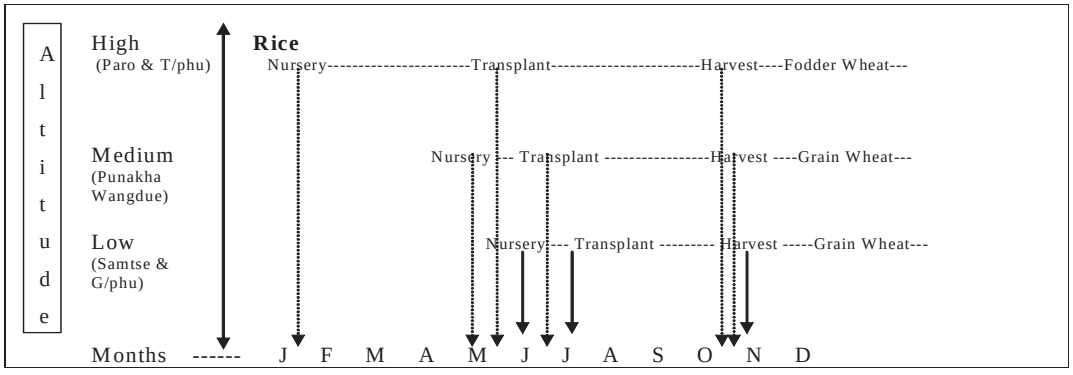

Table 8.9: Rice based Cropping Pattern

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Similarly for Maize based cropping pattern, we have the following combinations of crops in different altitude zones:

1. For high altitude zones (Drepong, Mongar)
   a. Maize – fallow
   b. Maize - Barley
   c. Maize - Mustard
2. For Mid-altitude zones (Chaskar, Yadi, Mongar)
   a. Maize/Potato – Mustard
   b. Maize – Rajma Beans
   c. Maize/Legume - Mustard
3. For Low altitude zones (Udzrong, T/Gang)
   a. Maize – Legume (Rajma)
   b. Maize/Millet – Legumes
   c. Maize – Maize

With Orchard /Plantation crops that are wide spaced and which take more than one growing season, various companion crops are possible. For instance, in many apple orchards, fodder grasses, potato, legume crops and chili are cultivated. Similarly in Citrus orchards, Maize, chili, legumes and vegetables are grown. All these are methods of intensifying land use for crop production purposes.

The type of cropping pattern that is followed will have direct bearing on the predominance of a particular species of weeds, insect pests or a disease pathogen. This is because of the kind of host available and the biological interaction between the species. A host and an organism associated (pest species) co-evolves as they are linked in evolutionary terms leading to selection of a resistant or a tolerant host species.

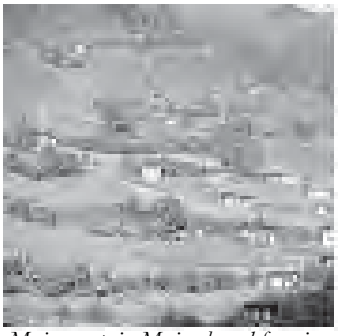

Figure 8.3: Maize crop in Maize based farming system Photograph: Courtesy of Mr. Tirtha (Maize breeder), Sr. Research Officer, RNR Research Center, Wangkhar (2006)

Figure 8.2: Rice Crop in a Rice Based Farming System

Figure 8.4:Mustard after Rice in Rice Based Farming System

<u>Photographs</u>: Courtesy Mr. Mahesh Gimaray (Rice Breeder) Sr.Research Officer, RNR Research Center, Bajo (2006)

Farming Practices

In general, at **a broader level** farming practices will include the various types of farming that would involve the use of agricultural resources like land, water, soil and inputs like seeds or animal breeds, fertilizers and various husbandry methods that would enhance production. Distinctly four farming practices could be listed:

1. Livestock farming
2. Organic Farming – from crops to livestock and others like NTFPs and medicinal and aromatic plants and herbs.
3. Conventional crop production – including horticulture and cereals crops
4. Aquaculture – including fish farming and aquatic plants

At a micro-level, for instance, within a farming system, say, crop production, we could again viewdifferent types of farming practices. Here we will consider mainly two types:

1. Modern agriculture - following the modern concept of Good Agriculture Practice (GAP) principles for producing quality and safe products while ensuring sustainability. **A note should be added here** since the concept of GAP is drawn

Farming Practices in Rice cultivation		
Cultivation Practices	Traditional	Modern
1. Choice of Variety	Traditional varieties	Hybrids with high yielding and resistance to certain insect pests and diseases
2. Nursery Sowing	On raised or flat bed	On raised nursery bed with adequate irrigation, fertilization and insect pests, diseases and weeds control
3. Land Preparation	Done through animals draught power and humans	Usually done mechanically
4. Transplant	Done manually and at random	Done through transplanters and in rows
5. Source of nutrient	Decomposed farmyard manure	Mostly inorganic chemical fertilizers
6. Weeding 7.	Manual	judicious use of chemical weedicides and mechanical weeders like rotary weeder
8. Irrigation – level of water	Irrigated wherever water is available and field moisture level is not maintained.	Field moisture level is maintained at saturation point (soil is completely soaked) or based on the importance of weed species, a level of 3-5 cm water level is maintained for controlling grass weeds.
9. Insect Pests and Disease management	Manual, and in some cases use of repellents were reported	Use of: resistant variety, and judicious use of chemical insecticides, fungicides and nematicide
10. Harvesting	Manual	Mechanical harvesters used
11. Threshing and Milling	Manual	Mechanical thresher and miller
12. Intensification & Extensification	Low input and smaller areas	High input and significantly larger area with market interest
13. Emphasis on Quality & Quantity	The focus is more on quantity production with the objective of family food self sufficiency.	The farmer here focuses both on quantity and quality for competing in the market for higher price.

Table 8.10: Farming Practices in Rice Production

based on the abuse of the technologies generated. A specific example is in cases of excessive and "untimed" use of pesticides that causes all sorts of hazards from personal health to environmental health. Also with modern agriculture which implies use of new technologies, the ecological balances are disturbed so it is management intensive for producing a profitable level of production.

2. Traditional agriculture – following the good old method of farming wherein disturbance in natural balance is minimal as technological intervention is minimal, so management is not very intensive.

In the first case, scientific interventions that would increase yield from crop or livestock is adopted for increasing production. The technologies so designed could be a refinement from the traditional from, for instance, line planting; crop rotation of legumes and cereals; or a completely new innovation like a new variety/breed (*this could be through gene manipulation which is called Genetically Modified Organisms*); or a method of production like use of transplanters or chemical weedicides. While in traditional type of agriculture, farming is based on traditional knowledge that has been passed down for generations. For example, in Bhutan, few decades back cultivation practices followed were traditional and based on indigenous knowledge of farming as given in the table as an example.

Similarly for both livestock rearing and forest resource use due to the advancement in the scientific knowledge and technologies, there is a marked improvement in all aspects of production practices. For instance, the breeds of animals are better and health improvement services are available and in use by the farmers like medication and vaccination; and improved high nutritive value feed and fodders are available. In forest, commercial logging will require to observe riparian areas (forest area near river banks) for protection of rivers or stream from pollution; look at soil aspects for ensure soil stability for controlling erosion and land slides; road buffers to protect the roads and wild life corridors are kept for safeguarding wild life; and local water sources are identified and protected. These aspects were not there in the past.

The modern farming practices are based on sustainable farming principles that advocate environmental health and safety while pursuing economic benefit.

Box 1

A CASE STUDY

(This is a hypothetical case study.However, the problem facing the Sha Ngawangling community could be real).

As an example to demonstrate the concepts discussed in this chapter, a case study from a warm temperate zone, Sha Ngawangling, gives a clear picture of how the livestock, forestry and crops are interrelated and interdependent.

In earlier days Sha Ngawangling is a thriving community recalls 71 year old Aap Dorji. The community is known for its high quality rice and chili. Many traders from other parts of Sha and Thimphu came to Ngawangling for their much known chili and rice. Aap Dorji recalls those days during the crop season, the fields were lush green, both wet land and dry lands; people were very busy and traders passing by always appreciated the crops in their fields. According to Aap Dorji, labour was not a problem then. Wild pests are recent phenomena he mentions. He prides of the good breeds of *Jatsam* cows and bulls. He remembers the thick community forest from where they collected abundant mushrooms, fuel wood, fodder and bamboo for weaving baskets of various sizes. He says water, for both drinking and irrigation (dry land and wet land) was in abundance. There was never a case about water. Now, every crop season people fight because water is always scarce. Aap Dorji laments for having to graze his cattle in far distance due to shortage of fodder and for having to carry fuel wood while returning home in the evenings from such a distance.

Sha Ngawangling community is situated at 2400 m on a mountain slope facing south east. During a survey carried out in 1983, the total number of house hold was recorded as 34 with 221 individuals. Over the years the population has increased and so has the number of house holds. A survey carried out in 2005 recorded a total population of 355 individuals in 62 households. The average number of livestock including cattle, horses and pigs per household is 9.7, which have almost remained same. However, the total population of livestock has almost doubled from 330 in 1985 to 603 in 2005. As per the first survey the average land holding is 1.5 acres of dry land and 2.5 acres of wet land. This has been drastically reduced to an average holding of less than an acre of dry land and less than 1.5 acres of wet land per house hold due to land fragmentation.

Problems facing the community

Fifteen years before the project started, there were only 34 households with 221 individuals. In the past 15 years 28 more houses were built and 134 new individuals were added through marriage and birth. The total number of livestock more than doubled from 330 to 603 in the last 15 years. This has a direct bearing on the availability of feed and fodder.

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The forest area covering more than 3000 hectares have been drastically reduced to less than 500 hectares due to population pressure, both man and animal; and Tseri cultivation over the past years. The destruction of their resource base had triggered a chain of events leading to food insecurity and aggravated poverty in the community.

The age old practice of collecting NTFPs, particularly the mushroom varieties like Coral mushroom (*Bjichu Kangru*); Oyster mushroom (*Chama Shamo*); Chanterelle (*Sesey Shamao*); Shimeji (*Karshing Shamo*); and Black Wood Ear (*Bjili Namcho*) which were once very common is no longer seen. It could be surmised that the destruction of forest have led to creation of a new ecosystem that has been not conducive for the growth of the mushroom species available in the past.

Wild pests like monkeys, deers and wild boars have become a pest now causing crop damage. Combined with this problem, the water source has dried up significantly leading to insufficient water for paddy and chili cultivation leading to decreased land under cultivation and production. A significant portion of dry land and wet land are left fallow. Crop guarding during the season is one of their major concerns since it affects their house hold food security.

Over the years, the forest fodder have been foraged beyond the recovering capacity of the ecosystem that farmers are under increased pressure to collect fodder from further distance and even graze their cattle at a longer distance. This leads to over stretching the already limited labour at the farm.

According to the report a significant portion of their drylands and wetlands, 27% of dryland and 31% of wetland, were fallowed at some point of time due to wild pests and labour shortage. Additionally, over the years land holding per house hold has decreased by half due to land fragmentation.

Farmers report of poor animal health and shortage of feed and fodder. They also highlight on the problem of getting adequate leaf litters for generating farm yard manure (FYM) from their shrunken forest leading to decreased crop yield. They also attribute the decreased crop yield to the inadequate irrigation water due to the drying up of water source as a result of extensive deforestation due to timber and fuel wood extraction for the growing population. Over grazing by the increased livestock population had also contributed to the destruction of the forest as young tree saplings are either destroyed through trampling or through foraging.

Rural to urban migration have been reported. The reasons cited were food insecurity due to low crop yields (affected by many factors discussed above) and also because of low level of cash income. This has in turn affected the available family labour for crop cultivation and also good husbandry of livestock.

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The Daunting Development Task

Mrs. Yargay Lhamo, the Extension Agent (EA) of the Geog reported the situation facing Ngawangling to the Ministry of Agriculture (MoA). The MoA fielded experts from the Dept. of Agriculture, Dept. of Livestock and Dept. of Forestry. After the field study a Community Development Program was prepared in consultation with the Sha Ngawangling community. The program's main development activities highlighted on afforestation with mixed tree species including several fodder species; development of 1.5 acre pasture per house hold (a total of 93 acres); and developing irrigation system with protection of water source for bringing back the fallowed paddy land and dryland under cultivation. It also highlighted on educating the community through trainings; consultative discussions on the problems facing the community and working in partnership. The program was endorsed by the GYT as a priority and presented at the DYT. After endorsing through the DYT, the proposal was forwarded to the Ministry of Agriculture (MoA). The MoA mobilized a fund of US $ 350000.00 through FAO (Food and Agriculture Organization) and as per the proposal submitted.

Upon approval of the fund, as per the project plan, the MoA deputed a team of experts from Dept. of Forestry, Dept. of Live stock and Dept. of Agriculture to initiate the development activities. Under the technical guidance of the experts, and leadership of Mrs. Yargay Lhamo, over the project period of 3 years, an area of over 1500 hectares were planted with mixed fodder tree species; a total of 98 acres were brought under pasture; and the irrigation system developed supplied adequate water for bringing total paddy land under cultivation and also supply adequate water for dry land crops.

After a period of 7 years following the project, the community is prospering and now the farmers have abandoned Tseri cultivation and taken up protection of their forest resource very seriously. Since the ecosystem has re-established, the farmers are now seen collecting their most preferred mushroom species. Of late the Dept. of Agriculture has started an Organic Framing program for this community for Shiitake mushroom; straw berries; selected vegetables and red rice since they did not use any form of agro-chemicals. The Dept. of Livestock has planned for initiating an Organic program for milk and milk products.

Since the Extension Agent of the Geog, Mrs. Yargay Lhamo had rescued the community from man-made disaster, she has been awarded the Outstanding Extension Agent Award and now co-ordinates the Organic program for the community. Aap Dorji, now in his 80s is a staunch nature conservationist and is always seen advising younger generation on the importance of living in harmony with nature. He says, "respect Mother Nature, she will nurture you with all her blessings".

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("As we are part of an ecosystem and the keeper of it, we are wholly responsible for the health of our ecosystem. Forest being the natural resource base; can be called the womb of nature, destruction of a forest resources lead to disasters like the one presented in the case study. In many communities much of the forest resources have been depleted beyond the recovering capacity of an ecosystem, thus, creating a new ecosystem whereby a completely new species of flora and fauna predominates. The alteration of an ecosystem leads to altered ecosystem product. Such examples are in abundance. Students could do a project on topics, such as, **Ecosystem analysis** *of a community wherein, from an ecosystem's perspective, they write on the history of the community; the changes seen by the community over the past decade; their awareness; correction measures deemed necessary and taken up if any; and student's observation and analysis. As part of their Ecosystem analysis, with guidance from teacher, students could attempt to look at the plausible causes or factors contributing to an ecosystem's health and that which are detrimental to an ecosystem's well being."*

Challenges to Farming

Considering the geophysical features of Bhutan, it has both strengths and weaknesses, in terms of what we can and can not take advantage in agricultural production. As has been discussed, the mountainous ecosystem of the Himalayas have established unique micro-ecosystems that has bestowed great species diversity, both flora and fauna. For example, Bhutan is enlisted as one of the 10 global hot spots of bio-diversity with over 8000 endemic species of fauna and flora recorded. This means the bio-potential is huge for exploiting the comparative advantage.

The other aspect is the limitations posed by our geo-physical features as a result of the kind of topography that we have. For instance, the modern technologies like cultivation with heavy machineries and equipments are not possible. Even the area required for commercial scale production is limited. So the economy of scale can not be exploited. Given this geo-physical limitations, we must look at the prevailing farming practices and consider the limitations therein to bring out the opportunities for accelerating the farming revolution, which has been initiated few decades back.

Within this geophysical context we will see the challenges facing our farming community. Farming, as mentioned earlier, is predominantly subsistence oriented, featuring a mix of crop cultivation, livestock rearing and use of forest resources. The mixed farming system followed is an age old mechanism of guaranteeing house hold food self sufficiency, wherein a family's requirements for food, fuel and fiber comes from the farm. Farming practices followed, as a function of mixed farming system, is very much limited in innovation for producing surplus with market interest. On the contrary, a commercial farm is highly organized focusing on quantity and quality of produce for market. Therefore, with a view to break away from subsistence oriented mixed farming system to commercial scale farming, we shall look at those limitations where certain interventions could be made for converting the limitations into opportunities.

a. Socio-Cultural Limitations

1. Level of literacy

A very high percentage of our farming community is either not at all literate or have very low level of literacy. As a result awareness on technological options and market is limited. This has a direct impact on the level of reception of technologies for adoption. With their limited capacity to assess risk and opportunities for adopting a particular technology, for instance, investing for purchase of agricultural inputs like quality seeds, fertilizers, other agro-chemicals and equipments farmers rarely take the risk. With the improvement in the literacy rate of farmers, their risk bearing capacity; and awareness and want for information will increase. This will lead to increased adoption rate of available technologies which will in turn help the farmer target for producing surplus for market.

2. The subsistence nature of farming

Farming in Bhutan is still largely subsistence oriented with farmers producing enough for their family. Commercial agriculture is emerging slowly and is yet to make a break away from subsistence, where intensification with heavy technological inputs will be the bottom line. In subsistence farming, resources at the farm are allocated for various and varied farm activities, thus limiting focused production in a particular commodity. Therefore, the willingness from the farming community for taking up feasible commercial ventures combined with government support will help in the emergence of a profitable farm.

3. The inheritance system with regard to land

The inheritance system with regard to land has led to land fragmentation for generations making commercial agriculture very difficult. In the past it was a system of providing social security. For producing surplus that can be sold, a minimum area is required that will take care of family food security and produce surplus for market. A land holding that is below the minimum acreage required to produce surplus means cost per unit area is high resulting in loss. That translates into problems associated with household food insecurity. Land fragmentation presents such risk.

b. Technological limitations

1. Options available to farmers in various eco-zones

As presented earlier, due to the diverse agro-ecological conditions that Bhutan is blessed with, we have different micro-ecosystems specific to a locality. This means developing a technology suited for a particular locality is our biggest challenge as technology generation is time consuming and resource required is extensive. For instance, in the plains where altitude variation is only a few degrees, a crop variety that is developed for a particular ecological zone could be grown on millions of hectares of land. Therefore, generating suitable technologies for the varying eco-zones is a huge challenge.

2. Adoption of technological packages

The recommended technological packages for production of a crop or rearing a livestock are rarely taken up in totality. For example, a

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technical package for chili production might recommend row-to-row and plant-to-plant distance; number of weedings at critical periods; amount of fertilizers to be applied; number of fungicides and insecticides to be applied during critical periods are seldom followed. This could be attributed to the limited capacity, awareness and the subsistence nature of farming which entails sharing of limited resources over many activities.

3. Pests causing damage and losses

There is no one cure for all problems. Damage and losses caused by pests like insect pests, weeds, disease organisms and vertebrate pests like wild boars and monkeys have to be addressed by various means. The means for managing such problems are some times beyond the affordability of our farmers as much of our farmers are subsistence oriented. Credit or lending schemes are not favourable for farmers to make borrowing in time for taking timely management actions.

c. Institutional Limitations

1. Availability and Access to Agricultural Inputs

Access to our rural population is improving. Since the population is spread over mountainous terrain, the delivery and distribution system for agricultural inputs like seeds, fertilizers, other agro-chemicals, equipments and implements is a huge challenge. This has led to the problem of getting the required input in time in remote rural areas. The rural credit scheme for farmers is not favorable for taking a loan and the access problem has only added to the problem.

2. Access to Market for the surplus produce

Market and market network for both internal and external market is still at its infancy. The Access to market is one of the focus areas for Ministry of Agriculture for enhancing the growth of agriculture. Farm roads linking communities to population centers like towns and road links is one major task. Our population is scattered and connecting communities and villages involve very high investment requiring donors and financial institutes willing to provide the required fund. Fund mobilization is a very difficult task.

d. Farm Labour Issue

Rural to Urban Migration

The factor contributing to rural-urban migration is vast. It could be summed up as due to the combination of unfavorable situations existing in the rural areas combined with opportunities that are available in the urban area. Under such situations the existing younger generations, with improved literacy rate tend to move to urban areas. This calls for developing rural areas into a "life and living friendly" environment, where opportunities are created for the farming community for sustaining a good livelihood aimed at mitigating farm labor shortage problem.

e. Limited Environmental awareness amongst the farming community

Man-made disasters

Environmental awareness amongst our general public is low and much lower in the rural areas given their low literacy rate. In many instances, land slides and soil erosions are caused due to activity or non-activity of the farming community. For instance, farm activities like excessive timber extraction, over grazing, unmanaged farm run off (that includes irrigation water; water used

for domestic purposes; and rain water) and farming practiced (unterraced and unprotected dry land farming on steep slopes and Tseri cultivation leading to soil erosion and water management concerns) followed have led to land slides and soil erosion thus reducing fertility and area for production.

Box 2 *International Centres of Excellence (Additional information only).*

Under CGIAR (Consultative Group on International Agriculture Research), a partnership comprising 47 countries, 4 private foundations, and 13 regional & international organizations provide finance, technical support and strategic direction to the sixteen international Agree. Research Centers (ARC) that work as a global network. The ARCs include:

1. CIAT – Intl. Cent. for Tropical Agri. – for tropical crops, HQ based in Colombia with regional office in Lao PDR
2. CIFOR – Cent. for Intl. Forestry Res. – Forestry related research; HQ based in Indonesia
3. CIMMYT – Intl. Maize & Wheat Improvement Center – HQ in Mexico.
4. CIP – Intl. Potato Res. Cent.; HQ in Peru
5. ICARDA – Intl. Cent. For Argil. Res. in the Dry Areas - for wheat, barley and legumes; HQ in Syria
6. ICLARM – Intl. Cent. for Living Aquatic Resources Mgt. (also called World Fish Center) – for res. in fish; HQ in Malaysia
7. ICRAF – Intl. Cent. for Res. in Agroforestry (now called The World Agroforestry Center) – based in Nairobi, Kenya for carrying out research in Agroforestry
8. ICRISAT – Intl. Crops Res. Inst. For the Semi-Arid Tropics for legume crops; HQ in Hyderabad, India
9. IFPRI – Intl. Food Policy Res. Inst. HQ Based in Washington, D.C, USA for research in the fields of agriculture, livestock, forestry, fisheries, policy, and natural resources management
10. IWMI – Intl. Water Mgt. Inst. concentrates on water and related land management based in Colombo, Sri Lanka
11. IITA – Intl. Inst. Of Tropical Agri. - For development of technologies that reduce producer and consumer risk, increase local production, and generate wealth; based in Africa
12. ILRI – Intl. Livestock Res. Inst. – HQ based in Nairobi, Kenya and works in livestock research and development
13. IPGRI – Intl. Plant Genetic Resources Inst. – HQ based in Rome, Italy; works in plant genetic resource conservation and utilization for feeding the world population
14. IRRI – Intl. Rice Res. Inst. – HQ based in Los Banos, The Philippines; works in Rice research
15. ISNAR – Intl. Service for National Agril. Res. – HQ based in Addis Ababa, Ethiopia; works under IFPRI and its mandate
16. WARDA – West Africa Development Association (also called Africa Rice Center) – HQ based in Cotonou, Benin; works in rice varietal development

a. ISRIC – Intl. Soil Reference & Information Center – HQ based in Wageningen, Netherlands; works in soil research and provides world soil information
b. WMO- World Meteorological Organization – HQ based in Geneva, Switzerland; provides information world weather, climate and hydrology
c. ACIAR – Australian Center for Intl. Agri. Res. – HQ based in Canberra, Australia; works in agriculture crop research

Note: Intl. – International; Res. Research; Agril. Agricultural; Agri. – Agriculture; Mgt. – Management; Cent. – Centre ; Inst. – Institute; HQ – Head Quarter

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Box 3 (Additional information only).

Some Demographic Information

Total Population – 672425
Resident Population – 634,982
Floating Population – 37,443
Urban Population – 196111 (30.9%)
Rural Population – 438871 (69.1%)
Total Male Population – 333595 (52.5%)
Total Female Population – 301387 (47.5%)
Male to Female ratio – 111 males: 100 females
Population Growth rate – 1.3%
Literacy rate (>6 years) - 59.5%

3 most populated Dzongkha	*3 least populated Dzongkha*
Thimphu – 98,676 (15.5%)	Gasa – 3116 (0.5%)
Chhukha – 74,387 (11.7%)	Haa – 11,648 (1.8%)
Samtse – 60,100 (9.5%)	Pemagatshel – 13,864 (2.2%)

Source: Population & Housing Census of Bhutan, 2005

National Poverty Line – Nu. 740.36 Per month; Population below poverty line – 31.7%

- 38.3% rural and 4.2 % is urban population is below the poverty line

Source: Poverty Analysis Report of Bhutan, 2004 (NSB)

Box 4 (Additional information only).

Definations: (from *G. V. GUENAT, 1991)*

1. *Subsistence Farming – in a very strict sense, is defined as farming with no interaction with markets. Nothing is sold, and nothing is purchased, consumption is based only on own production. No marketable surplus is generated.*
2. *Traditional Farming: The term traditional farming should not viewed static and backward, as there is dynamism and changes that take place within the traditional farming. The difference between the traditional and the modern farming is the objective of farming and ass a result the focus on production.*
3. *Level of Market Integration of our farmers is best described by G. V. GUENAT, 1991 (Doctoral thesis – The Transformation of Traditional farming in selected areas of central Bhutan). He quotes Ellis (1988) who claims that "the peasant populations (meaning farmer populations as we refer in Bhutan) occupy the margin of the modern world economy. With one foot in the market and the other in the subsistence they are neither fully integrated into that economy nor wholly insulated from its pressures."*

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Questions and activities.

1. What is a farming system?

2. Identify the farming system prevalent in Bhutan and discuss the nature of the farming system practiced.

3. List the different types of production system based on land use types.

4. Within each production system identify the main crops grown.

5. What is a cropping pattern?

6. Discuss the main cropping patterns prevalent in Bhutan and underline how a cropping pattern affects crop management.

7. What is a farming practice?

8. Attempt to analyse and discuss on farming practices followed in a particular crop in Bhutan.

9. Comment on the farming practise followed and suggest any improvements that can be brought about.

10. List the agro-ecological zones.

11. Under the different agro-ecological zones identify the most predominant production system.

12. Under each agro-ecological zone:
    a. Identify one activity that contributes most to the family food security;
    b. Discuss the opportunities for enhancing the economic returns without endangering the environmental health and safety from the activity identified.

13. Discuss the opportunities and challenges in agricultural development in Bhutan.

14. From the Case Study, identify and discuss on the main cause of the disaster facing Sha Ngawangling.

15. Discuss on the lessons learned from the case study.

16. Elaborate on the inter-dependence of farming and protection & conservation of an ecosystem.

17. Discuss on:
    a. The impact and implication of population (man and animal) on natural resources

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Chapter 9

THE GROWTH OF INDUSTRIES

KEY IDEAS

Pre-Modern Industries
Modern Industries
Tourism

In previous courses in geography, you learned about the three different sectors of industries – primary, secondary and tertiary. As you may remember, industries that have direct involvement in collecting raw materials fall into the primary sector. For example, agriculture and mining are primary industries. Manufacturing industries that process raw material, causing it to undergo a physical change, are called secondary industries. Retail dealers, restaurant and hotel managers, transporters, tourist agents, bankers, teachers and doctors are all engaged in **service industries** and are thus a part of the tertiary sector.

In this chapter, we shall look at how modern secondary and service industries have developed in Bhutan. But before discussing the coming of the modern industries, we shall take a look at the pre-modern industries.

Like any other country in the world, Bhutan's industrial history can be divided into a pre-modern and a modern period. The modern period began in the late 1950s, a few years after the 3rd Druk Gyalpo ascended the Golden Throne in 1952. The tradition of manufacturing goods at home, for family use and for barter, that prevailed in the pre-modern period also continues to be practised in many parts of the country today.

Pre-Modern Industries

During the long period of isolation which lasted until the beginning of the 1960s, the economic development of Bhutan remained limited mainly to agriculture. The main function of the manufacturers was to provide tools and other household needs of the farmers and their families. That is why the small manufacturing units were dispersed throughout the country. Some of the popular pre-modern industries are discussed below.

Textile Works

Home based textile work has been a popular industry in this country for a very long time.

Figure 9-1 Examples of two craft works carried out in the country. These items have earned their right place and value in the modern day market and encouraged further development of our traditional craft works.

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Much of the work of sorting, cleaning, spinning and weaving was performed by women, along with much of the other farm work. The types of clothes they wove depended on the raw materials available. For example, in Bumthang, parts of Mangde valley and in the high altitude settlements, like Merak, Sakteng, Dur, Busa and Sephu, people raised sheep and so they were engaged in woollen textile production. In many parts of eastern Bhutan and in the Kheng valleys, people cultivated cotton as an annual crop and thus made cotton clothes. In the Samdrup Jongkhar and Orong areas, they also raised silk worms and made cloth from raw silk called **bura.**

Most materials used in weaving was available locally. The yarn and dyes, which are used to make the cloth and the wood and bamboo for the looms, are also found within Bhutan. The textile industries in the kingdom are still home-based except for two small-scale factories in Phuntsholing. Home-based textile production is mainly for household use although some of the cloth is also sold. In the past, a part of the cloth people produced was used to pay government taxes.

In spite of the stiff competition from cheaper factory-made cloth, traditional hand-woven cloth has maintained its great popularity throughout the country. The beauty of the intricate patterns has made Bhutanese weaving famous throughout the world.

Bamboo Works

Besides producing textiles, the people of Kheng use bamboo to make baskets, hats and other useful kitchen items. Skilled basket makers can be found in both the foothills and the high altitude regions. Although the raw materials used and the type of baskets made differ, the people in both regions barter their goods for cereals and other agricultural products with people from other parts of the country. Nowadays, many baskets are also made for sale in markets such as the ones in Thimphu.

Wood Works

Owing to the abundance of forest resources, wood work has always been an important craft of the Bhutanese. Different types of wood are used to make tools, containers and decorative items. Almost every farmer knows how to make the wooden tools needed on the farm. There are some very specialized crafts people in eastern Bhutan are skilled in. They use lathes to make beautiful cups and bowls. Cups called **dza-shing phob,** made from nodules found mainly in poplar, maple or wormwood, are very popular among Bhutanese people. A cup made of *dza-shing* may cost as much as 5000 Ngultrrums. Other popular kinds of wood work are the decorative wood carvings which embellish buildings, and the carvings of xylographs or printing blocks.

Desho (Traditional Paper)

Desho is the traditional paper made in Bhutan. Paper making in this country is a living tradition. It is not known for how long *desho* making has existed in Bhutan, nor do we know who introduced the skill. But when Samuel Turner visited Bhutan in 1783, he found *desho* making a well established tradition and he described desho as the strongest paper he had ever seen. The biography of Guru Padma Sambhava mentions that during the 8th century A.D. Bhutan exported *desho* to Tibet.

Desho is made from the bark of daphne, commonly known as **de shing.** It is a plant with fibrous bark. It grows at elevations between 1200 and 3000 metres above sea level and is found across the entire country.

Basts are removed from the daphne plants and cut into short pieces. The basts are soaked, cleaned and cooked and then beaten into a soft pulp. The pulp is mixed with water and then spread over a mat covered by cotton cloth. The mat is then

shaken from side to side until the pulp is evenly spread. It is then dried by the sun and wind.

Due to its strong fibre, desho is mainly used for important documents and religious scripts that need to be preserved for ages. Nowadays, it is also used for wrapping parcels and gifts.

Desho making has now assumed a commercial scale in Thimphu and Tashigang. There is increasing market demand for this traditional paper and it is now being exported to a few countries such as Japan. Unlike paper making industries in other countries the process of making *desho* does not use any chemicals that could cause environmental pollution.

Iron and Gold Smithies

Sometime around the 8th century, Sendha Gyap of Bumthang is said to have built an iron castle at Chag-khar on the bank of Chamkhar Chu. One of the 84 Buddhist Siddhas, known as **Drubthob Chagzampa,** who visited Bhutan 12th or 13th century, is said to have built seven iron bridges in this country. This suggests that the tradition of working with iron in Bhutan goes back many centuries.

Iron, silver and gold smiths have a long history in Bhutan and their traditions are now embedded deeply in our culture. In our country, crafts such as wood and metal working are considered professional occupations open to any person with sufficient interest and talent. These crafts supplied utensils, tools, weapons and ornaments to various people according to their needs. The skills of these crafts people and their work continue to be in demand and are highly valued.

A person who possessed the skills of all the crafts described above and other such as painting, sculpting and carpentry used to earn a high regard in our society in the past. They are collectively known as *Zorig Chusum* (the 13 crafts). The 15th century saint Pema Lingpa and Zhabdrung Ngawang Namgyel in the 17th century, were amongst the few who achieved all the 13 skills. These are also traditions that all Bhutanese feel proud of and thus they make every attempt to ensure their continuity.

Figure 9-2 Left, daphne plants; Right, beating cooked basts into pulps.

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Questions and Activities

1 List the items at your home that are made from the following materials and are manufactured using pre-modern technology
Wood Bamboo Iron Textile

2a Why do we call some industries pre-modern and some modern?
b Which industries are pre-modern?

3a Ask the other students in your class which industrial sector their parents' work falls into. Find the total number engaged in each of the sectors.

Primary	Secondary	Tertiary
?	?	?

b Calculate the percentage engaged in each of these sectors.

4 Consult the latest statistical year book and find out the percentage of people involved in different sectors of industry.

5a In which part of Bhutan are most people engaged in textile works?

Field Study

Visit a family in a town or in a village and study the textile crafts in which members of the family are engaged. Write a small report to present your findings clearly. Use the following format to collect information.

1 Study the raw materials, process and products.

2 Study the tools used in the process.

3 Calculate the following:
a cost of raw materials;
b cost of labour for collecting, sorting, washing, dyeing, weaving, etc; and
c cost of final products at market rate.

4 Add all the money spent and subtract it from the gross total.

5 See if the family is making a profit or running a loss, and by how much.

6 Where is the product sold?

7 What percentage of the family's income comes from selling textiles?

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Modern Industries

Heavy machinery came to Bhutan only after 1961 when the construction of the National Highway or **Zhung Lam** from Phuntsholing to Thimphu and Paro began. The motor road made it possible to transport heavy machines from India. As road transport has expanded over the past 30 years, the number of factories has grown steadily. The reasons for industrial development in Bhutan are many. Some of them are:

a To increase the people's level of income, which then increases their ability to purchase goods and services, leading to economic growth.

b To encourage entrepreneurship among as many people as possible.

Region	L	M	S	C	Tot
A	3	1	74	419	497
B	30	37	76	56	199
C	2	0	19	61	82
D	0	0	6	62	68
E	3	5	5	57	70
F	0	0	4	65	69
Total	38	43	184	620	985

Region A: Thimphu, Paro, Haa, Punakha, Wangdue and Gasa.
Region B: Chukha and Samtse.
Region C: Sarpang, Tsirang and Dagana.
Region D: Trongsa, Zhemgang and Bumthang.
Region E: S Jongkhar and P Gatshel.
Region F: Trashigang, T Yangtse, Mongar and Lhuentse
Scale:L= Large M = Medium S = Small C = Cottage

Table 9-1 Number of industries by scale (Production and Manufacturing) in 2005.
Source: Dept. of Industry, December 2005.

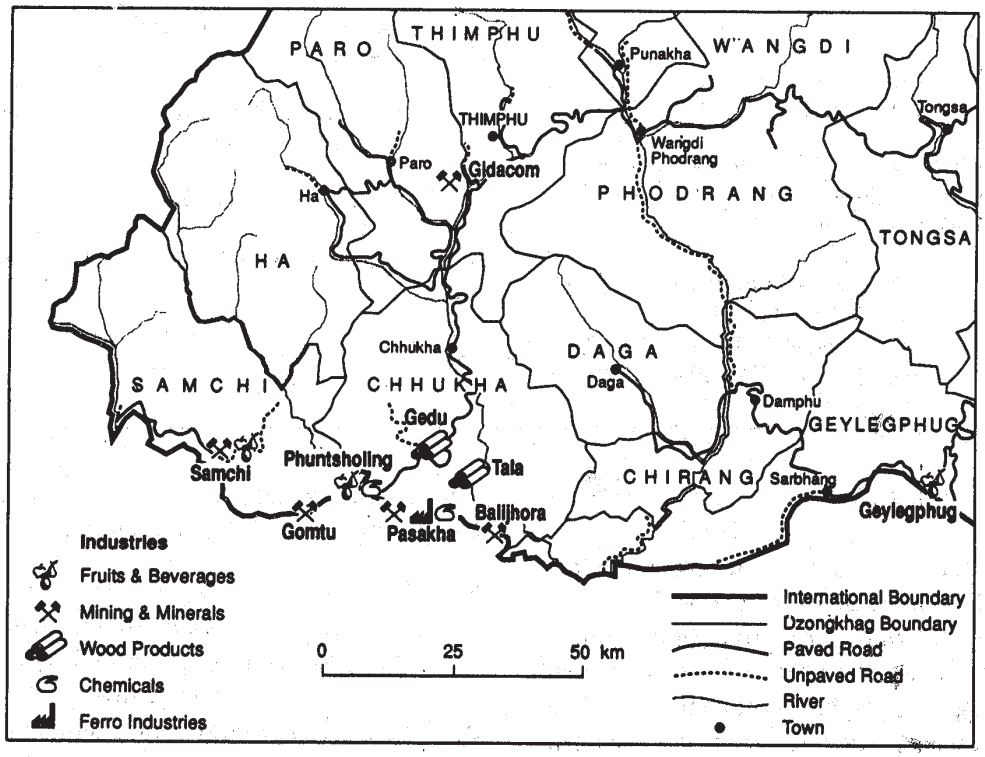

Figure 9-3 Map of south-western Bhutan showing the location of BBPL and BCCL.

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c To produce goods of good quality by using local materials, so that they can be sold abroad.
d To help reduce our dependence on imported goods.
e To create jobs for people who are unemployed.

Distribution of Industries

Table 9-1 shows that most large scale industries are located in Region A. There are several factors that have led to the concentration of industries in this area.

Firstly, the national highway helps in transporting bulky machines and raw materials to the factory sites. Secondly, the hydroelectric power (HEP) station at Chukha has become a reliable source of power to run the machines in the factories. Thirdly, the communication facilities developed in this region before they did in any other area, and this helped our industrialists to contact partners in different parts of the world. Phuntsholing, which serves as the terminal point to this region, is accessible from India by road, railway and by air.

As the transport system, the communication system and the power supply are further developed, industries will grow in other parts of the country as well, using as yet untapped resources.

In the previous class, we discussed what factors determine the location of an industry. An individual person, a company, or the Government finally makes the decision as to where a factory should be located. They usually consider factors such as the supply of raw materials and labour, transportation, power supply and the location and size of the market for the finished goods.

Two of Bhutan's largest industries are Bhutan Board Products Limited at Tala and Bhutan Carbide and Chemicals Ltd. which is located in Pasakha. The case studies of these two industries in Boxes 9-1 and 9-2 and Figure 9-3 clearly show how the above factors have influenced the decision makers to locate these factories at their present sites.

Questions and Activities

1 Read the case study of the Bhutan Board Products Limited in Box 9-1 and answer the following questions.
   a What factors helped to determine the location of the factory in Tala?
   b How does BBPL attempt to reduce its impact on the environment during the extraction of raw materials?
   c How do you think this industry will benefit the locality in which it is situated?

2 Read the case study on the Bhutan Carbide and Chemicals Limited in Box 9-2. Why is the location of BCCL factory advantageous to the company?

3 List the factors that have led to the concentration of large scale industries in Region A.

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Bhutan Board Products Limited
A Case Study

Bhutan Board Products Limited is the first manufacturer of wood based **graded particle board** within the South Asia region. It is capable of producing 80 cubic metres of particle board with an average thickness of 18 millimetres everyday, using German technology.

Site construction began in 1983 and the factory went into commercial production in 1990. This factory is located at Tala, some 5 kilometres off the Phuntsholing-Thimphu Zhung Lam. It was a joint venture between the Royal Government of Bhutan and H&K company. Over Nu. 235 million has been invested in this enterprise.

Location

A very important factor in deciding to locate the factory at Tala was the site's proximity to the large forests. The plant does not require good grade wood for its raw material. In fact, BBPL can use the branches, twigs and poor quality logs which would normally be wasted as they cannot be used in the production of lumber. Presently it uses waste wood from Gedu Wood Manufacturing Company just 8 kilometres away, as well as some wood from the Paro and Thimphu areas.

The factory is also very close to the main power line that takes the hydroelectric power from Chuka to Phuntsholing. It is only about 50 kilometres from Phuntsholing, which makes the distribution of the products to India, its main market, relatively easy.

The Process

Logs are first washed, then cut into chips, which are further cut into smaller **flakes.** These are dried to reduce moisture content. The dried flakes are then sorted into two sizes – fine and coarse. The finer ones are used for making the surface layer of the board and the coarser flakes make the core layer of the board. These sorted flakes are then mixed with resin and spread into a **mat** in three layers. First, a fine layer is spread, then a layer of coarser flakes, again followed by a layer of fine flakes. The mats are hot pressed, cooled, sanded and laminated. These are allowed to dry for 3-4 days and are then ready for sale.

The Market Value

The value of products that come out of the factory can be increased if they are processed further. The particle board is used for manufacturing furniture, house panels and chalk boards in schools. The sale price is less if the products are sold just as particle boards. However, the company also has a ready-to-assemble furniture unit in Pasakha. By selling the finished goods, for example, boards already cut into the required sizes and shapes and ready to assemble as furniture at their destination, the company increases the value of the boards.

BBPL and the Environment

BBPL owes its existence to nature and pays careful attention to the safeguarding of the forests. More than a million saplings are raised in a nursery. The company has been given 3000 hectares of forest land around the factory at Tala. Each year, 300 hectares of forest land will be cleared and replanted with 100,000 new saplings of willow, conifers and deciduous trees. In the tenth year, when the last 300 hectares of forest is cleared and replanted, the first tract of land will be ready to cut. Thus a sufficient supply of raw material will flow in a cycle from the 3000 hectares of land.

Besides, unwanted trees, branches and fallen logs cleared from the forest can also be used by the factory, keeping the forest in good condition and reducing the chance of forest fires. It is thus a self sustaining scheme.

Employment and Ownership

As per the Subscription Clause of the Articles of Incorporation (AoI) submitted by BCCL the following is the pattern of share holding by respective share holders (BBPL).

Share Holder	No. of Share	% of Share
The Royal Government	628,334	44.88
The Bank of Bhutan	172,400	12.31
H & K Company	48,000	3.43
The Monastic Body	70,330	5.03
Army Welfare Project	40,000	2.86
BBPL Employees		
41,990 3.00		
RBA	29,700	2.12
Others	369,260	26.37

Box 9-1 Bhutan Board Products Limited. An example of wood based industry. Source: BBPL, September 1992 and Dept. of Industry, 2006.

Bhutan Carbide and Chemicals Ltd.
A Case Study

The Product
Calcium Carbide (CaC_2) is a chemical compound. It is usually grey or reddish brown in colour, depending on the impurities it contains. The commercial grade limestone must contain at least 77% CaC_2.

Raw Materials
This is the first chemical industry in the kingdom. Most of the major raw materials required to make calcium carbide are found in Bhutan. The calcium comes from the local deposits of limestone and most of the carbon comes from charcoal produced from the forests. BCCL is the largest industrial wood user in the kingdom. However, since the supply of charcoal is not enough to meet the demands, the company requires other sources of carbon. This additional carbon is obtained from raw petroleum coke, Meghalaya soft coal, or soft low volatile coal.

The Use of Carbide Chemicals
Calcium Carbide is used in the manufacturing of acetylene gas, which is used for cutting and welding of metals. It is also used in the production of Polyvinyl Chloride (PVC), acetylene black used in dry cells, and for removing sulphur from steel. Sometimes, it is used to artificially ripen fruit. The company exports most of the product to India, and some of it goes to Bangladesh.

Location
The factory is located in Pasakha. It is easily accessible to India by motor road and it is close to the sources of the raw materials. Limestone is extracted from Hauri Khola in Samtse Dzongkhag, and charcoal comes from individual contractors in the area. The other raw materials such as petroleum and coke are imported from Assam in India at present because there is an insufficient supply of charcoal in Bhutan.

To supply the future charcoal needs of the factory, the company has started planting an area of 350 hectares in Samdrup Jongkhar. Once, there is a sufficient supply of moisture free charcoal in the kingdom, import of petroleum coke will not be necessary.

BCCL and the Environment
The production of charcoal from the 350 hectares of forest area will ensure self sufficiency. Another problem is pollution in the form of dust emitted from the factory. The management is preparing to fix a dust absorption plant, which will suck in all the dust emitted in the production process.

Ownership
As per the Subscription Clause of the Articles of Incorporation (AoI) submitted by BCCL the following is the pattern of share holding by respective share holders.

Share Holders	No. of Shares	% of Shares
1 Dasho U. Dorji	26,440	26.44
2 Dasho Topgyal Dorji	8,520	8.52
3 Dasho Wangchuck Dorji	8,520	8.52
4 Bank of Bhutan Ltd.	15,845	15.845
5 RICBL	18,137	13.137
6 Other Shareholders	22,538	22.538

Box 9-2 Bhutan Carbide and Chemicals Ltd.
Source: Kuensel, Vol. VII No. 25, June 27, 1992, Management of BCCL, Sept. 1992 and Dept. of Industry (2006).

Figure 9-4 BBPL factory in Tala

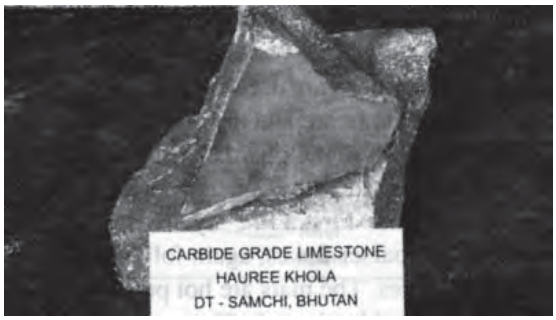

Figure 9-5 A raw material used by BCCL

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Service Industries

Service industries are growing quickly throughout Bhutan. New schools, shops and banks are opening and more telephones are being connected in towns and villages every year. However, one of Bhutan's most important service industries in terms of income is **tourism.**

Tourism

Travel has always been an important part of human activities. People travelled mainly to look for land, food, shelter and opportunities for trade. Now that many people work in offices and have three or four weeks of holidays a year there is a new reason to travel. People travel for enjoyment. They travel because it is a pleasant way to fill their leisure time. People travelling for this purpose has given rise to an industry called **tourism.** Tourism involves those activities undertaken by people who stay away from home for 24 hours or more on holiday. The development of tourism mainly depends on three factors:

- Attractions
- Accessibility
- Adequate service infrastructure

Countries and regions hoping to encourage tourists to come to their area must have something special that will attract people. These attractions must also be widely advertised so that people come to know about them. Different things attract different people. Some people are interested in resting in the sun at a luxury resort after a hard year at work, while others either want activity holidays to stretch their muscles, or cultural activities to stretch their minds. Because of its rich cultural and natural heritage, Bhutan attracts tourists in the latter categories. Tourists come to Bhutan to trek through areas of pristine natural beauty as well as to learn about its unique culture by visiting dzongs, villages, festivals and religious sites.

Accessibility is very important. Tourists must be able to get easily from their home country to the area that they are visiting. As most tourists have only two or three weeks of holidays a year, it is very important that they are able to access the area they wish to visit quickly and efficiently. Since Druk Air, the carrier of the kingdom's flag, expanded its services to include connections to Calcutta, New Delhi, Dacca, Kathmandu and Bangkok, access to Bhutan for tourists has been greatly improved.

Once inside a country, there must be a well developed service infrastructure so that the tourists will have adequate accommodation, food and transportation during their visit. Tourist organizations usually spring up in the locality to provide such services. In Thimphu alone more than 30 travel agencies and 10 tourist hotels have come up during the last 20 years.

Impact of Tourism

Although there are a number of benefits to having tourists come to Bhutan, tourism can have a negative impact on the country unless it is very carefully managed. The Royal Government is aware of this fact and has set its policies accordingly. Since the opening of Bhutan to outside visitors in 1974, tourism in this country has always been controlled. Less than 3,000 people visit Bhutan annually.

One of the biggest concerns is that tourism may cause the desecration of religious shrines and images. The significance of religious images to the local people is different from what they are to those who are visiting. While the tourists make the best out of what they pay for their visits they may unknowingly, and sometimes knowingly, cause offence by taking photographs or smoking in areas held sacred by the local people. They probably do not realise the impacts of photography of

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sacred objects and these end up in books or magazines that may eventually go into the waste bin. It would be seen as a desecration of the holy object. Because of this concern, the government has restricted the tourist entry to the most sacred temples and monasteries.

Another major concern is the environmental impact of tourism. It has been calculated by some environmentalists that if 15 people travel for 15 days, they need a supply of 80 kilograms of food as well as many other items. Of this, 25 kilograms is waste and will probably be thrown away around the camping sites. It has been found in Nepal that the solid waste left behind by the tourists has littered the otherwise beautiful mountains.

Tourism also has a cultural impact. People are exposed to different food and ways of life including dress. This could change their attitude towards their local traditions. However, tourism can also enhance the interaction between people from different countries and cultures. People learn from each other as they share their experiences. This interaction among people and sharing of experiences helps promote global understanding in a world that becomes more interconnected everyday.

Year	**Total Arrival**
1999	7158
2000	7559
2001	6393
2002	5599
2003	6261
2004	9259
2005	13626
2006 till Oct.	14414

Table9.2: Arrival of tourist between 1999 to October 2006
Source: Dept. of Tourism

Epilogue

A country is considered industrialised if more than three quarters of its population is engaged in secondary and tertiary sectors of industry. Employment of large numbers of people in these two sectors is one of the main features of developed countries. Like most of the developing countries, Bhutan's employment pattern is the reverse of that in industrialised nations. While agriculture remains the basis of our economy, industrial development must take place to support this. At the same time, it is also equally important to promote the traditional crafts in the villages.

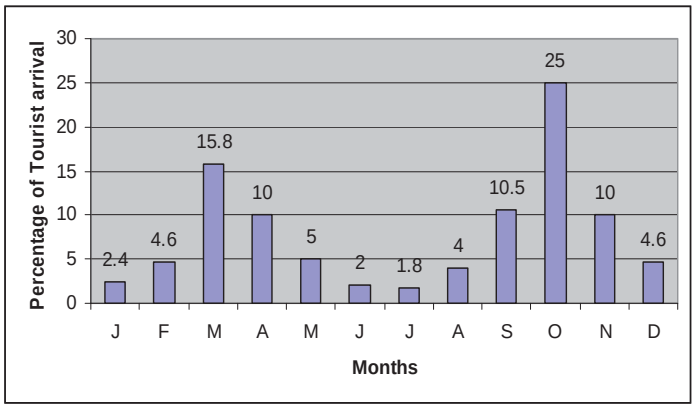

Figure 9-6 Arrival of tourist by seasons., Source: Dept. of Tourism

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Questions and Activities

1a Make a list of things that will attract tourists to your local area.

b Write an advertising that could be read on a radio programme to advertise these attractions.

c What service facilities are available in your area for tourists? Are there enough services for the present demand?

d What positive and negative impacts have tourists caused in either your local villages and towns?

2 Study Figure 9-6

a What does the graph tell us about the arrival of tourists in the country?

b Why is that the line indicates low arrival in some months?

3. a. There is a dichotomy between promoting tourism and preserving environment. How can you reconcile the two?

b "The lack of interest among the youth in the *Tshechu* was a cause of concern for many elders attending three day Wangduephodrang *Tshechu*" which concluded quite recently. The youth prefer to attend the fair rather than watch the Tsechu" (Kuensel September 25, 2004. Page 4). With reference to the above statement explain the reasons why the youth are losing interest in Tsechu? Suggest a few measures so that our youth will take interest in the *Tsechus*

Summary Activities

1 Write definitions for the following important terms found in the text:
- Service industries
- tourism
- market
- capital

2 What has given rise to the development of modern industries in Bhutan?

3 What conditions are considered before the site for a factory is chosen?

4 Study Figure 9-7 and then write an essay that discusses the differences and similarities between pre-modern and modern industries in Bhutan.

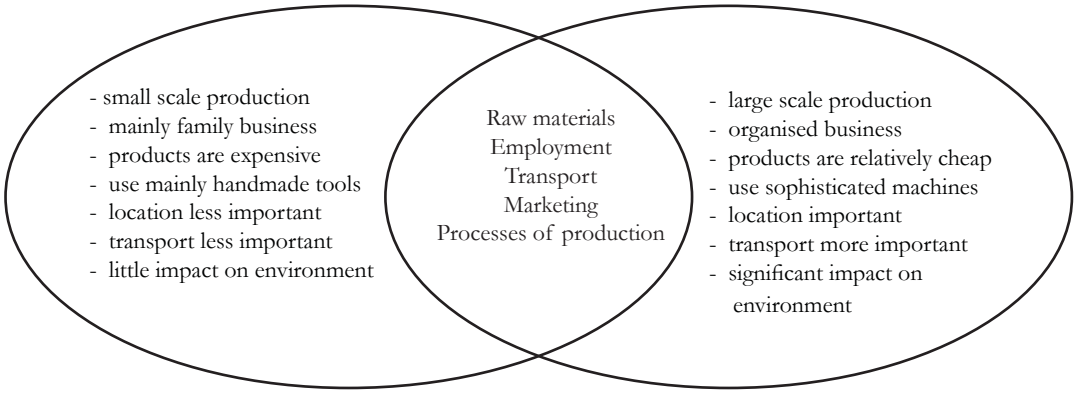

Figure 9-7 A comparative diagram of pre-modern and modern industries in Bhutan

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Chapter 10

SOURCES OF ENERGY

KEY IDEAS

Energy in Early Days
Types of Energy
Generation of Electricity
Alternative Sources of Power
Future of Power in Bhutan

In this chapter, we will be discussing the sources of energy that provide us with heat, light and power to run our vehicles, office equipment and industrial machines.

We begin with a brief look at energy use in early village homes. Then we will consider the present day sources of energy. Next, we turn to look in detail at the history of Bhutan's electricity generation, which started less than twenty years ago and the tremendous impact the Chukha hydro-power station has had on the country. Finally, we discuss other alternative sources of energy that could be of importance to our kingdom in the future.

Energy in the Early Days

Before the generation of hydro-electricity, our people used dried bamboo torches for outdoor light and *mebchi* (pine wood) for indoor light. The mebchi gave poor light and much smoke which made the homes unhealthy.

In pre-modern industrial activities, humans and animals provided the main source of power. A woodworker would need the help of another person to move the **lathe** and a blacksmith would need to use one of his hands to blow the coal fire, using the leather **bellows** (see Figures 10-1 and 10-2).

Figure 10-1 A wood worker using the legs of a helper to set the lathe in motion

Figure 10-2 A blacksmith using bellows to produce heat from his coal fire

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The 1950s and 1960s saw kerosene lanterns used in schools and offices and in a few village homes. But transporting kerosene all the way from the border towns to the interior of the country was difficult and expensive.

Thirty years ago, there were no motor roads nor buses or trucks. Pack animals and people carried all the needed supplies. The journey sometimes took a very long time.

Types of Energy

We use many different types of energy in Bhutan today. We use liquid fossil fuels such as diesel, petrol and kerosene. Diesel and petrol are mainly used for vehicles. However, in some places diesel is still used to generate electricity. Kerosene is used in stoves, room heaters and lamps to provide heat and light. Liquid fuels are not found in Bhutan and we have to import them from India. They are also difficult and dangerous to transport.

We also use solid fuel. As in the past, the main types of fuel we use for cooking and heating is wood. In Bhutan, 97 percent of our people depend on wood for heat energy. We are one of the highest consumers of fuel wood on a per capital basis in the world.

In towns and cities of Bhutan, it has now become popular to cook on gas stoves. In 1993 it was reported that in Thimphu more than 100 cylinders of gas were sold each day. Gas is cleaner and easier to use than wood or kerosene but we also have to import it from India. Gas stoves are also more expensive than other types of stoves.

Energy from water has been in use for a long time in this country. Prayer wheels and flour mills are still run by water in many parts of the kingdom. Now the energy produced by running water is also being used to make hydro-electricity.

Generation of Electricity

Electricity can be produced from a number of different forms of energy. Figure 10-3 shows the percentage of Bhutan's electrical power produced from each source of energy. As we can see, water power is the single most important source of energy for electric power used to account for only half of the country's electrical production in the early 1980s. In 1982, for example only 3.45 MW of electricity was produced from six micro-hydel power stations and 3.05 MW produced from seven diesel power stations.

Now, we have 1020 MW Tala HEP, 336 MW Chukkha HEP, 64 MW Basochu HEP and 60 MW Kurichu HEP. However, there still are diesel power stations and micro-hydel stations generating electricity.

Electricity is useful to us in many different ways. It provides heat and light to our houses and streets at night. It also runs the machinery in our offices and factories. Without electricity, we would have to continue depending on fuel wood, as in the past, or on imported fossil fuel. Hydro electricity has two great advantages over oil and wood. First, it does not emit pollutants into the atmosphere. Secondly, running water is a renewable resource available abundantly in Bhutan.

Electricity from Diesel

Several towns are provided with diesel powered engines to supply electricity to offices and schools. But generation of electricity from diesel involves constant supervision, transportation of fuels and maintenance, and as such, this system has become unpopular. Even so, in 1989 the electricity produced from diesel was 4.8 MW, an increase of almost 7 percent from 1982. Now, diesel as a source of energy has gone up to 16.404 MW.

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Potential for Hydro-Electricity

The torrential rivers and streams, that drop from an altitude of more than six thousand metres to about two hundred metres within a distance of less than a hundred and fifty kilometres, provide us with a great potential source of energy. This has been estimated to be approximately 20,000 MW. Even though we have tapped only a small amount of this enormous potential, it is more than meeting our present needs. The hydro-electricity from Tala, Chukha, Basochu , Kurichu and the other power stations in Bhutan is now running our factories, lighting all the towns and many villages. This is only 27.5 percent of the total tapped energy. The other 72.5 percent is sold and exported to India.

Hydro-Electric Power (HEP)

Hydro-electric power is produced by dropping water from a great height through large pipes called **penstocks**. When water drops from great heights, it has tremendous force which sets the turbine or **rotor** in motion. Field poles are mounted on the rotor, which rotates inside the **stator.** The movements of the field posts in the stator produce electricity. How power is produced at the Chuka power station is further discussed in Box 10-1.

Questions and Activities

1 List the advantages and disadvantages of the method used to light houses in the olden days.
2 Write a short account, describing how wood workers move their lathes.
3 Why is generation of electricity important to us in Bhutan?
4 List the difficulties in generating electricity from diesel oil.
5 With the help of your physics teachers, describe how water energy is turned into electric energy.

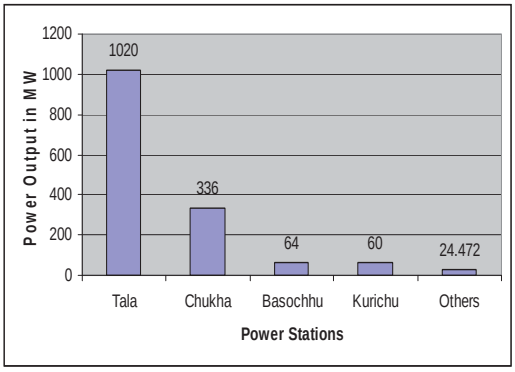

Figure 10-3 Energy produced by major Hydel and other Electric Power Stations in Bhutan.
(Source: Department of Energy, 2006)

Figure 10-4 A micro hydel power station. The perfect energy transformer for rural country side.

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Alternative Sources of Power (Wind Power)

Besides running water, wind and sun are also continuous sources of energy. As discussed in the chapter on climate, there is a large contrast in temperature between the deeper valleys and the surrounding high mountains. The morning sun warms up the air in the valleys, causing it to expand and rise. The cold and heavy mountain air rushes down the valley to take the place of the displaced air, creating strong winds.

These strong winds are a great potential source of energy, which can be harnessed to produce electricity to light many houses. This has been done in Bumthang. Wind energy can also be harnessed to pump water from the rivers to irrigate the fields. This is especially important for Bhutan as many of our farms are located at elevations that are higher than the river beds.

The use of wind energy to pump water from the rivers can be an appropriate technology for use in Bhutan. At the moment, a lot of labour and resources are used in building and maintaining irrigation channels. **Windmills** such as the one at Wangdi Phodrang, which draws up 2000 gallons of water in an hour and costs almost nothing in maintenance, can improve Bhutan's irrigation system in the future.

The Story of the Chukha Power Station

At present, there are ten major HEP stations in Bhutan, of which Chukha is the largest. The HEP station at Chukha was built with assistance from India. Preliminary investigation of the river flow, and its reliability through different seasons, and the study of rock structure for tunnels and dams began in 1961. The result of the studies showed that the Wang Chu alone has the potential to produce about 3000 MW of electricity, and that the HEP station at Chukha could generate 336 MW.

The Chukha HEP station is located on the left bank of the Wang Chu on the Phuntsholing-Thimphu national highway. It is a run-of-the river scheme. The Wang Chu is first stopped at a **diversion dam** below Tsimakothi town and then taken by a **head race tunnel,** dug out of solid granite rocks, more than 6 kilometres to a point above the power station. From there the water is dropped down to the power house through a pressure shaft tunnel called **penstock.**

There is a **desilting chamber** attached to the head race tunnel near the diversion dam through which any silt, sand and pieces of wood are flushed back into the river. Without this facility, the river load would damage the turbines in the power house.

The power house consists of an underground cavern hollowed out nearly 400 metres inside the face of the cliff. Within this chamber there are four turbines, each having a 84 MW capacity. The water from the power house runs out through a **tail race tunnel** and joins the Wang Chu, nearly a kilometre away.

The electricity generated from the power house is then taken to the **switch yard** located near the ruined Chukha Dzong. From the transmission system at the switch yard, a double and a single line of 220 KV transmission lines take the power to India. One 66 KV line to Phuntsholing and another to Thimphu to distribute power for domestic use.

The Chukha HEP station was built at an enormous cost of Nu. 430 million. Over 200,000 metric tonnes of cement, 32,300 metric tonnes of steel and 1472 metric tonnes of explosives were used in its construction. Completion took nearly 27 years from the start of investigation to the final commissioning in 1988.

Chunka was selected as the first major HEP station because it is located on the national highway. This has not only helped the transportation of heavy equipment from India and abroad but also made it easier to take transmission lines to India. Moreover the Wang Chu has its source from glaciers and snow and collects run off water during the monsoon season.

Box 10-1 Chukha Hydro-Power Corporation. *Source: Chukha Hydro-Power Corporation 1992 and CSO 1991.*

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Year	Power output in million units*	Remarks
1986-87	565.13	1st and 2nd turbines set up in 1986
1987-88	1244.72	3rd and 4th turbines set up in 1988
1988-89	1541.66	-
1989-90	1554.30	-
1990-91	1554.38	-
1991-92	1554.39	-
2005-06	1931.907	-

Table 10-2 Production of Energy from Chukha from Sept. 1986 to 2006

Import	34.322
Internal use	738.772
Export	1943.427

Table 10-3 Export, import and internal use of energy fin 2005-2006 (in million units). (Source: Department of Energy, 2006)*

* 100 Watt = 1 Kilo Watt
100 Kilo Watt = 1 Mega Watt
1 K W used for 1 hour is counted as 1 unit

Figure 10-5 220 KV power line a new feature on the landscape.

Figure 10-6 A view of the diversion dam near Tsimakothi.

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Figure 10-7 Wind mill in Wangdiphodrang draws water for irrigation.

Figure 10-8 Tapping wind energy for domestic purposes.

Figure 10-9 Solar house to preserve vegetable, designed at Bonday farm, Paro

Solar

Many of the hill slopes of Bhutan face south, and are thus exposed to the direct impact of the sun's rays during the day. The sun's rays are particularly strong during the summer season. The southern, eastern and western regions are most suitable for tapping solar energy. High altitude settlements are not ideal for tapping solar energy as many of these areas are often cloudy, foggy and have little sunshine.

The use of photovoltaic cells that collect energy directly from the sun and convert it to electricity has been recommended for use in Bhutan. Although the initial expense is rather high, they are cheap to maintain and relatively easy to transport to rural areas. This system is particularly appropriate for many isolated rural settlements, which are difficult and expensive to reach by normal hydro-electric power lines.

A four point photovoltaic system, sufficient to light a house, would cost around ten thousand ngulturms, as given in Table 10-3.

Main Parts	Quantity	Cost in Nu.
1. Solar Panel (12V 40W)	1	11,500
2. Controller	1	1,550
3. Storage Battery	1	11,800
4. Bulb	1	1,625
5. Wire	per meter	55

Table 10-3 Cost Breakdown of 4 point Photovoltaic System. Source: DSB Solar System, 2006.

The Department of Power, in Thimphu, estimated that a sum of 80,000 ngultrum per household would have to be invested in order to provide power generated by hydro-electricity. This sum includes internal wiring, transmission lines, generation set and construction. In addition, there is the maintenance cost in hydro-electricity.

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Solar energy can also be used for heating water for washing purposes, especially in cold places where water is too cold to use without warming.

Solar energy has been in use in Bhutan since ancient times to preserve food such as meat, vegetables and mushrooms. But a new technique has been introduced to improve this traditional system of preserving food. This involves a simple dome like container with racks inside it. Meat or mushrooms can be spread on a tray and kept in the rack. The air inside is heated up as the solar rays are absorbed by the iron roof. There are outlets below the roof through which hot air escapes and an entrance at the side through which cool air enters. The items are dried faster than by the usual way of drying them outside, and they are also safe from animals and birds. The glass panel in front of the house also helps to heat the air which then flows into it.

Bio-gas

Almost all Bhutanese households own livestock. In many farming villages, animals are sent out to graze in the forest land, where their dung is deposited and wasted. Enough animal waste can be collected for individual households to produce gas for use as cooking fuel or to light the house. The use of bio-gas is, of course, not feasible for settlements above 1000 metres in elevation as the climate is not warm enough to ensure a constant production and supply of gas. The use of bio-gas is a possibility, however, in some parts of the central valleys and in the southern foothills.

Thermal

In many countries, coal is one of the most important sources of power. Coal is burned to heat water to produce steam, which turns the turbines to make electricity. It is only possible in a place where coal is found in sufficient quantity. Wood can also be used in the same way to produce thermal electricity. As this requires a vast supply of wood, it is impractical in most places.

Coal is found in Bhutan only in a small area in the Samdrup Jongkhar Dzongkhag. It is a non-renewable resource and can be easily exhausted. Deriving energy from coal is also a difficult process and it produces black smoke, which pollutes the air.

Hot springs bring the geothermal energy from the interior of the earth to the surface. In countries such as Iceland and New Zealand, this is an important source of energy. The hot water and steam from the springs can be distributed through a pipeline system and used directly to heat the houses or the heat can be used to produce thermal electricity. Although Bhutan has a few small hot springs, they are located far from any settlements. So, the use of hot springs here as a source of energy is not feasible.

The Future of Power in Bhutan

Power generated from these alternative sources may not be sufficient to run Bhutan's industries. But, for domestic use, they could be a cheaper and more convenient source of energy to provide light and heat. If their use is encouraged, we could become less dependent on fuel wood and the quality of life in the most isolated areas of the country could be improved.

People have used energy since ancient times. Our ancestors have used the energy provided by water, wind and sun for many, many centuries. Water has been used to turn the prayer wheels to spread the message of the Dharma, to grind cereals into flour and to carry logs for great distances. People also use wind energy to remove husks from cereals. Solar energy is used daily by people to dry their wet clothes, preserve their vegetables and cereals, and to grow their crops. We should now attempt to improve the technology to increase the efficient use of the available energy. This will make us less dependent on fossils fuels and fuel wood.

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The majority of our people live in villages, where lighting and heating facilities have changed very little during the 30 years of development. This is mainly because our mountainous terrain stands as a physical barrier to the construction of large power stations and power distribution network.

A number of nucleated settlements which are close to the road, such as Yadi in Mongar and Ura in Bumthang now have electric power supply from micro hydel power stations. These micro-hydel power stations do not require major road improvements. The equipment needed for their construction can be easily transported along the existing road system.

There are many isolated villages in the mountains that are a week's walk or more from the nearest road. It is both difficult and highly uneconomic to stretch electric lines over such long distances. For people living in such settlements, the alternative sources of power such as solar and wind energy could provide a change in their living conditions.

Hydro-electric energy is also a mover of economic growth in our country. The macro power stations are good sources of revenue from exports of energy as well as the prime source of power to our factories, which produce goods for export and for local use, The Chukha HEP station contributed 2,092.682 million ngultrums (30.01%) to the revenue during the 2005-2006 fiscal year, making it the biggest source of revenue for the country. Basochu HEP also contributed 121.581 million ngultrums (1.74%). Now, Tala HEP will become the major source of national revenue.In the running waters of Bhutan, we have a big hope for the future, but assuring the continuous flow of water in the rivers is important.

Questions and Activities

1 Study Box 10-1

a What conditions might have helped decide the selection of the present site of the Chukha HEP?

b Use the following list of terms to draw a flow diagram that shows the process through which running water is turned into electricity at Chukha.

- Penstock
- Tail Race Tunnel
- Diversion Dam
- Power House
- Desdilting Chamber
- Head Race Tunnel
- Switchyard
- Transmission lines

2 Discuss what is meant by the term 'renewable energy' and list some examples.

Summary Activities

1 Give the meanings of the following words as they are used in the text.
- Bellows
- windmill
- fossil fuels
- geothermal energy
- photovoltaic cell
- thermal electricity

2a Is it possible to replace conventional forms of energy with alternative forms of energy in Bhutan?

b How can we make use of these sources of power? (An example is given for you).

Sources of Power	Uses
Wind	Cam pump water for irrigation and help in agriculture
Bio-gas	?
Solar	?

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Chapter 11

TRADE, TRANSPORT AND COMMUNICATION

KEY IDEAS

Trade
Communication and Transport
Impact of Transport and Communication

Trade

All human beings have many needs, but the resources with which we can produce goods to meet all our needs are limited. People living in some parts of the world are able to produce goods which those in other parts cannot produce for themselves. In order to get those things which they themselves do not produce, a system of exchange of goods with money has developed over the centuries. This exchange is called **trade.**

Trade transactions have been going on in this country for years. For many of the goods needed at home, Bhutanese depend on smooth trade transactions with other countries. One of the most important items traded in the past was the brown salt from Tibet. At times, salt became so expensive that it was traded at par with rice. Our traders exported rice, wheat and barley flour, dried fruits and *desho* to Tibet in exchange for silk, brocades, jewels and brown salts. With India we traded handicrafts for sugar, metal utensils and soap.

Both transport and communication systems have added advantages to the potential entrepreneurs of Bhutan in the coming years, as the merchant in the picture.

Figure 11-1 Successful businessman started as a small time trader.

Trade, transport and communication are interlinked. Through the communication networks traders acquire information on the demands and availability of supply of certain goods. This allows them to react immediately to the market situation.

Trading in Bhutan has in the past been limited. Our traders travelled to Tibet in the north and to the northern towns of India in the south. Some traders used mule caravans but many travelled on foot carrying goods on their backs. It often took months for them to make a round trip.

Modern transport systems were unknown in Bhutan until the 1960s. Due to the rugged, mountainous terrain, our people did not make wheels to use in transporting goods as they did in most other countries. So people did not even use carts drawn by animals for transporting goods. Transporting trade goods was particularly difficult at certain times of the year and in certain regions.

During the monsoon season the hot and humid conditions and malarial infested jungles posed great difficulties in the southern parts, while leeches and wild animals were problems on the

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other routes. The northern passes by which the Bhutanese traders crossed over into Tibet were sealed off by snow during the long winter. In other parts of the year, robbers often instilled fear in travellers along these northern routes.

Modern Trade

Trade is an important part of our economic system because it allows us to make full use of our available resources, thus increasing our national wealth. Modern trade involves the exchange of goods with money in large quantities and a complex network of interactions amongst a large number of countries.

Modern trade is usually dominated by those countries which have already made progress in manufacturing goods and have efficient transport and communication systems. Poorer countries, which do not have efficient manufacturing systems, tend to export primary products such as raw materials for industries and agricultural goods in order to earn some foreign exchange. This has led to the exploitation of natural resources in many of the developing countries.

Balance of Payments

Bhutan remained isolated till the 1960s. Within the last 30 years, it has come into contact with many trading partners and the need for trade has increased many times since then. India has remained Bhutan's main trading partner. The details of this trade are shown in Table 11-1 (a) and (b).

By the time Bhutan joined the world community and began to trade on a large scale, manufactured goods were already available at relatively cheap prices. Any attempt to manufacture them ourselves would have been uneconomical as we would have had to face stiff competition. So instead of making things for ourselves, our traders depended on imported goods as shown in Table 11-1b.

Tables 11-1 a & b Bhutan's trade pattern with India in 1982 and 1988.

(a) Exports to India

Items	1982 value	Items	1988 Value
Cement	31.12	Cement & Carbide	177.94
Fruits	24.84	Fruits	67.92
Food	17.31	Food	60.53
Timber	18.32	Timber	197.13
		Block Board	31.04
		Electric Energy	337.26

Nu. in millions (for selected goods only).

(b) Imports from India

Items	1982 Value	Items	1988 Value
Fuel	31.12	Fuel	49.14
Food	30.57	Food	142.56
Building Materials	32.79	Building Materials	32.66
Motorcars etc.	22.34	Motorcars etc.	79.77
Electric Energy	10.08	Agri. Machinery	47.30
		Electric Goods	84.85

Nu. in millions (selected goods only).]
Source: Ministry of Trade and Industries, 1992

You will notice in Table 11-2 that the balance of trade has always been negative. This means that what we are able to sell is far less than what we buy. That is why the balance of trade is unfavourable for Bhutan. If the volume of exports exceeded our imports, our earnings from other countries would be higher than what we pay out for imported goods. In such a case the balance of payment would be **favourable** to us, as we would gain from the trade. But at present, we pay out more than what we earn in trade; thus we have an overall trade **deficit.**

To be able to reduce this unfavourable trade balance, we will need to increase our exports or

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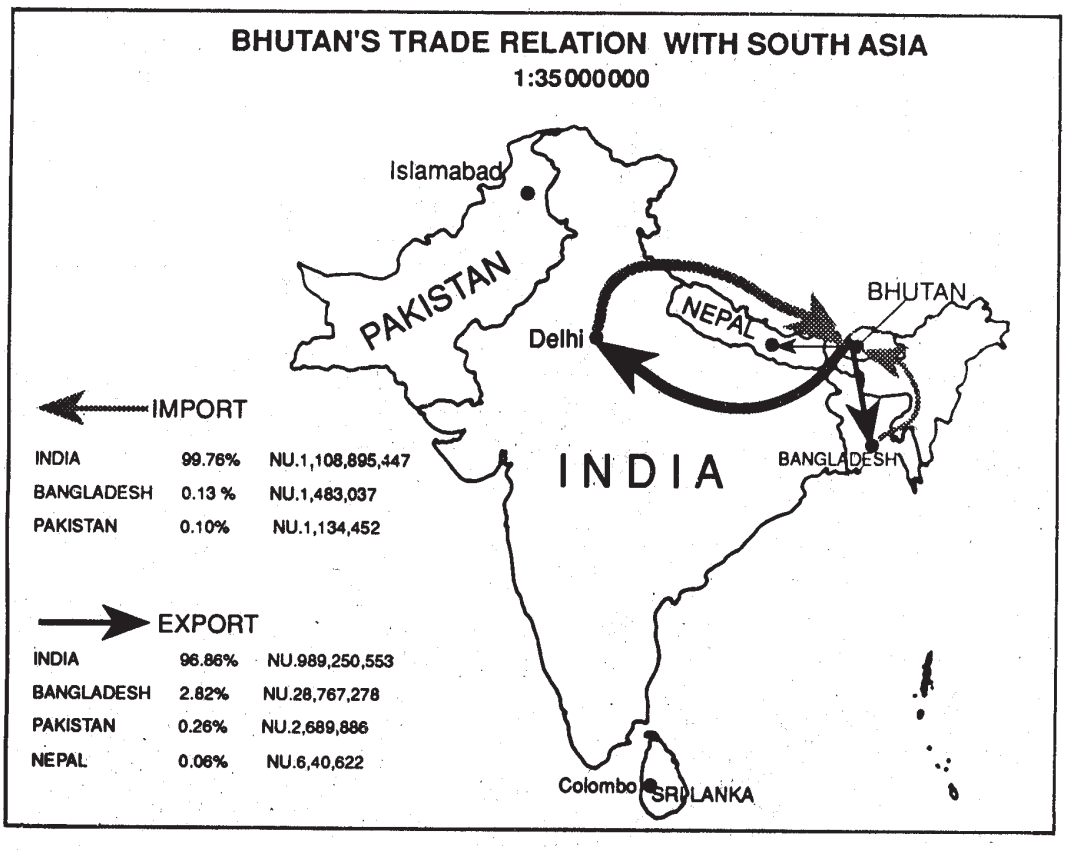

Figure 11-2 Map of South Asia showing trade links with Bhutan during 1992.

reduce our imports. One of the problems with developing countries like Bhutan is that our export items are mainly primary raw materials, while our imports consist mainly of finished goods. Because primary materials are still raw, they are sold at lower prices and in return we are buying finished goods at higher prices. Our imports are mainly automobiles, machines and machine parts, electronic goods, hardware, building materials and aircraft.

Even though the raw materials are processed at home and sold in the form of finished goods, there is a limit to what we can export. We have to face the competitors in the market, who are already well established. For example, Bhutan can now produce good quality garments, but the textile industry in India has been in the market for so long that they can afford to sell their products at lower prices. We may not be able to match these prices as we have to recover the capital investment along with covering and operating costs of the business. The challenge to the business community in Bhutan is to find the types of products that are presently in short supply through a careful analysis of market trends.

We have the potential to increase the exports of some goods in order to improve the balance of our foreign trade. The Chukha Hydel Project has shown us that this is possible. During the late 1980s, the sale of power from this project has helped improve the balance of trade with India as shown in Table 11-2.

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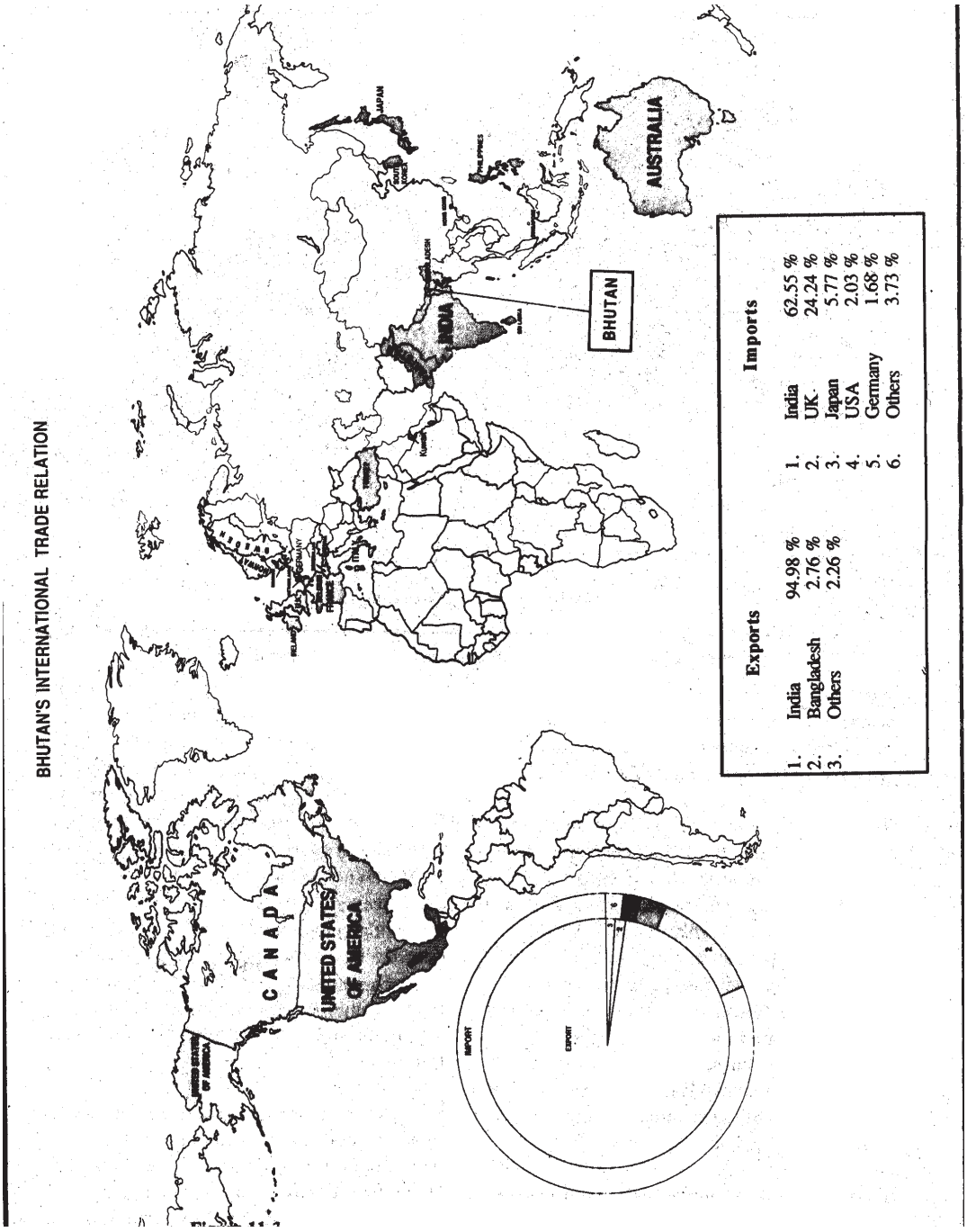

Figure 11-3 Map of the world showing trade links with Bhutan during 1992.

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Figure 11-4 A trader using modern communication facilities.

Table 11-2 Bhutan's trade balance with India and the rest of the world, in millions of ngultrums.

Year	India	Rest of world
1981	-287	-255
1982	-290	-93
1983	-251	-123
1985	-564	-89
1986	-456	-347
1987	-199	-213
1988	-120	-611

(Source: Ministry of Trade and Industries, 1992)

Development of Communication and Transport in Bhutan

Over the last few decades, transport and communication systems have improved tremendously throughout the world as well as in Bhutan.

Questions and Activities

1a What is trade?
b What factors have helped to develop trade in our country?

2 Study Figure 11-1.
a Would you describe this man as a traditional or modern trader? Why?
b List the things with which you can differentiate traditional trade from modern trade.

3 What difficulties did the Bhutanese traders face in the past?

4 List the facilities that help modern traders in Bhutan to carry out their work efficiently.

5 Study Tables 11-1a and b.
a What differences do you notice in Bhutan's international trade between 1982 and 1988?
b Why do you think the total value of imports was higher in 1988 than it was in 1982?

6a What do you think makes the balance of payments always negative?
b What does this mean to the economy of the country?
c What measures do you think we should be taking to improve our balance of payments?

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Prior to the modernisation period in Bhutan, exchange of information and goods depended on humans and animals and was, of course, a slow process. The revolution in sending information from one place to another began when wireless communication was established in 1955. Since then, the establishment of telephone networks, radio broadcasts, newspapers, telex, satellite telecommunication, and facsimile transmission, generally known as **fax**, have continued to increase the ease with which the people of Bhutan can communicate with each other and the rest of the world.

The use of telephone in Bhutan came in the early 1960s with the completion of the construction of first motorable road in 1961 by the Bhutan Engineering Services, the parent department of the present Department of Roads. There were thee main lines connecting Phuentsholing with Thimphu and Paro, Gelephu with Trongsa and Samdrup Jongkhar with Trashigang. By the mid-1960s telephones were also used by various offices of the Royal Government.

In 1969, telegraph services were opened in Phuntsholing and Thimphu to enhance communication. Until the mid 1980s, wireless, telegraph and telephone were the fastest means of communication within Bhutan. Communication with other countries was mainly through postal services. By 1984, Bhutan was linked with other countries through the Indo-Bhutan micro-wave telecommunication via India. This was followed in 1986, by the commissioning of a telex system. In 1988, the satellite earth station was commissioned in Thimphu giving us more access to the rest of the world. The digital micro-wave system installed in Thimphu marked a revolution in the history of communication in Bhutan. People in Bhutan can now communicate directly with many countries of the world. The international telephone connections and the fax facilities have many advantages for trade. In August 1993, the internal telephone network was expanded when Thimphu's telephone links with Trongsa, Bumthang, Mongar and Trashigang were opened. Soon, the entire kingdom will be connected by an efficient network of telephones.

Figure 11-5 Satellite disc in Thimphu.

We are living in a world where an increasing number of people from different places with different cultural and linguistic backgrounds interact with one another daily. In order to understand this complex world in which we live, we need access to a good flow of information to keep us up-to-date about important national and international events. It also helps us to understand and appreciate the way people from different cultural backgrounds see the world.

Table 11-3 Time Chart for Bhutan Postal Products and Services.

Sl. No.	Name of Product/service	Year of Introduction
1	**Financial Services** • Fax Money Order in Bhutan • Express Money Order with India • International Money Order with Japan • Western Union Money Transfer	 1992 2000 2002 2002
2	**Courier Services** • International Express Mail (EMS) • Domestic EMS • Post Overnight Courier (POC) • Desk to Desk Courier (DTDC)	 1993 1998 1998 2004
3	**Local Urgent Mail (LUM)**	1997
4	**Electronic Mail** • Fax mail • Public Call Office (PCO) • E-Post	 1992 2001 2004
5	**Logistics** • Domestic Cargo Service • GATI Express service with India only • Customs Clearance Service	 2000 2000 2001
6	**Retail Service** • Lottery • Newspapers • Recharge vouchers • Pension Payments	 1997 1997 2004 2006
7	**Transport** • Mail cum passenger bus service between Thimphu and p/ling • Passenger bus service between p/ling and Kolkata • City Bus Service	 1997 1997 2001

(Source: Bhutan Postal Corporation Ltd. Thimphu, 2006)

Mass communication networks spread information quickly across the globe. Within hours of events occurring in Europe, North America or Africa, we hear about them in Bhutan on the evening news broadcast of the Bhutan Broadcasting Service Television (BBS TV) and BBS Radio as well as Kuzoo FM Radio. Newspapers such as the Kuensel, Bhutan Times and Bhutan Observer and radio and television broadcasts, and B Mobile and Druknet are often referred to as the **mass media.** They are called this because these communication systems reach a very wide audience. Thus, most of the people in the county, the **masses**, are informed of the news through these forms of media.

The mass media spreads information quickly from its point of broadcast or publication to its audience. However, the speed at which the information travels and the depth of coverage provided on particular topics or events depends on the form of media used.

For example, news, advertisements and public information get to the people through Radio or TV faster than through the print media. The BBS also can provide information in local and national languages bringing the news even to those people who cannot read. The *Kuensel*, *Bhutan Times* or *Bhutan Observer* on the other hand, can cover stories in much more detail than is possible on a radio broadcast.

In the absence of a mass communication system, information is spread through conversation. For instance, one person tells the news about an archery tournament in Thimphu to two other people, each of whom then tells two more persons, and so on, as shown in Figure 11-8. But the process of spreading information and the distance covered and the correctness of the information are limited.

Figure 11-9 shows the flow of information through a mass communication system. Any news or information provided through the radio will reach the entire population at the same time. In this process the flow of information covers a great distance within a very short time.

The mass media play a very important role in helping us to understand the world around us, particularly when we are so dependent on one another. In modern Bhutanese society, mass communication informs and advises people about new techniques in farming, raising livestock, and health care, as well as providing them with up-to-date news and an enjoyable form of entertainment at the end of the day. This vital chapter was opened up in the life of the Bhutanese in the 1960s.

Transport Networks in Bhutan

There are only two types of mechanized transport system in Bhutan: road and air. Air transport is the latest and connects Bhutan with five cities in South and Southeast Asia. You learned about the history of air transport in Class 8. So, here we will look at Bhutan's network of motorable roads.

Bhutan depends heavily on the road networks as do most mountainous landlocked countries. Table 11-5 shows that the number of vehicles on the roads of Bhutan has been increasing dramatically year by year. If all the vehicles in Bhutan, including two wheelers, were to be put on the road at the same time, there would be approximately 8 vehicles for every 1 kilometre of road.

All of Bhutan's road network is linked with the Indian road system. Towns such as Samtse, Phuntsholing, Sarpang, Gelephu and Samdrup Jongkhar are closest to India and are the entry points into Bhutan. As can be seen in Figure 11-6, roads from these nodes proceed into the interior

of the country. They follow the river valleys and connect, as far as possible, settlements and district centres.

Table 11-4 No. of vehicles, travellers and road accidents in Bhutan between 1984 and 2006.

Year	No. of vehicles Including bikes	Passengers carried	road accidents
1984	2345	1,264,000	135
1985	2980	1,239,000	187
1986	4881	1,142,000	230
1987	5721	1,228,000	246
1988	8929	n.a.	254
1989	9941	1,290,000	302
1990	11,348	n.a.	258
1991	14078	n.a.	220
1992	n.a.	4,011,000	254
2005	n.a	n.a	472
2006	32,587	n.a	n.a

(Source: CSO, 1991; Rev. & Cstms, 1994; RBP, 1994 and RSTA, 2006)

Although Bhutan has been able to develop a substantial network of roads since the first road was built between Phuntsholing and Thimphu in the early 1960s, the mountainous terrain makes the cost of transportation very high within the country. In 1993, a prominent industrialist noted that in Bhutan the average cost of transporting one ton of material one kilometre was Nu. 4, whereas it only cost about Nu. 1 to transport the same amount of material over the same distance in India. Due to the fact that the transportation cost often adds substantially to the final cost of products sold in the market, it is important that business managers choose the most efficient route to supply their customers. Let us examine the efficiency of our road network.

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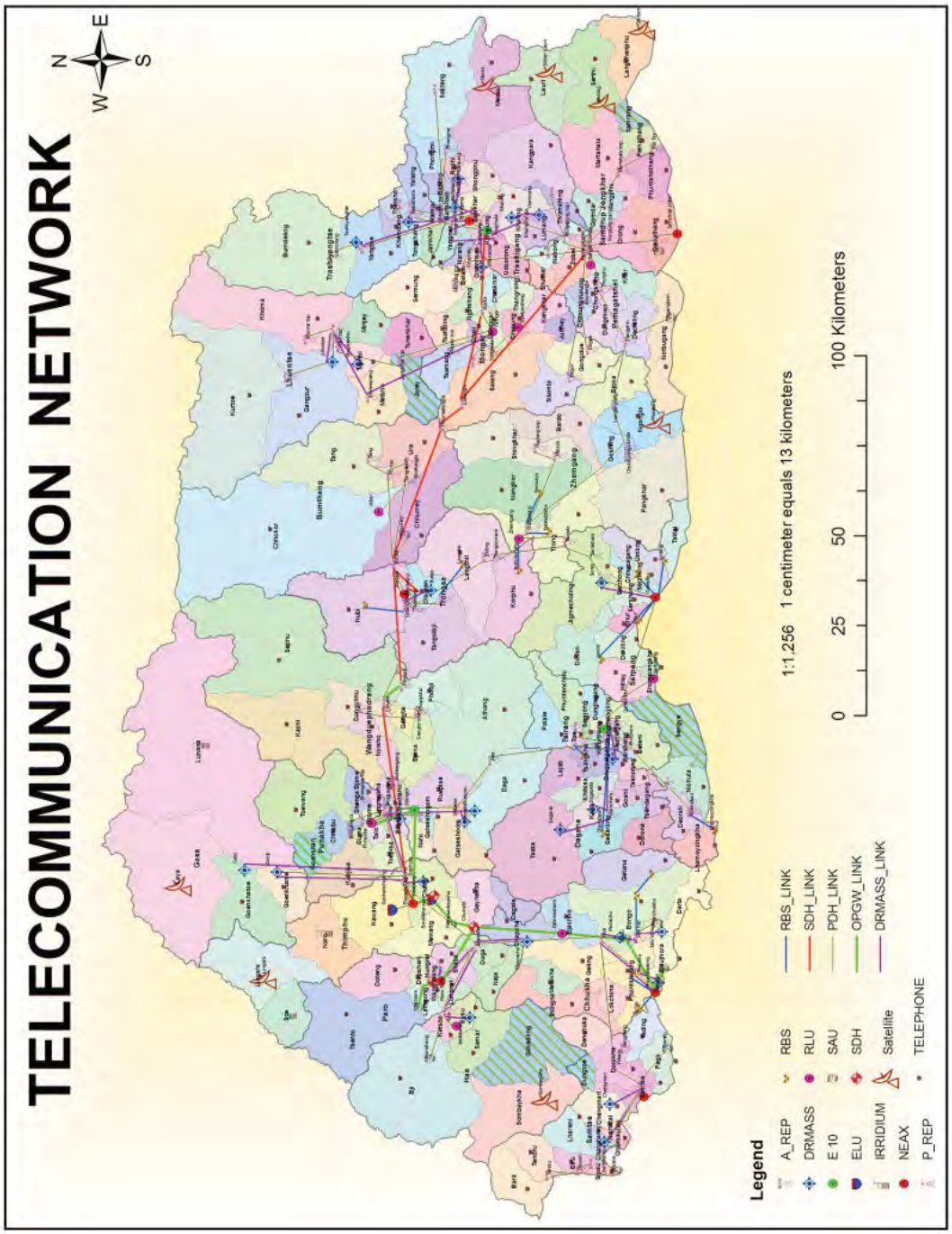

Figure 11-6 A Map of Bhutan showing communication and road networks.

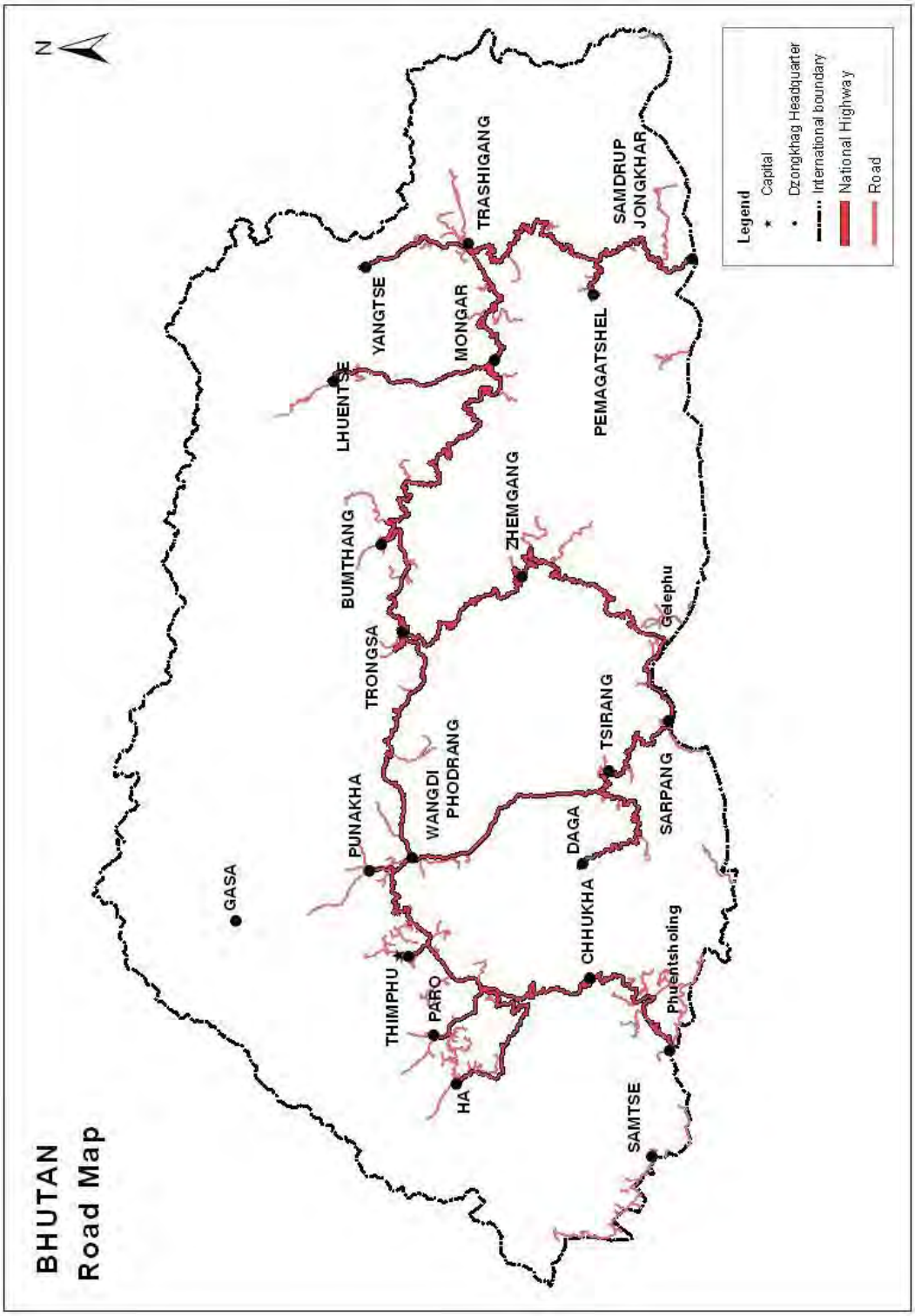

Figure 11-7 Map of Bhutan showing road networks

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Transport Efficiency

The efficiency of the road network depends on factors such as, the number of settlements they link, the distance between two settlements and the number of people that use the network. There are two elements in the transport network. One is the line of transport, called **links,** and the other is the points they join, called **nodes.** A node may be a junction where two or more roads join, or a settlement through which the road passes. Trongsa is at the junction of three highways and Zhemgang is a small town on the Gelephu-Trongsa highway. Both are nodes.

If we divide the number of links by the number of nodes, the answer shows the efficiency of the network. For example, in Figure 11-7, there are six links and seven nodes between Phuntsholing and Sarpang. The efficiency is (6/7) 0.85. This measurement is high, and indicates that the road network is well connected. The higher the value, the better connected is the network.

We can also measure a network in terms of the accessibility, meaning how easily a node can be approached from another node. This can be measured by using the accessibility matrix and index, as shown in Table 11-5.

The matrix indicates the number of links between each pair of nodes. By adding up the total for each row, we get the total number of links which shows the relative accessibility of that town or node from other towns in the country. This number is called the **accessibility index.** The node with the lowest index number is the most easily accessible place and the one to which more people are likely to travel because of the short distance. The higher the index number, the less accessible a node is, and thus fewer people are likely to travel to it as it will be more expensive. In Table 11-5, Thimphu is the most accessible town from other parts of western Bhutan.

Impact of Transport and Communication

We know that good transport and communication systems help to strengthen and expand trading networks. People now spend relatively less time in their own localities than they did in the past, as they have access to road transport. This allows them to move more easily from place to place and also makes it easier and cheaper for exchange of goods and information. This exchange of goods and information between different places is sometimes called **spatial interaction,** and can bring changes in both places.

Some of you will have grandparents or even parents who have not moved outside the valley in which they were born. Some of you may also have parents or someone in the family who have travelled to different parts of the kingdom or even to other parts of the world. In the past, trade and transport had not developed to any great extent and hence there was little interaction. Improved transport and communication systems have led to more spatial interaction as people need to move from one place to another, to trade, to see places and to carry out official business.

As people interact with those from other regions to trade goods or carry out other forms of business, it causes many other changes as people are exposed to new food habits, clothing and ideas. Today's students see more of the outside world than those who went to school in the 1960s. In the early 1960s, spatial interaction was limited to very few people. The vision of the world held by students in the 1960s was different from that of today's students.

Our food habits have changed greatly. Most of the older generations do not like sweet foodstuffs, as they had very few sweets for most of their youth. Some grandparents complain about people never carrying their cups with them these days.

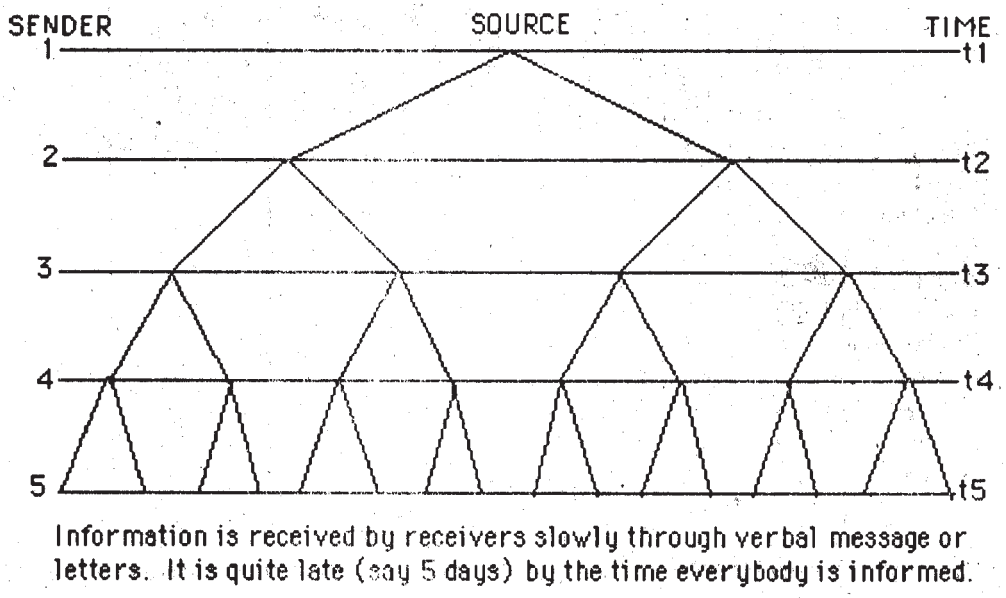

Figure 11-8 Slow spread of information through verbal communication.

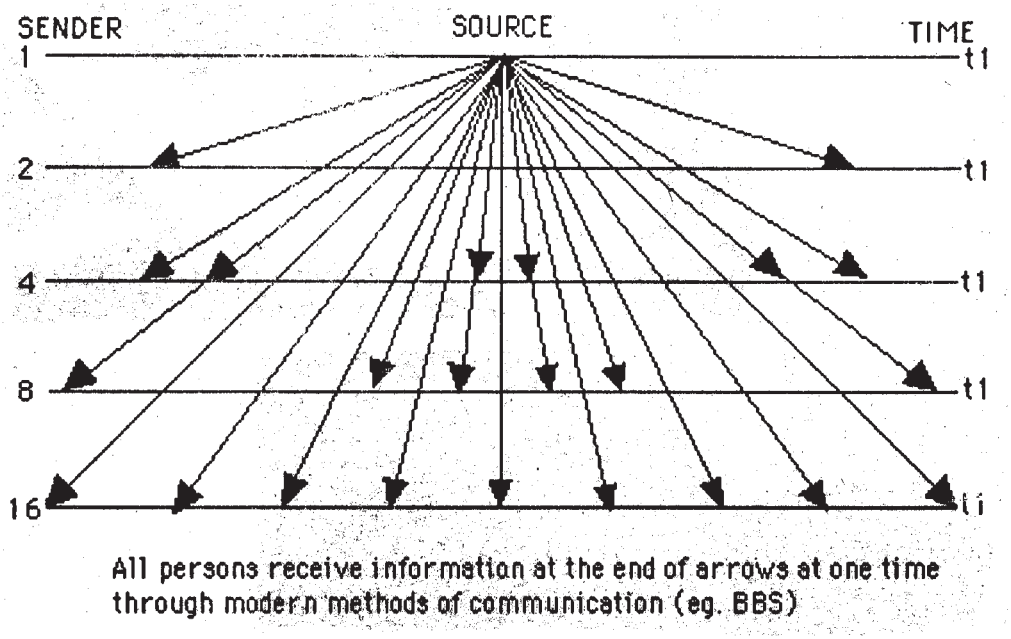

Figure 11-9 Sending information through the BBS.

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	P/Ling	Chukha	Chu-dzom	Paro	Thimphu	Haa	W/Phodrang	Punakha	Tsirang	Dagana	Sarbhang	Accessibility Index
1. P/Ling	0	1	2	3	3	3	4	4	5	6	6	37
2. Chukha	1	0	1	2	2	2	3	3	4	5	5	28
3. Chu-dzom	2	1	0	1	1	1	2	2	3	4	4	21
4. Paro	3	2	1	0	2	2	1	1	2	3	3	30
5. Thimphu	3	2	1	2	0	2	1	1	2	3	3	20
6. Haa	3	2	1	2	2	0	3	3	4	5	5	30
7. W/Phodrang	4	3	2	3	1	3	0	1	1	2	2	22
8. Punakha	4	3	2	1	1	3	1	0	2	3	3	25
9. Tsigang	5	4	3	4	2	4	1	1	0	1	1	26
10. Dagana	6	5	4	5	3	5	2	2	1	0	2	35
11. Sarbhang	7	5	4	5	3	5	2	2	1	2	0	36

Table 11-5 Accessibility Matrix and Index (Assuming that people travelling to these towns use only the roads within Bhutan).

Figure 11-10 Transport in the past involved a lot of hardship, like this man struggling over a suspension bridge made of cane (Tsha-zum)

Figure 11-11 Foggy Weather on the Thimphu-Phuntsholing Zhunglam poses another problem for road transportation.

The recent increase in the pace of change is the result of exposure to new ideas and trade brought about by the improved transport and communication networks. There are many more changes that have taken place which cannot all be mentioned in this chapter. You may ask your parents and grandparents about life when they were young and compare the information with your experiences.

Questions and Activities

1 Why is it important to know about the people and places of other lands?

2 Make a list of the ten most interesting things that you have learned from our two mass communication systems – the BBS and the *Kuensel* in the last month.

3 What would be the state of information flow if it is spread only from person to person?

4 In what ways has the development of extensive communication systems influenced our lifestyles in Bhutan?

5 Study Table 11-5 and Figure 11-6.

a Which is the most accessible place in the table? Why?
b Calculate the accessibility index between Thimphu and Dagana and Thimphu and Phuntsholing.
c Which direction is more efficient?
d Do a similar exercise on other routes on the road map.

6a Explain what is meant by the term "spatial interaction"?
b What are the benefits and drawbacks of spatial interaction in our world today?

7 List the problems and benefits associated with road transport in Bhutan.
8. What would be the role of Bhutan post with Mobile phone and Internet gaining more popularity?
9 Explain why Mobile Phones are becoming popular in urban Bhutan.
10. What role should the Bhutan Television play in the face of growing cable TV culture?

Summary Activities

1 Look up the following terms in the text and describe their meaning.

- Trade
- balance of payments
- favourable balance of trade
- accessibility index
- mass media

2 With the help of your teachers and friends, try to develop a diagram showing how trade, transport and communication are related.

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Chapter 12

PEOPLE AND THE ENVIRONMENT

KEY IDEAS

Growth of Population
Natural Ecosystem
Development of Technological Capacity
Impact of Population on Environment
Environmental Problems in Bhutan

In the preceding chapter, we have discussed the natural and man-made environments as separate topics. In this chapter, we shall try to discuss them side by side and see how the two interact with each other. In the process, we shall attempt to find answers to the following questions.

a) Why does population grow so rapidly?
b) What is a natural ecosystem?
c) How does the human population affect natural ecosystem?
d) What can we do to help sustain Bhutan's natural environment?

Why does human population grow so rapidly?

In 2006, the world population reached 6.55 billion. That day was designated as **World Population Day**, to be an annual reminder that the size of the population and the rate at which it is increasing are formidable problems for the future of the world. By June, 1992, the world population has rise to 5.48 billion and it is expected to reach 7.6 billion sometime in 2020. At present, the world's population is growing at the staggering rate of three people per second. This adds 250,000 people to the world every day! Table 12-1 shows the history of the world's increasing rate if population growth.

Years	Population	No. of Years
0 – 1850	1 billion	2.5 million years
1850 – 1930	2 billion	80 years
1930 – 1960	3 billion	30 years
1930 – 1975	4 billion	15 years
1975 – 1986	5 billion	11 years
1986 – 1990	5.3 billion	4 years
1990-2006	6.55 billion	16 years

Table 12-1 World Population Growth.
Source: Population Education: A National Source Book, Thimphu, 1992 and http://en.wikipedia.org/wiki/list_of_countries_by_population

You will remember from your previous classes that there are a number of things that increase the rate at which the population of a country grows. Three of the most important factors are listed below:

- Reduction in death rate as a result of better medical facilities and an improved standard of living due to increased per capita income.
- Increase in the survival of children due to the availability of better medical care for mothers and babies during and after pregnancy.
- High rates of illiteracy in many developing countries where the general population is governed by religious and economic conditions. For instance, some people think many children are God's gift or that more children will bring extra income to the family.

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Figure 12-1 Social services provided to the people contribute to population growth in Bhutan.

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The Nature of Population Growth

Table 12-1 shows that the length of time it takes to add another billion people to the world population becomes shorter as the years go by. Why do you think this is so?

Countries	1981	1990	2006
Bangladesh	90.00	116.00	148,610,000
Bhutan	0.59	0.60	0.635
China	1008.00	1139.00	1,313,700,000
India	700.00	853.00	1,118,700,000
Indonesia	150.00	184.00	233,220,000
Japan	117.00	124.00	127,417,000
Myanmar	28.00	42.00	50,519,000
Nepal	15.00	19.00	27,133,000
Pakistan	83.00	123.00	158,570,000
Philippines	48.00	62.00	90,236,000
Sri Lanka	15.00	17.00	20,734,000
Thailand	44.00	56.70	64,800,000

Table 12-2 Population situation in selected Asian countries between 1981 and 2006 (figure in millions) (Source: The Far East and Australia Review (1986) for 1981 data. State of the World Population, UNESCO, (1992) for 1990 data. Population and Housing Census of Bhutan, 2005. http://en.wikipedia.org/wiki/list_of_countries_by_population)

Although the population increase between 1981 and 2006 varies from country to country, it is obvious from Table 12-2 that no country has maintained a stable population. In some countries, the increase has been immense. For instance, the population of both India and China has increased by more than 100 million people during this period.

Think of a student body of 400 children in a school and increase it by 4 percent over the previous year. There will be 416 students, an increase of 16 students. But if the school has 800 students and it grows by an additional 3 percent (1 percent less), the number added will still be much greater as there will now be an extra 24 students. Our world is caught up in a similar population spiral. Although many countries have reduced their annual growth rate from more than 2.5 percent in the 1960s to less than 2 percent at present, the growth of population is much higher because of the sheer size of the population.

The world population is said to be growing at an exponential rate. This means, if the population grows at the rate of 2 percent per year, the total population will double in 34 years. But if the increase is 3 percent, the doubling period will be only 20 years. It is similar to increasing the total amount in a fixed deposit account in the bank where compound interest is calculated every year on the gross total. The total grows faster if the capital is large and more slowly if the capital is small. The periods in which population will double are calculated in Table 12-3 for different growth rates.

Governments and people all over the world have been working hard to improve the living conditions of their people. They help improve standards of living, by providing better medical facilities, educational services and by encouraging the development of new farming techniques.

It is the achievements in these areas that have contributed to the rapid growth of population. The death rate has decreased and the birth rate has increased, because people can afford better food and medical care. Earlier, many children used to die before completing one year of age, but now more of them survive.

Thomas Malthus, who lived in the 18th century, predicted that the population of the earth would grow faster than its food supply and beyond its carrying capacity. Human population growth is seen as a problem because of its impact on the land, the water and the air and on the natural ecosystems of the earth, which provide the basis for our existence. We begin the next section by trying to define what is meant by the term a **natural ecosystem**.

Growth Rate (percent)	Years to Double
0.1	673
0.5	133
1.0	71
1.5	40
2.0	34
2.5	28
3.0	20
3.5	18
4.0	17

Table 12-3 The nature of population growth. (Source: Ecology 2000)

What is a Natural Ecosystem?

You have already learnt in your previous classes that living organisms do not exist on their own as individuals or as a single group. Their existence depends upon the presence of many other biotic organisms and abiotic substances. They are not haphazardly arranged, but are a part of a very systematic unit. Biotic organisms and abiotic substances interact to produce and exchange food and energy for living organisms to grow within a particular boundary. Such a unit is called an **ecosystem.**

An ecosystem includes both **producers** and **consumers.** Abiotic substances interact with biotic organisms to produce food and energy. For instance, light energy from the sun interacts with plants to convert carbon dioxide and water into carbohydrates and oxygen through a process called **photosynthesis.** This makes the plants the producers of food.

Other living organisms that eat plants are consumers of carbohydrates and oxygen. Such consumers who get their food from plants directly are **herbivores** – like the deer. There are some consumers like the tiger who get their energy from the flesh of plant eaters. They are the **carnivores.** Some consumers eat both plants and flesh and are called **omnivores.** A bear is an omnivore. When animals and plants die, their bodies are broken down and the nutrients stored in them are consumed by **macro-consumers** such as insects and the **micro-consumers** such as the bacteria that cause decay. The nutrients are finally returned to the soil through decay. The soil returns the nutrients to the plants, which will be eaten by herbivores. Food and energy are transformed from one organism to another in this way and this is called the **food chain.**

Questions and Activities

1a Draw a line graph to illustrate the information provided in Table 12-1.
 b Describe the nature of the graph.
 c What does it indicate?
2 Think of three reasons, other than those cited in the text, that will lead to rapid population growth in a country.
3a Draw a bar graph to illustrate the data in Table 12-2.
 b Describe the pattern in the graph.
 c Calculate the annual population growth rates of Bangladesh and Sri Lanka?
4 Why can a country with a low growth rate actually have more people added to its population each year than a country that has a higher rate of growth?
5 Do you think Thomas Malthus' prediction that the population of the earth will grow faster than the food supply is inevitable or can technology help us to avoid this crisis?
6 Study Figure 12-1: How do you think this activity will help increase population in the country?

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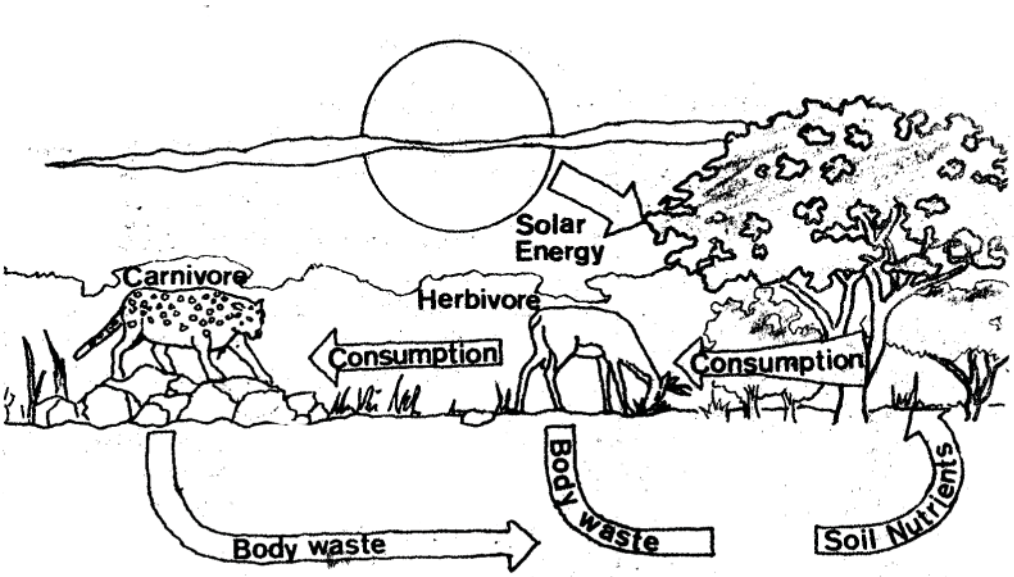

Figure 12-2 Energy flow in a natural ecosystem.

Figure 12-3 Activities that indicate human dependence on nature.

Interaction Between Humans and Natural Systems

Biologically, humans are similar to animals and are part of the natural ecosystem. However, humans are the largest and the most gluttonous consumers in the ecosystem. We are the consumers of soil nutrients through various types of farming for food and raw materials. Much of our food comes directly from the green forests in the form of vegetables and herbs. A large number of wild and domestic animals are the sources of nutrients and income for the human population. We either hunt them or butcher them regularly for consumption. Humans cannot survive without the four main elements of the natural environment – heat energy, the soil, the water and the air. In Bhutanese terms we call these elements the **jungwa zhi.**

Large-scale consumption by people can upset the delicate balance of the ecosystem. Intentionally or unintentionally, people are constantly changing the environment. Large forested areas have been cut down to be used as farmland. Such a change is deliberate. Sometimes, the deforestation will lead to soil erosion, as the farming methods are not always suitable to a hill slope situation. Soil erosion will also change the environment, as the original living organisms will be replaced by new ones. In an area affected by severe landslides, the alder tree or **gama shing** dominates the vegetation, as it can grow faster than other trees in such places. Such a change is accidental, because this is not the main intention of people when they cut down trees.

Some of the changes to the natural environment brought about by people are listed below:

1) Cutting down forests has sped up soil erosion.

2) Grazing by domestic animals has changed the structure and fertility of soils.

3) Pollution from automobiles and factories and the use of fertilizers and pesticides has brought undesirable changes to life in the water, air and ground.

4) The building of large dams, the cutting down of extensive areas of forests and the emissions from factories have brought changes to the local and global climate.

Figure 12-4 Eucalyptus a new vegetation introduced by humans in Bhutan.

Figure 12-5 Alder trees dominate the land slide areas as they grow faster than other trees.

In ancient times, the growth of human population was controlled by epidemics, crop failure and war. Over the centuries, humans have developed new technological strength to combat natural calamities. The human population has grown many times during the last hundred years and its consumption capacity has also increased greatly over this time.

Questions and Activities

1 What is a "natural ecosystem"?
2 Why is it important to maintain the balance in an ecosystem?
3 a Select a very small area in the valley such as the drainage basin of a small stream.
b What human impact can you notice in this area?
c How has nature reacted to the human impact?
4 Study Figure 12-2. Describe the diagram explaining how energy is transferred from one element to the other.
5 Select any 3 or 4 animals/birds/insects in the local area and show how energy is transferred from one to the other with the help of sketch diagram and indicate the energy flow by arrows.
6 Study Figure 12-6. What environmental impact would these animals cause?

Development in Technological Capacity

Developments in science and technology have provided a tremendous amount of comfort and luxury to people. Now, we can lengthen our lives with the help of advanced medical services, travel from one place to another faster than before and adjust our working conditions by heating or cooling the workplace.

A machine in a Paro farm can do the work of many people at a time. In America, a single farmer can work on more land in a week with a tractor than his ancestor could in a life-time using spades and hoes. In 1987, a total of 126,000 cars rolled off the assembly lines each day in the world. Today, there are nearly 400 million vehicles on the streets in different parts of the world.

Although we do not manufacture any motor vehicles in our country, Bhutanese have managed to import large numbers of vehicles as shown in Table 12-4.

Year	Light Vehicles	Heavy vehicles	Two wheelers
2000	7438	2062	7793
2001	8905	2853	8165
2002	10071	2747	8371
2003	11428	4841	7507
2004	12638	4345	7707

Table 12-4 Number of vehicles imported between 2000 to 2004
(Source: Statistical Year Book 2005, NSB)

Figure 12-6 Domestic animals depend on nature as much as humans.

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The economic appetite of humans can be compared with that of a young caterpillar in our vegetable garden. Today, people build houses not only for their own shelter but also to earn money. To build these extra shelters, they ravage the earth, digging out rocks and minerals to manufacture cement and cut down forests for timber. With the help of technology, the process of carrying out this work has been made many times faster.

Impact of Population on the Natural Environment

Our earth is like a bus. If the population is about the size it can manage to carry, we can live in prosperity and comfort. But if the number grows beyond its carrying capacity, it will collapse in terms of food production, and in terms of its ability to provide shelter and adequate space. Through our day-to-day activities we are unintentionally damaging the environment of the **"bus"** on which we are travelling through space. The details of how some of this damage is occurring is discussed below.

Figure 12-7 Power tillers on the farm save labours.

Box 12-1 *A tale of bus journey.*

TO TRONGSA BY BUS

On a late summer day in 1974, the public bus from Thimphu to Trongsa was ready to roll off from Lungten Zampa Bus Terminal. It had a capacity of 40 passengers.

When it left the terminal at 8 o'clock in the morning, there were 30 people on board. Since it was not loaded to full capacity, it seemed quite comfortable and enjoyable. Three hours later it arrived at Wangdue Phodrang. It had picked up 18 passengers on the way at different points.

After refuelling at Wangdue, it resumed the journey with the addition of another 5 passengers. The capacity of the bus had been exceeded by 13 passengers by then. It picked up another 4 at Chuzom and there were 6 more people waiting at Nobding. All these people were desperate as there was no other transport for 3 more days. The bus continued to move although it was overloaded with 23 extra passengers.

The vehicle was moving much more slowly than before. Inside, it was crowded, there was no space to move, smokers were affecting the non-smokers, and there was much vomiting and moaning! Before crossing Pele La one of the tyres burst and the fixing of another tyre, also old, took a long time. Fifteen minutes later, another tyre burst and there was no spare. It was dark. There were no settlements around the area and nowhere for anyone to go. There was nothing one can do except spend the night there and ignore the hunger, pains and the falling temperature.

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The Ozone Depletion

We have read so much about the importance of solar energy, but what we receive on the earth's surface is not the entire heat energy emitted by the sun. Our atmosphere is composed of many gases of which ozone is a vital one. **Short wave radiation** (also called **ultra-violet rays)** from the sun is absorbed by ozone and clouds present in the atmosphere. Thus, only solar radiation with **longer wave-lengths** is allowed through to the earth's surface. This is very important as ultra-violet rays are very harmful to humans. They can cause skin cancer and also damage our eyes.

Although it is a very minor substance found usually from 10-50 kilometres from above the earth's surface, ozone has a tremendous capacity to absorb the ultra-violet rays emitted by the sun. This makes it an important shield for all living things on the earth's surface, and this shield should not be broken. However, recently, scientists studying the ozone layer have discovered a hole in this protective cover above the Antarctic. The hole is getting larger and areas such as New Zealand and Southern Australia are now receiving marked increases in ultra-violet radiation. Scientists believe this hole in the ozone layer is largely caused by the increased amount of **chlorofluorocarbons (CFCs)** that are being released into the atmosphere. CFC is a substance used as a coolant in refrigerators and air conditioners. The CFCs are released to the atmosphere when these household appliances are not working correctly. CFCs are also released when some types of aerosol sprays are used and through the burning of plastics. Once in the atmosphere, the CFCs break down the ozone molecules on contact through a chemical reaction.

Climate Change

Temperature is an important element of climate. During the last Ice Age, the temperature was just 5° C below the present global temperature. This decrease in temperature was sufficient to create ice caps in many parts of the earth. Research suggests that the change is going to be different in future. It is said that by year 2030, the world temperature will increase between 1.5 and 4.5 degrees C, leading to **global warming.** Global warming will have tremendous effect on human life. All the ice stored in high altitudes and on the mountains will melt and flow into the sea. Some scientists predict that of all the ice in the Antarctic melts, the sea

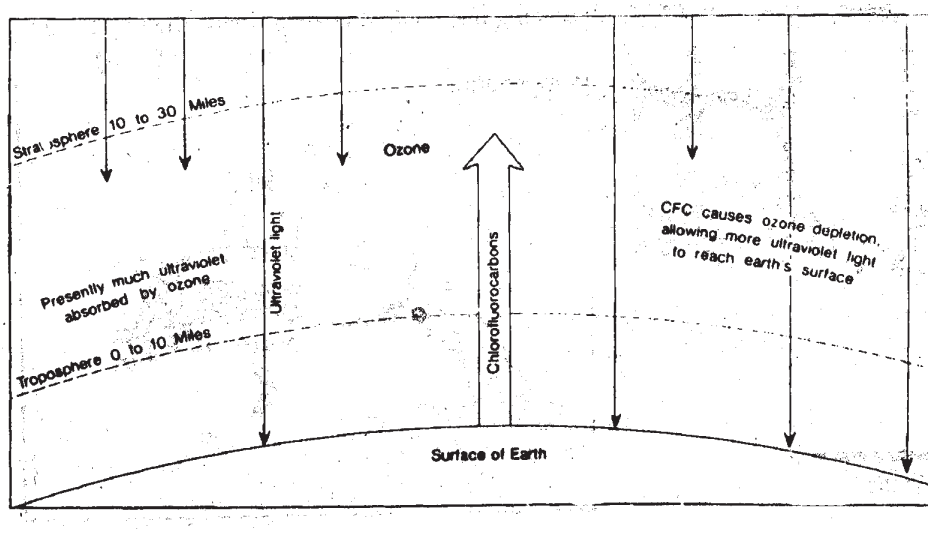

Figure 12-8 Diagram showing the effect of ozone depression. Source: Jackson and Hudman, Cultural Geography, 1990.

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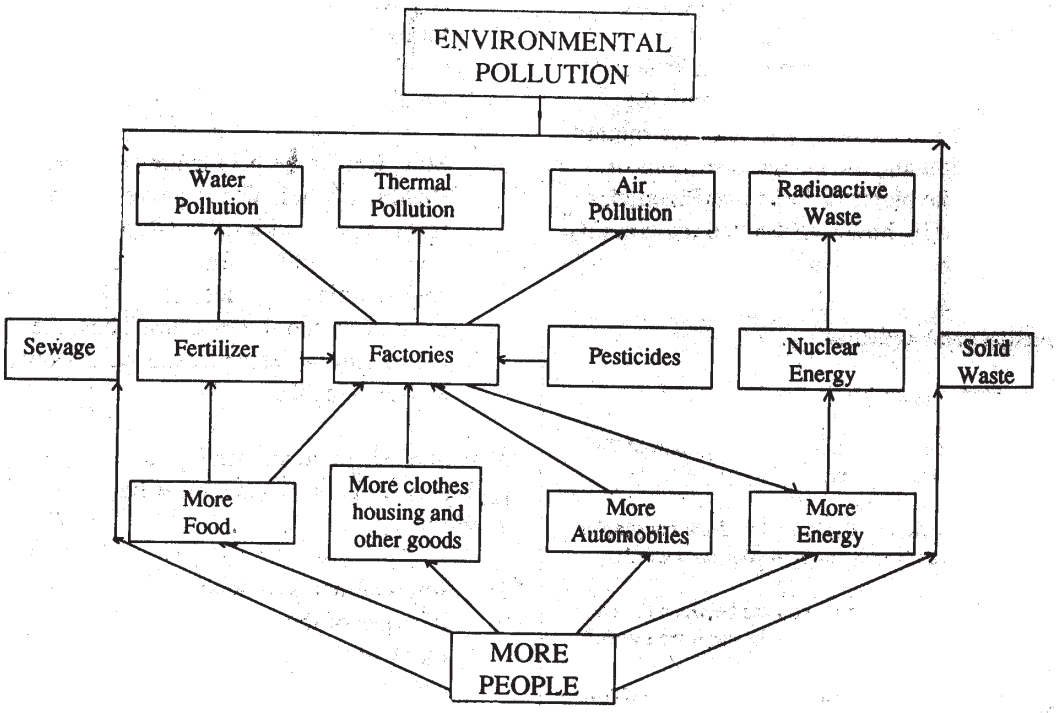

Figure 12-9 Relations between increasing population and environmental pollution
Source: UNESCO, 1990

level will rise by as much as 20 metres. Many countries near the sea, or surrounded by sea could be submerged under water. People living in such places would migrate and increase the population pressure in other parts of the world. Land for farming would be in short supply.

Combustion of the carbon based fuels, such as coal, petroleum, natural gas and wood is believed to increase the amount of carbon dioxide in the atmosphere. In the past, any carbon dioxide released by human activities was transformed into oxygen by the vast coverage of vegetation on our planet. But now the loss of vegetation, especially in the equatorial regions, and increased combustion of fuels have led to a significant increase in the amount of carbon dioxide in the atmosphere.

This increase in the amount of carbon dioxide in the atmosphere causes what has come to be known as the **"Green House Effect"**. It is called so because carbon dioxide has a very unusual characteristic. It allows the short wave radiation of the incoming solar energy to pass through it. At the same time, however, it traps the longer wave radiation of the heat which is being emitted from the earth's surface. Thus, like the glass in a green house, the carbon dioxide does not allow heat radiation to escape and causes an increase in the temperature of the lower layer of the atmosphere.

All countries of the globe contribute to some extent to these environmental problems. It is true that bigger countries that consume vast quantities of natural resources are responsible for most of

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this environmental degradation. But, even small countries like Bhutan contribute to these global problems through such activities as deforestation and the emissions of carbon dioxide, CFCs and methane.

Within the South Asian region, however, Bhutan's influence on the regional environment is much greater than its small population suggests. This is because the Himalayas are the head waters of the mighty Brahmaputra and Ganges. Millions of people in the plains of India and Bangladesh are affected by how well Bhutan manages its delicate mountain environment.

Questions and Activities

1 Study Figure 12-7.
List the advantages and disadvantages of this machine in Bhutan.
2 Use the data in Table 12-4 to draw bar graphs and describe the graph in your own words.
3 What connection do you see between the bus described in the box and the earth we live in?
4 If the average global temperature does increase, how will this affect the countries in the South Asian region over the next hundred years?

Environmental Problems in Bhutan

In terms of population and environment, Bhutan at present seems in a much better position than many other countries. The natural forest cover is still more or less in its primary form. Many parts of the country where the forest had been degraded are now slowly being replanted with saplings. The population density of Bhutan is approximately 16 persons per square kilometre, which is very low compared with that in many countries.

There are three reasons why Bhutan's environmental problems are not severe:

a) Hydroelectricity, which is the main source of power does not release pollutants into the environment.

b) Industrial development is a recent feature in the country. Most of the industries are wood-based, using hydroelectricity as the main source of power. Industrial plants are also very few in number and are not concentrated in a small area.

c) Most Bhutanese people are governed by Buddhist beliefs, which prevent them from causing widespread destruction of trees and wildlife. Besides, our rural communities have not yet picked up the habit of wasteful life styles. Thus, the use of natural resources has been slow and sustainable.

Nevertheless, there are some practical problems, which will need immediate attention:

1. Improvements in health services and incomes of the people will help save many of the children from early death and lengthen our life span. This will lead to a rapid growth of population.
2. A survey has shown that nearly all the land available for cultivation is already in use. Any further expansion of land to meet the demand of an increasing population will lead to destruction of forest and erosion of the top soil. The new land acquired for settlement will be on much steeper slopes and more prone to erosional forces. Moreover, many of our farmers own less than 2 hectares of cultivable land. Small farms like these will become even smaller, when the farm land is distributed among successive children of the family. The pressure on small farmlands will be more when the yield will have to be increased by using chemical fertilizers in order to feed the growing number of mouths in the family.

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3. Increased population will also lead to an increased demand for livestock, which is an essential source of income for our farmers. This will lead to overgrazing and reduce the natural capacity of the land to regenerate fodder.

   Ruminants such as the cattle, yaks, goats and sheep also emit methane gas. If their population grows, there will be an increased output of methane into the atmosphere.

4. Bhutan has now become a trading partner with many countries. The vast areas of forest will help us earn some revenue through the export of timber and timber products. In 2006, there are as many as 414 wood based industries compared with only 103 in 1990 and 40 in 1980 in Bhutan. Our per capita consumption of fuel wood, which is 3.5 cubic metre per annum, is one of the highest in the world. This would eventually lead to the devastation of our forests.

5. Landslides are common during the monsoon. Construction of main motor roads and feeder roads destabilizes the soil along the slopes. It has been said that the Himalayan soils are geologically unsettled. Disturbances by human activities will make the problem worse, if proper planning is not carried out.

6. Urban centres and industries usually have the problems of pollution and lack of proper facilities for disposing of solid waste such as that from the kitchen, human wastes and industries. When the industries expand and urbanisation is on the increase, such problems will grow, leading to poor sanitation and health, and even endangering life as water and air quality deteriorate.

7. Increased consumption of fossil fuels and natural gas indicates the level of development, but it is also an index of atmospheric pollution. Table 12-5 shows petrol, diesel and natural gas consumption in Bhutan over half a decade.

Figure 12-10 Reforestation has been a part of the national plan to maintain forest coverage to the maximum. Top, degraded forest in Chuzom. Below, after plantation.

Table 12-5 Fuel consumption in Bhutan from 2002 to 2006.

Product	Volume and Value	Year			
		2002	2003	2004	2005
Petrol	Volume in KL	9,112	10,229	11,800	13,775
	Value in million	208,340	261,642	340.030	449.000
Diesel	Volume in KL	43,507	48,599	50,809	51,440
	Value in million	655.810	854.291	1,023.240	1,263.300
LPG	Volume in MT	3,887.250	4,017.000	4,055.000	4,472.000
	Value in million	54.860	56.400	65.850	74.380
Kerosene	Volume in KL	9,001	9,706	9,781	12,545
	Value in million	74,560	81.040	81.410	105.170

(Source: Tashi Commercial Corporation, Phuntsholing, 1992 and Dept. Energy, 2006.)

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How to Sustain Bhutan's Natural Environment?

It is very simple talk about how to sustain our resources in future. Suppose there is plenty of food on a table and a very long queue of people coming to get the food. We are presently serving ourselves with food at the table and those behind us are our future generations. We can take as much as we want and leave very little for those behind us. We will perhaps throw the food away because we cannot eat all of it, or eat it even if our hunger is satisfied. Alternatively, we can take an amount that is just enough to satisfy our hunger and leave enough for everyone in the queue, so that the food on the table is sufficient till the last person. Sustainable use of the resources simply means sharing them among ourselves and with those who follow us.

It is always better to prevent the problems before they occur rather than try to solve them when they are with us. Bhutan is presently in a situation where prevention is possible. Conservation is one such way of preventing possible disasters in the future. Some suggestions are describe below.

Family Size

You have noticed that most of the problems described above arise from an increase in population. It may seem, then, that curbing the growth of population can eliminate many of the problems. Bhutan's population has not reached an alarming level, but it will do so in the course of time. What should be done at the present time is to limit family size, so that parents can provide better food, clothing and education for all the children within their limited resources.

People can do this by delaying marriage. In most countries today people marry in their mid-twenties and some do not marry until they are in their thirties. Most people now keep a gap of at least three years between the first and the second child. Families usually bring up two to three children.

The advantages of doing this is that the women can maintain better health. Families with fewer children can provide better food, clothes and education. The children also have better opportunities for getting jobs and a better place in society as they have been brought up in a sound condition. This is less possible in a family which has a large number of children and limited resources.

Government Policies

The Royal Government of Bhutan has worked out programmes which will help make sustainable use of our resources. The Department of Forestry has estimated that in order to keep the balance between human activities and the natural environment, 60 percent of the country's geographical area should be preserved in forest cover at all times.

In order to achieve this, the government has in place the policy and legal framework such as the Forest and Nature Conservation Act of 1995, the Mines and Minerals Management Act of 1995, the Biodiversity Act of 2000 and the Environment Impact Assessment Act of 2000. The main purpose of these papers is to forestall any negative impact on the natural environment that would result from economic and developmental activities.

An environmental trust fund called the Bhutan Trust Fund for Environmental Conservation (BTFEC) is already in operation, supporting conservation and environmental education programs in the country. The trust fund was established in 1991 with an initial amount of 10 million US dollars with contribution from the World Wide Fund for Nature (WWF), the World Bank/Global Environment Facility (GEF), the Goverment of Netherlands, Norway and our own contribution to it. At the moment, the capital has grown up to 30 million US Dollar and the investment income from this principal amount is used to fund conservation of the environment and environmental education programs in the country. It will also help set up national parks

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and programmes to increase the awareness of the public regarding the importance of using environment friendly farming and forestry techniques and keeping the environment clean.

The Government has reserved as much as 26 percent of the country as protected areas and another 9 percent as biological corridors for the preservation and conservation of Bhutan's wildlife and biodiversity. It is also trying to assure that afforestation takes place in areas where trees have been cut down. During the period from 1987 to 1992, a total land area of 18,000 hectares were replanted with trees. The 2nd of June, the Coronation Day of the fourth Druk Gyalpo, has been designated as **Social Forestry Day** to highlight the importance of trees in our daily life.

Literacy

We need to open the door of literacy and education to many of our people living in rural areas and especially to rural women.

It is said,

if you educate a man, you educate a member of the family. But if you educate a woman, you educate the whole family.

It is the woman who is with the children for most of their childhood and it is the mother from whom most of our children learn. If a woman decides, it is a decision for the family. Educating girls means educating future mothers. Awareness of the environment and the impact of various activities on the natural environment can be made possible only through education.

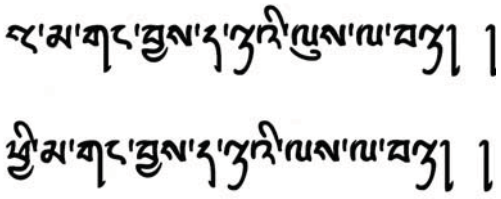
If we want, it is possible to use these natural resources wisely and still have enough for both ourselves at present and for our children, grandchildren, great grandchildren and their descendants. Education is the most effective tool for reshaping our minds and attitudes. It is through education that we will come to realise how important nature is to our very survival.

Epilogue

It is important to bear in mind that the density of population is not a criterion to rate a country rich or poor. A country is poor and overpopulated when the resources available cannot support the existing population, in spite of a low density. Some European countries have a density as high as 400 persons per square kilometre, and still enjoy high standard of living as they have adequate resources to support the population.

Bhutan's density may be low, but the resource are limited and we are still developing. We have no reason to be complacent.

Throughout this book, you have learnt how people and the natural environment interact, and how people's activities have affected the ecosystem on which we depend. It is important that each of you use this knowledge when you make decisions, and then act accordingly with conviction. Remember, what you do at the present time will vastly affect the well being of our future generations. A saying in our country goes thus:



Look at the present physical condition to learn what deeds were done in the past life;
Look at the present deeds to know what will one be in the next life.

It is quite possible that we will be reborn in a future life to suffer the consequences, or to enjoy the results, of the deeds or our present life.

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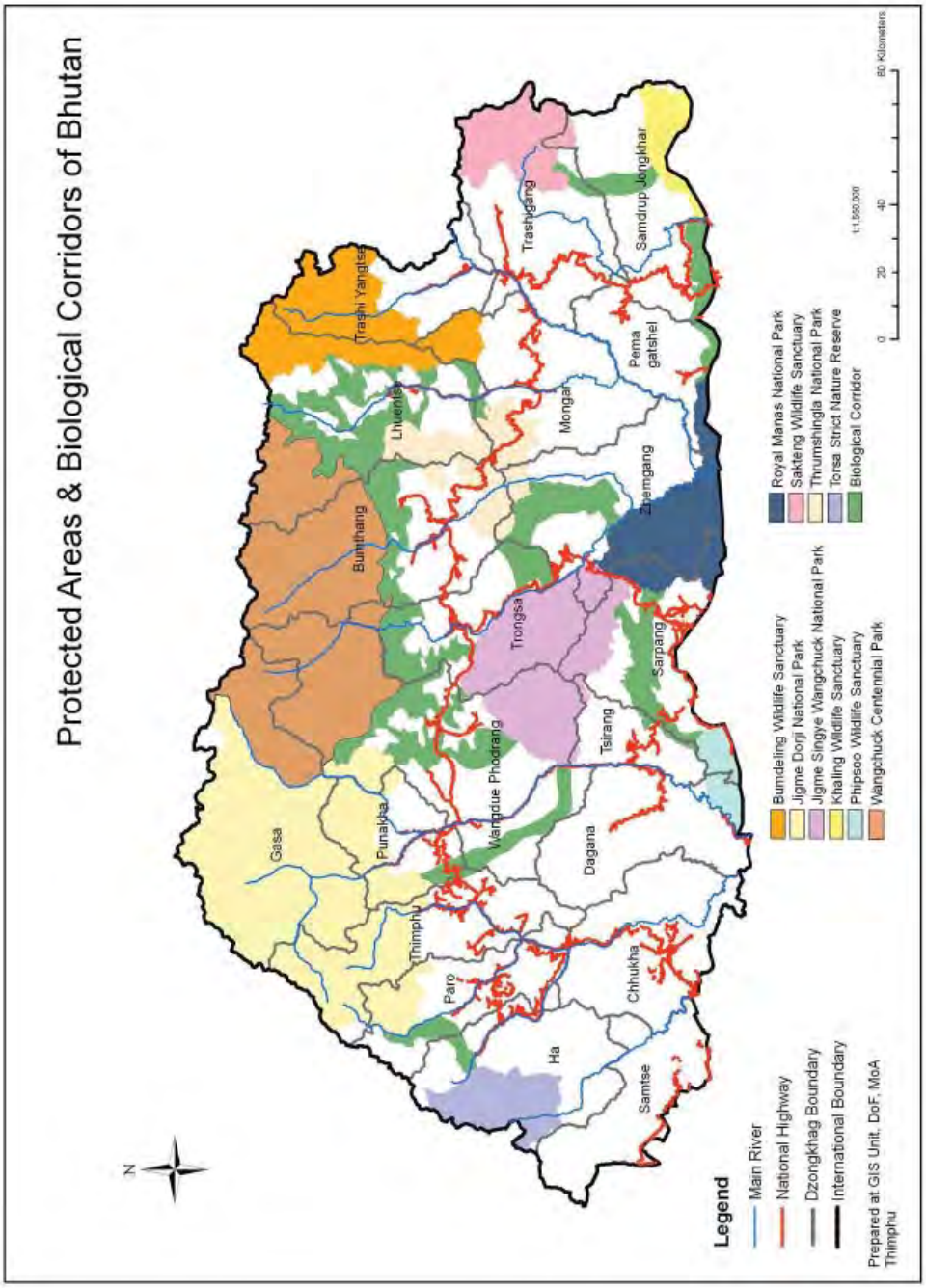

Figure 12-11 Map of Bhutan showing protected areas and wildlife sanctuaries.

Questions and Activities

1 If there is no problem of degradation of the environment in Bhutan, why do you think we should worry so much now?

2 a Use the data in Table 12-5 to draw bar graphs or line graphs for the three fuels.

b Describe the pattern produced by these graphs.

3a Why do you think overpopulation is related to environmental degradation?

b List the steps that you think are practical solutions to the problems on our earth today.

4 Make a list of how you think Bhutan's natural environment could be influenced by other countries or vice-versa.

Summary Activities

1 Describe the meaning of the following terms in your own words and phrases:
- natural ecosystem
- producer
- consumer
- food chain
- carrying capacity
- global warming
- sustainable use of resources

2 Draw a flow diagram in which you can show the relationship between the natural environment and human activities.

3 Divide yourself into groups of 6 or 7 and take an idea from this chapter that you think is important for the general public to understand. Write a short skit of 5-10 minutes duration and perform it at a community gathering.

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