UNIT 1 INTRODUCTION TO NATURAL RESOURCES

Structure

1.1 INTRODUCTION

Nature has bestowed us with many gifts. They are commonly called as *natural resources*. The natural resources have made this planet livable and have supported the evolution and sustenance of living organisms. Natural resources are of utmost importance to all living beings particularly to humans.

In this unit, we will be discussing about natural resources such as *land*, *water*, *energy*, *minerals*, *forests* and *wildlife*. Natural resources can be classified as *physical resources* or *biotic resources* and in another way as *renewable* or *non-renewable resources*.

India is a vast country and is blessed with many natural resources. We will discuss some general features about India. The availability and distribution of these resources will be described in detail so that you can appreciate the resource wealth of our country. We are fortunate in having all the vital natural resources such as land, water, minerals and a large variety of living organisms. A brief discussion of various natural resources would form part of this unit. However, in Units 2 and 3, you would study about them in more detail.

The consumption of natural resources is increasing because of many factors such as increasing population, increasing pace of development including industrialization, urbanization, mining and related activities etc. However, the amount of natural resources is limited and they are depleting at a very fast rate. Thus, there is an urgent need for their conservation. This aspect of natural resources is dealt in Unit 4.

Objectives

After studying this unit, you should be able to:

- explain the meaning of the term resource;
- distinguish between different types of resources;
- discuss the importance of natural resources;

- describe important features of India – geographical setting, climate, physical features, rainfall, natural resources etc.; and
- explain the distribution of various natural resources in India and highlight their importance.

1.2 WHAT IS A RESOURCE?

A *resource* is anything we get from the environment to meet our needs and wants. Some resources are directly available for use. The examples of such resources being freshwater, air, plants and animals.

Natural resources are the raw materials available in the environment that organisms use for their survival. They may be either *biotic* (forests and wildlife) or *abiotic* (water, soil, air and minerals) in nature. The food you eat, the cloths you wear, and the roof over your head – all of these are necessary for your survival and they come from *natural resources*. Natural resources are, of course, the physical bases for human life.

The **fertile farmland**, for example, is a natural resource that supports food production. However, a **fast flowing river** is an example of a *potential resource* for producing hydroelectricity. In the case of the fertile farmland and fast flowing river, useful products such as food and electricity can be derived, but the value of the wilderness area or mountain cannot be expressed in similar material terms. This is not to say that they have no value, but their value is of a kind *different* from that of the farmland and the river. The wilderness and mountains too are also important natural resources. They are of enormous aesthetic value.

Natural resources can be defined as *those parts of nature that can provide goods and services for humans including opportunities for recreation, the appreciation of scenic beauty, and the disposal of wastes*.

The natural resources can be broadly categorized into the following three categories:

- One category of resources consists of raw materials and energy resources used by humans. Usually these are used as inputs into the economic system. These have traditionally been regarded as natural resources. Their examples are minerals, ores, coal and oil.

- The natural environment also provides the essential life-support system for humans, including oxygen to breath and water to drink as well as material goods such as food.

- Thirdly, another group of resources comprises parts of the environment that can provide services rather than material goods. They provide the sump into which the waste products of the economic system and human life, in general, are disposed. In addition to purification of air, other natural processes such as *nitrogen fixation*, *soil formation* and its *fertility* are very important for the survival of human beings.

1.2.1 Types of Natural Resources

Natural resources can be classified in various ways. The natural resources are divided into two categories *viz.* **abiotic** (or **physical resources**) and **biotic resources**. The biotic resources constitute plants, animals and micro-organisms whereas the abiotic resources include non-living materials such as land, soil, water, metals and minerals.

Another common categorization of natural resources is into ***renewable*** and ***non-renewable resources***, or alternatively as ***flow*** or ***stock resources***. *Solar energy*, and *water* are examples of flow resources, which are permanently available (at least on the

human time scale) in a continuous supply. On the other hand, the stock resources are those whose quantities are fixed and they keep decreasing with their human use. The examples of stock resources being *fossil fuel deposits, mineral deposits* etc. The former are not affected by human use while the latter group of resources can be modified very easily in the course of their human use.

Renewable resources are those natural resources that can be replaced by nature over a period of time. Trees, wildlife and soil are renewable resources. Air, water and sunlight are also renewable resources on which all life depends. However, their excessive use or reckless exploitation can destroy and permanently wipe them out irreversibly e.g. excessive hunting of wildlife species can lead to their extinction.

Fossil fuels are fuels made up of dead remains of organisms that lived millions of years ago. Fossil fuels such as – petroleum, coal, oil and natural gas as well as mineral and metal ores represent non-renewable resources which keep on decreasing with growing human use.

Non-renewable resources are those natural resources that are available only in limited amounts and are not easily replaced by nature. Many of the products you depend on every day are made from non-renewable resources. Plastic toothbrushes, polystryrene cups and gasoline – all are made from petroleum which is a non-renewable resource and is a *fossil fuel*.

There is another category of natural resources which are – **aesthetic** or **amenity resources**. Examples of such resources are solitude, the scenic beauty and peaceful surroundings. As the population levels rise and a need to get away from the crowd increases, aesthetic resources become more and more important.

SAQ 1

What is a natural resource? How are natural resources useful to us?

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SAQ 2

What do you understand by abiotic and biotic resources? Explain using examples.

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1.3 INDIA – GENERAL INFORMATION

India is the second most populous country in the world and ranks second only to China. In 2004, it had a population of 1,065,070, yielding an average population density of 358 persons per sq.km. (928 per sq.km). An estimated 72 percent of India's inhabitants live in rural areas. The population grew by 21.3 percent between 1990 and

2000. The population statistics is given in Table 1.1 and the population density of India is shown in Fig.1.1.

National Flag

National Emblem

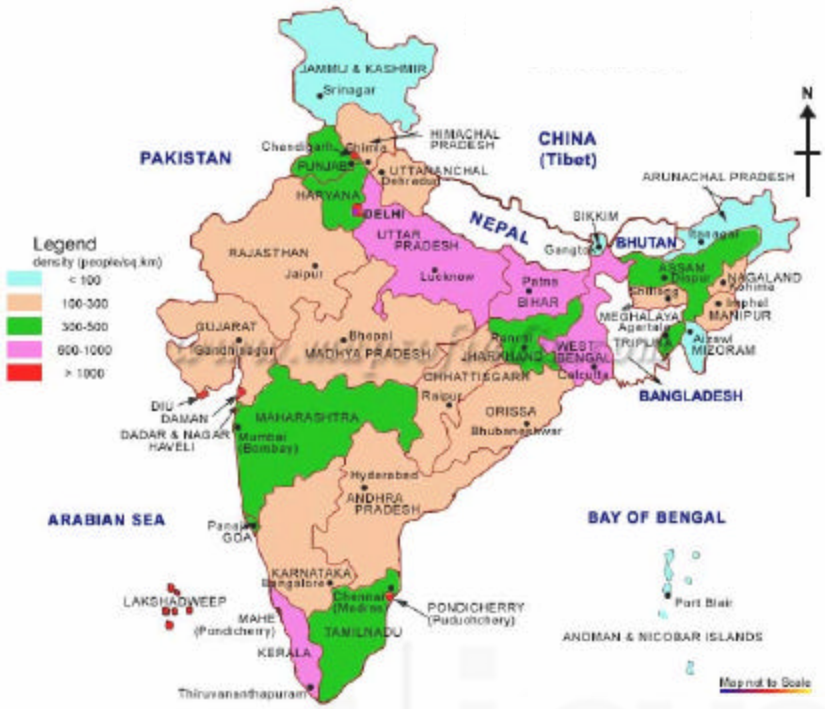

Fig.1.1: Population Density Map of India-2001

Table 1.1: Population growth in India

Sl.No.	States/Union Territories	1951	1961	1971	1981	1991	2001
1.	Uttar Pradesh	60274	70144	83849	105137	132062	166198
2.	Maharashtra	32003	39554	50412	62783	78937	96879
3.	Bihar	29085	34841	42126	52303	64531	82999
4.	West Bengal	26300	34926	44312	54581	68078	80176
5.	Andhra Pradesh	31115	35983	43503	53551	66508	76210
6.	Tamil Nadu	30119	33687	41199	48408	55859	62406
7.	Madhya Pradesh	18615	23218	30017	38169	48566	60348
8.	Rajasthan	15971	20156	25766	34262	44006	56507
9.	Karnataka	19402	23587	29299	37196	44977	52851
10.	Gujarat	16263	20633	26697	34086	41310	50671
11.	Orissa	14646	17549	21945	26370	31660	36805
12.	Kerala	13549	16904	21347	25454	29099	31841
13.	Jharkhand	9697	11606	14227	17612	21844	26946
14.	Assam(2)	8029	10837	14625	18041	22414	26656
15.	Punjab	9161	11135	13551	16789	20282	24359
16.	Haryana	5674	7591	10036	12922	16464	21145
17.	Chhatisgarh	7457	9154	11637	14010	17615	20834
18.	Delhi*	1744	2659	4066	6220	9421	13851
19.	Jammu & Kashmir (3)	3254	3561	4617	5987	7837	10144
20.	Uttaranchal	2946	3611	4493	5726	7051	8489
21.	Himachal Pradesh	2386	2812	3460	4281	5171	6078
22.	Tripura	639	1142	1556	2053	2757	3199
23.	Meghalaya	606	769	1012	1336	1775	2319
24.	Manipur(4)	578	780	1073	1421	1837	2294
25.	Nagaland	213	969	516	775	1210	1990
26.	Goa	547	590	795	1008	1170	1348
27.	Arunachal Pradesh (1)	0	337	468	632	866	1098
28.	Pondicherry*	317	369	472	604	808	974
29.	Chandigarh*	24	120	257	452	642	901
30.	Mizoram	196	266	332	494	690	889

31.	Sikkim	138	162	210	316	406	541
32.	Andeman & Nicobar Islands*	31	64	115	189	281	356
33.	Dadra & Nagar Haveli*	42	58	74	104	138	220
34.	Daman & Diu*	49	37	63	79	102	158
35.	Lakshadweep*	21	24	32	40	52	61
ALL INDIA[2,3,4]		**361088**	**439235**	**548160**	**683329**	**846421**	**1028737**

Note: (1) Census used for the first time in 1961.
(2) The 1981 Census could not be held in Assam. Total population for 1981 has been worked out by interpolation.
(3) The 1991 Census could not be held in Jammu & Kashmir. Total population for 1991 has been worked out by interpolation.
(4) India and Manipur figures include estimated population for those of the three sub-divisions viz. Mao Maram, Paomata and Purul Senapati district of Manipur as census results of 2001 in these three sub-divisions were cancelled due to technical and administrative reasons.

Source: Office of the Registrar General of India, Ministry of Home Affairs.
Economic Survey, 2004-2005

India is located in South Asia as is shown in Fig.1.2. It is bounded on the north by Afghanistan, China, Nepal and Bhutan. On its eastern side are Bangladesh and Myanamar while Pakistan is on its west.

Fig.1.2: Position of the India in the South Asia

In terms of the geographical size, India is the seventh largest country in the world. India has a landmass of 3.29 million sq.km. The length of the country from North to South is about 3,050 km and from East to West, it extends to about 2,950 km. It has a coastline of over 7000 km. India is divided into 28 states and 7 union territories including the National Capital Territory of Delhi as is shown in Table 1.2. The capital city of India is New Delhi. India is the largest democracy of the world. The country has a large diversity of cultures, religions and languages.

Table 1.2: States and Union Territories

States		Union Territories
1. Andhra Pradesh	15. Maharashtra	1. Andaman and Nicobar Islands
2. Arunachal Pradesh	16. Manipur	2. Chandigarh
3. Assam	17. Meghalaya	3. Dadra and Nagar Haveli
4. Bihar	18. Mizoram	4. Daman and Diu
5. Chhattisgarh	19. Nagaland	5. Lakshadweep
6. Goa	20. Orissa	6. Pondicherry
7. Gujarat	21. Punjab	
8. Haryana	22. Rajasthan	**National Capital Territory**
9. Himachal Pradesh	23. Sikkim	Delhi
10. Jammu and Kashmir	24. Tamil Nadu	
11. Jharkhand	25. Tripura	
12. Karnataka	26. Uttaranchal	
13. Kerala	27. Uttar Pradesh	
14. Madhya Pradesh	28. West Bengal	

The physical division of states and union territories on the map of India are shown in Fig.1.3.

Fig.1.3: States and Union Territories of India

Some general facts about India are as follows:

Land Area : 3.29 million square kilometers

Capital : New Delhi

Population : 1,065 million (2004)

Population Density : 358 persons per sq.km.

Life Expectancy : 60.4 years, male: 61.8 years, female: 59 years

Literacy Rate : 65.38 percent (Kerala has the highest literacy rate of 90.92 per cent. As per 2001 census, all states and union territories have achieved a male literacy rate of 60 percent and most of the states have attained a female literacy rate of over 50 percent).

Languages Spoken : India is a multilingual country with 18 principal languages recognised by the constitution.

1.3.1 Climate

India is mainly a tropical country but exhibits almost all climatic conditions from hot deserts to cold deserts due to great altitudinal variations. There are following four seasons:

i) Winter (December-February),
ii) Summer (March-June),
iii) South-west monsoon season (June-September), and
iv) Post monsoon season (October- November).

During the post monsoon season, commonly known as winter monsoon, monsoon rains begin over north India and pass over the Bay of Bengal before reaching the Andamans and the South-east coast. However, the south-west or the summer monsoon is the main source of rainfall in the country providing 80% of the precipitation.

Different climatic regions of India are shown on the map of India in Fig.1.4.

Fig.1.4: Climatic Regions of India

1.3.2 Agro-climatic Zones

The country is divided into fifteen agricultural regions based on agro-climatic features such as soil type, climate, temperature, rainfall and availability of water.

1. Western Himalayan division
2. Eastern Himalayan division
3. Lower Gangetic plain region
4. Middle Gangetic plain region
5. Upper Gangetic plain region
6. Trans Gangetic Plain region
7. Eastern plateau and hill region
8. Central plateau and hill region
9. Western plateau and hill region
10. Southern plateau and hill region
11. East coast plain and hill region
12. West coast plain and hill region
13. Gujarat plain and hill region
14. West plain and hill region
15. Island region

1.3.3 Physiogeography of India

Physiographically, India may be divided into seven well defined regions, see Fig.1. 5.

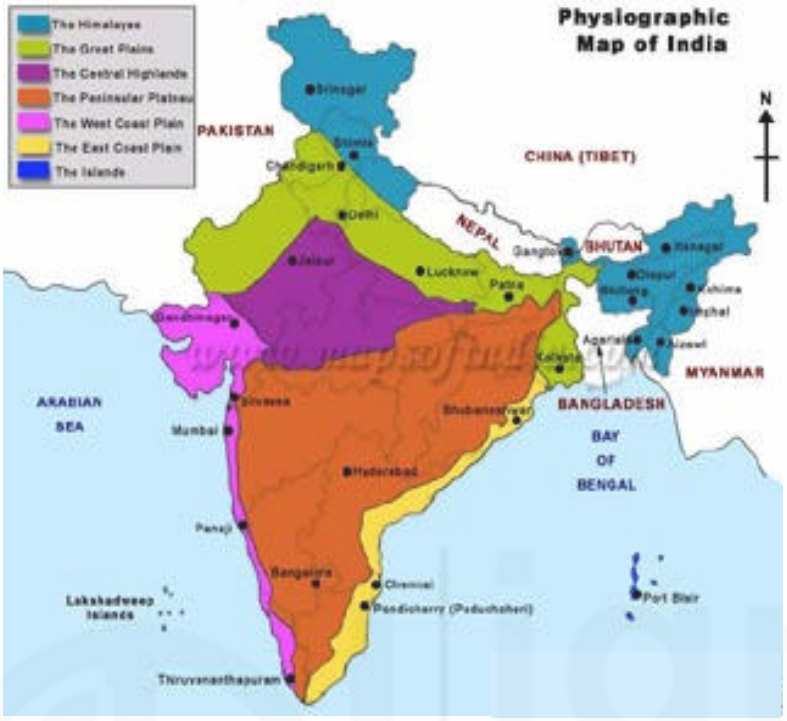

Fig.1.5: Physiogeographic regions of India

1. The Northern Mountains, comprising the mighty Himalayan ranges;
2. The Great Plains, traversed by the Indus and Ganga Brahmaputra river systems. As much as one third of this lies in the arid zone of western Rajasthan. The remaining area is mostly fertile plains;
3. The Central Highlands, consisting of a wide belt of hills running east-west starting from Aravalli ranges in the west and terminating in a steep escarpment in the east. The area lies between the Great Plains and the Deccan Plateau;
4. The Peninsular Plateaus comprising the Western Ghats, Eastern Ghats, North Deccan Plateau, South Deccan Plateau and Eastern Plateau;
5. The East Coast, a belt of land of about 100-130 km wide, bordering the Bay of Bengal and lying to the east of the Eastern Ghats;
6. The West Coast, a narrow belt of land of about 10-25 km wide, bordering the Arabian Sea and lying to the west of the Western Ghats, and;
7. The islands, comprising the coral islands of Lakshadeep in Arabian Sea and Andaman and Nicobar Islands in the Bay of Bengal.

1.4 NATURAL RESOURCES

India is blessed with a large variety of natural resources. Land and water are the two most important resources. Besides, the country is also rich in energy and mineral resources. A wide range of climatic and physiogeographic conditions has made India rich in forest and wild life resources also. In this section, we will highlight the wealth of natural resources found in India.

1.4.1 Land and Soil

Land and *Soil* are unique physical resources. **Land** is a basic resource and provides habitat for all terrestrial plant and animal life. It also provides ground for all ecosystems. **Soil** and its **fertility** are very valuable resources which sustain our food production system and form the basis of Indian agricultural economy.

Soil supports the growth of plants on the earth's surface. It supplies essential nutrients and provides water needed for plant growth. Soil also forms the substrate for micro-organisms. The main components of soil being mineral matter, organic matter, water, air and living organisms.

Soils of India can be broadly classified into three categories.

i) **Fertile soils** – These are arable and cultivable soils. *Alluvial*, *black* and *red* soils belongs to this category.
ii) **Potentially arable soils** – These include *saline* and *alkaline* soils.
iii) **Soils which are not suitable for cultivation** – The examples of this category of soils are *laterite*, *forest* and *hill* soils.

Different types of soils of India are shown in Fig.1.6.

Fig.1.6: Soils of India

Alluvial soils cover about 78 mha (about 24%) of the total land and occur in the great Indo-Gangetic Plains, in the valleys of Narmada and Tapti in Madhya Pradesh and the Cauvery in Tamil Nadu. These soils are considered very good for the production of wheat, rice other cereals, pulses, oil seeds, potato, sugarcane, etc. The **black** cotton soils cover about 51.8 mha.and are found in the States of Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Andhra Pradesh, Tamil Nadu, Uttar Pradesh and Rajasthan. These are also considered good for cultivation of cotton, cereals, pulses, oil seeds, citrus fruits, vegetables, etc. In addition, **Red soils** have been estimated to occur in 51.8 mha and are primarily found in Tamil Nadu, Karnataka, Kerala, Maharashtra, Andhra Pradesh, Madhya Pradesh, Bihar and West Bengal. These are most suited for rice, ragi (millet), tobacco and vegetable cultivation. **Laterite** and **lateritic soils** occur in 12.6 mha. Laterite soils are common in the low hills of Andhra Pradesh, Karnataka, Kerala, Madhya Pradesh, Orissa and Assam. These are not considered good for

agriculture. The **desert soils** cover an area of about 37 mha and are not suitable for agriculture.

The geographical area of India, i.e., 329 mha is only 2.4% of the world's total area on which 16.7% of the world's population and about 18% of the world's livestock population lives. Out of this, roughly 264 mha of land is available for agriculture, forestry and related purposes.

On account of growing population and cumulative human impact, our land resources have fast deteriorated. The per capita availability of land resource in India is less than 0.27 hectares and is likely to reduce further under the pressure of growing population. In view of this, it is important to prevent any degradation of land resources which represent a vital life support system and restore the potential of degraded land to meet our present and future needs.

1.4.2 Water

Water is the most essential component for survival of life. It is distributed on earth in various bodies and forms. Oceans contain 97.2% of total water whereas ice caps and glaciers have 2.15%. Together, these two resources account for more than 99% of total water on the Earth but both these resources are generally not of much use to human beings. The share of grand water is 0.31% whereas rivers and streams have 0.0001% of total water.

Water has been important for mankind since ancient times. Many civilizations originated near the banks of the rivers. Our own civilization – Indus valley civilization is one such example.

The water resources of India are listed in Table 1.3.

Table 1.3: National Water Resources

Sl. No.	Water resources	Quantity (Cu. km.)
1.	Annual Precipitation Volume (including snowfall)	4000
2.	Average Annual Potential flow in Rivers	1869
3.	Per Capita Water Availability (1997)	1967
4.	Estimated Utilizable Water Resources i) Surface Water Resources 690 Cu.km. ii) Ground Water Resources 432 Cu.km.	1122

The main sources of water in India bein g rainfall (including snowfall) and a large network of rivers. Let us now study about them in a little more detail.

A. Rainfall

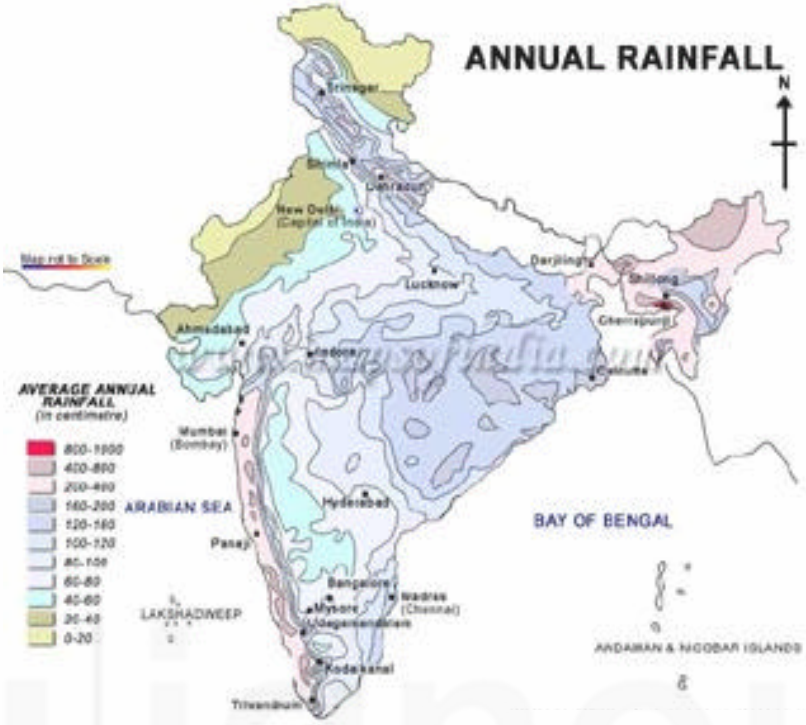

Fig.1.7: Annual Rainfall pattern in India

India receives annually about 4000 cubic kilometres of water through precipitation. About 80% of the country's annual rainfall is mainly form the South-West monsoon season of June to September, followed by the North-West monsoon in November-December. Most of rainfall is therefore few months in a year, the country remaining dry for almost the rest of the year. Also, the rainfall is highly variable both spatially and in quantity, see Fig.1.7 above. It varies from as low as 100 mm in western Rajasthan to as high as 9000 mm in Meghalaya in the north-east India. Monsoon rainfall is usually torrential in intensity. This results in tremendous run-of resulting in soil erosion.

a) Major rivers of India

The rivers of India can be divided into three groups: the great Himalayan rivers of the north, the westward-flowing rivers of central India, and the eastward-flowing rivers of the Deccan Plateau and the rest of peninsular India. Only small portions of India's rivers are navigable because of silting and the wide seasonal variation in water flow. Water transport is thus of little importance in India. Barrages, structures that redirect water flow, have been erected on many of the rivers for irrigation, diverting water into canal systems.

The major rivers of India are shown in Fig.1.8. The Indian subcontinent's three great northern rivers, the Indus, the Brahmaputra and the Ganges, flow through India. The Indus (about 2,900 km) originates in the Himalayas of western Tibet, flows through the Ladakh region of Jammu and Kashmir State, then enters Pakistan. The waters of three of its tributaries, the Sutlej, Ravi, and Chenab have been diverted, under the Indus Water Treaty, for use in India. The Brahmaputra (about 2,900 km) rises in the Tibetan Himalayas and flows through Assam state and then south through Bangladesh to the Bay of Bengal. The Ganges (about 2,510 km), known as *Ganga* in India, rises in the Indian Himalayas and enters the Gangetic Plain. At Allahabad it is joined by its major tributary, the Yamuna. The main branch of the Ganges flows through Bangladesh to the Bay of Bengal, while a second branch meets the bay in India, near Calcutta. Both the Brahmaputra and

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Ganges rivers discharge enormous amounts of water, almost all of it during the monsoon season.

Fig.1.8: Major rivers of India

The Narmada (1,289 km) is India's major west-flowing river; it flows mainly in the state of Madhya Pradesh, emptying into the Arabian Sea in Gujarat state.

Three major rivers flow east into the Bay of Bengal, rising from the western hills of the Deccan Plateau. The northernmost is the Godavari (about 1,400 km). It has a south of the Godavari is the Krishna (about 1,300 km). The smallest of the three rivers is the Kaveri (760 km).

India has a number of other significant rivers. Tributaries of the Ganges from the north include the Kosi, Gandak, Ghaghara, Gumti, and Sarda rivers. Joining the Ganges from the south are the Betwa, Chambal, and Son rivers. The Mahi, Sabarmati, and Tapi flow west into the Arabian Sea in Gujarat. Flowing west to join the Indus River in Pakistan are the Beas, Chenab, Jhelum, Ravi, and Sutlej, all rivers of the Punjab region of India and Pakistan. The Mahanadi and Brahmani rivers rise in Madhya Pradesh and Orissa states, respectively, and flow east to empty into the Bay of Bengal. The waters of all these rivers are used to irrigate crops, but the amount stored for purposes of irrigation and power generation varies enormously from river to river.

Fig.1.9 shows major river basins of India.

Fig.1.9: Major rivers basins of India

Basinwise ground water potential is given below in Table 1.4.

Table 1.4: Basinwise ground water potential

Sl. No.	Name of Basin	Total Replenishable Ground Water Resources (Cubic km/Year)
1.	Brahmai with Baitarni	4.05
2.	Brahmaputra	26.55
3.	Cambai Composite	7.19
4.	Cauvery	12.30
5.	Ganga	170.99
6.	Godavari	40.65
7.	Indus	26.49
8.	Krishna	26.41
9.	Kutch & Saurashtra Composite	11.23
10.	Madras and South Tamil Nadu	18.22
11.	Mahanadi	16.46
12.	Meghna	8.52
13.	Narmada	10.83
14.	Northeast Composite	18.84
15.	Pennar	4.93
16.	Subarnrekha	1.82
17.	Tapi	8.27
18.	Western Ghat	17.69

Total	**431.42**

Twelve rivers of India are classified as major rivers whose total catchment area is 252.8 million hectare (mha). Of the major rivers, the Ganga – Brahmaputra Meghana system is the biggest with catchment area of about 110 mha which is more than 43 percent of the catchment area of all the major rivers in the country. The other major rivers with catchment area more than 10 mha are Indus (32.1 mha), Godavari (31.3 mha), Krishna, (25.9 mha) and Mahanadi (14.2 mha). The catchment area of medium rivers is about 25 mha. Subernarekha with 1.9 mha catchment area is the largest river among the medium rivers in the country. Table 1.5 lists the length and catchment area of major rivers.

Table 1.5: Major river basins

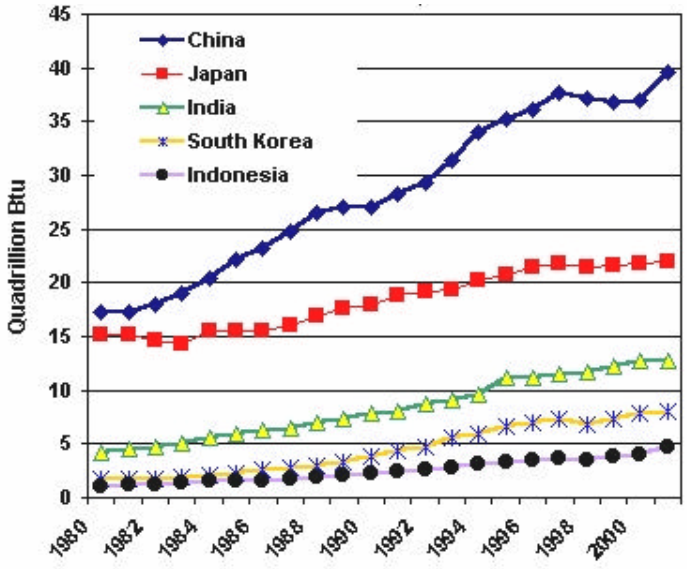
Sl. No.	Name of the River	Origin	Length (km.)	Catchment Area (Sq. km.)
1.	Indus	Mansarovar (Tibet)	1114 +	321289 +
2.	a) Ganga	Gangotri (Uttar Kashi)	2525 +	861452 +
	b) Brahmaputra	Kailash Range (Tibet)	916 +	194413 +
	c) Barak & other rivers flowing into Meghna, like Gomti, Muhari, Fenny etc.			41723 +
3.	Sabarmati	Aravalli Hills (Rajasthan)	371	21674
4.	Mahi	Dhar (Madhya Pradesh)	583	34842
5.	Narmada	Amarkantak (Madhya Pradesh)	1312	98796
6.	Tapi	Betul (Madhya Pradesh)	724	65145
7.	Brahmani	Ranchi (Bihar)	799	39033
8.	Mahanadi	Nazri Town (Madhya Pradesh)	851	141589
9.	Godavari	Nasik (Maharashtra)	1465	312812
10.	Krishna	Mahabaleshwar (Maharashtra)	1401	258948
11.	Pennar	Kolar (Karnataka)	597	55213
12.	Cauvery	Coorg (Karnataka)	800	81155
			Total	**2528084**

1.4.3 Energy Resources

There is a direct relationship between population growth, economic standards and energy consumptions. The per capita energy consumption and GNP a country are indicators of living standards of its people.

The energy consumption is increasing rapidly day by day both in developing and developed countries. The energy consumption in some of the Asian Countries is shown in Fig.1.10.

The energy demands in India also risen from 4.16 quadrillion Btu (quads) in 1980 to 12.8 quads in 2001. The energy consumption is still below that of Germany (14.35 quads), Japan (21.92 quads), China (39.67 quads), and the United States (97.05 quads).



Source: EIA

Fig.1.10: Energy consumption trends of some Asian countries

The consumption by India with 16.6% of world's population only 3.4% of world's energy consumption whereas it is 24.5% for the United States with 4.6% of world's population. The population of India crossed one billion in the year 2000 and there is increasing energy demand to meet the growing needs of increasing this developing economy. The consumption of electricity in India for recent years is given in Table 1.6.

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Table 1.6: Electricity consumption for various uses in India

Year	Domestic	Commercial	Industry	Traction	Agriculture	Others
1965-51+	12.6	7.5	62.6	7.4	3.9	4.0
1960-61	10.7	6.1	69.4	3.3	6.0	4.5
1970-71	8.8	5.9	67.6	3.2	10.2	4.3
1975-76	9.7	5.8	62.4	3.1	14.5	4.5
1977-78	9.9	6.4	61.6	3.3	14.6	4.2
1978-79	9.8	5.6	61.8	2.8	15.6	4.4
1979-80	10.8	6.0	58.9	2.9	17.2	4.2
1980-81	11.2	5.7	58.4	2.7	17.6	4.4
1981-82	11.6	5.8	58.8	2.8	16.8	4.2
1982-83	12.7	6.1	55.4	2.8	18.6	4.4
1983-84	12.9	6.4	55.8	2.6	17.8	4.5
1984-85	13.6	6.1	55.2	2.5	18.4	4.2
1985-86	14.0	5.9	54.5	2.5	19.1	4.0
1986-87	14.2	5.7	51.7	2.4	21.7	4.3
1987-88	15.2	6.1	47.5	2.5	24.2	4.5
1988-89	15.5	6.2	47.1	2.3	24.3	4.6
1989-90	16.9	5.4	46.0	2.3	25.1	4.3
1990-91	16.0	5.9	44.2	2.2	26.4	4.5
1991-92	17.3	5.8	42.0	2.2	28.2	4.5
1992-93	18.0	5.7	40.9	2.3	28.7	4.4
1993-94	18.2	5.9	39.6	2.3	29.7	4.3
1994-95	18.5	6.1	38.6	2.3	30.5	4.0
1995-96	18.7	6.1	37.8	2.3	30.9	4.2
1996-97	19.7	6.2	37.2	2.4	30.0	4.5
1997-98	20.3	6.5	35.4	2.3	30.8	4.7
1998-99	21.0	6.4	33.9	2.4	31.4	4.9
1999-00	22.2	6.3	34.8	2.6	29.2	4.9
2000-01	23.9	7.1	34.0	2.6	26.8	5.6
2001-02	24.7	7.5	33.3	2.5	25.3	6.7
2002-03	24.6	7.5	33.9	2.6	24.9	6.5

2003-04*	24.9	7.8	34.5	2.6	24.1	6.5

+ On a calendar year basis. **Source:** Ministry of Power
Note: Figures may not add up to 100 percent owing to rounding off

This increasing demand of energy is being met by a large variety of sources such as coal, petroleum, natural gas, nuclear and other renewable resources. Fig.1.11 shows the contribution of various energy resources.

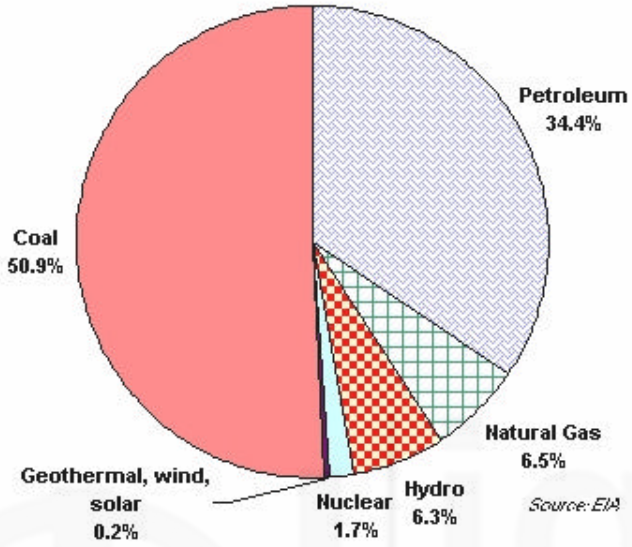


Fig.1.11: Contribution of different resources to energy production

Table 1.7 gives data for sector-wise supply of energy.

Table 1.7: Contribution of various resources for energy requirements

Sector	1970-71	1980-81	1990-91	2001-02*
Coal	36.48	56.96	94.68	133.89
Lignite	0.81	1.23	3.34	6.52
Oil	7.01	10.79	33.92	32.03
Natural gas	0.6	1.41	11.73	26.72
Hydro power	2.17	4.0	6.16	6.37
Nuclear power	0.63	0.78	1.6	5.15
Wind power	-	-	-	0.14
Total	47.67	75.19	151.43	210.82
Net imports	12.66	24.63	31.69	87.85
Commercial energy supply	60.33	99.82	183.12	298.67
Primary non-commercial energy supply	86.72	108.48	122.07	139.02
Total Primary energy supply	**147.05**	**208.3**	**305.19**	**437.69**

* provisional **Source:** Planning Commission (2002)
MTOE – million tones of oil equivalent

The estimated energy demand for some future years is given in Table 1.8.

Table 1.8: Sector-wise estimated energy demand

Primary fuel	Demand in original		Demand (MTOE)	
	2006-07	2011-12	2006-07	2011-12
Coal (MT)	460.50	620.00	190.00	254.93
Lignite (MT)	57.79	81.54	15.51	22.05
Oil (MT)	134.50	172.47	144.58	185.40
Natural gas (BCM)	47.45	64.00	42.70	57.60
Hydro power (BkWh)	148.08	215.66	12.73	18.54
Nuclear power (BkWh)	23.15	54.74	6.04	14.64
Wind power (BkWh)	4.00	11.62	0.35	1.00
Total commercial energy	-	-	411.91	553.68

Source: http://www.teriin.org/energy/future.htm

Coal has been and will be one of the major energy source because of its availability and cheaper cost. It is mainly used for power generation, industries and as domestic fuel. India is the third largest coal producing country of the world. The coal production statistics are given in Table 1.9.

Table 1.9: Production of coal and lignite

(Million tonnes)

Year	Coal				Lignite	Total coal and lignite (5)+(6)
	Coking		Non-coking	Total		
	Metallurgical	Non-Metallurgical				
1950-51	N.A.	N.A.	N.A.	32.30	N.A.	32.30
1960-61	16.99	N.A.	38.24	55.23	N.A.	55.23
1970-71	17.82	N.A.	55.13	72.95	3.39	76.34
1975-76	22.19	7.93	69.51	99.63	3.03	102.66
1976-77	23.65	8.18	69.16	100.99	4.02	105.01
1977-78	23.23	8.10	69.65	100.98	3.58	104.56
1978-79	22.54	8.67	70.74	101.95	3.30	105.25
1979-80	24.19	6.68	73.07	103.94	2.90	106.84
1980-81	24.59	8.03	81.29	113.91	5.11	119.02
1981-82	26.89	9.23	88.11	124.23	6.31	130.54
1982-83	30.10	7.47	92.93	130.50	6.93	137.43
1983-84	30.11	6.24	101.87	138.22	7.30	145.52
1984-85	30.57	6.04	110.80	147.41	7.80	155.21
1985-86	29.07	6.57	118.56	154.20	8.05	162.25
1986-87	27.91	11.63	126.23	165.77	9.43	175.20
1987-88	26.28	14.73	138.71	179.72	11.16	190.88

1988-89	25.16	17.56	151.88	194.60	12.40	207.00
1989-90	24.50	19.93	156.46	200.89	12.80	213.69
1990-91	24.10	21.20	166.43	211.73	13.77	225.50
1991-92	26.33	19.95	183.00	229.28	14.55	243.83
1992-93	25.72	19.64	192.90	238.26	16.62	254.88
1993-94	25.99	19.07	200.98	246.04	18.10	264.14
1994-95	24.54	19.71	209.55	253.80	19.34	273.14
1995-96	23.53	16.57	230.03	270.13	22.14	292.27
1996-97	22.64	17.90	245.12	285.66	22.54	308.20
1997-98	24.16	19.34	252.43	295.93	23.05	318.98
1998-99	23.82	15.36	253.09	292.27	23.42	315.69
1999-2000	21.23	12.02	266.72	299.97	22.12	322.09
2000-2001	19.31	11.77	278.55	309.63	22.95	332.58
2001-2002*	17.96	10.71	299.12	327.79	24.81	352.60
2002-2003*	18.35	11.84	311.08	341.27	26.02	367.29
2003-2004	18.28	11.12	331.77	361.17	27.96	389.13
2003-2004 (Apr to Nov.)	10.85	6.63	201.62	219.10	17.45	236.57
2004-2005(P) (Apr to Nov.)	11.46	6.50	212.85	233.25	18.76	252.03

* Including Meghalaya Coal. N.A.: Not available (P) Provisional **Source:** Ministry of Coal
Website: http://indiabudget.nic.in

Similar to coal production, the petroleum and natural gas production has also witnessed a growth but still we are dependent upon the import of crude oil to meet over energy requirements. During 2001-02, the crude oil production was 32.03 MT whereas 75.63 MT crude oil was imported. The production of natural gas in 2001-02 was 29.7 billion cubic meters. However, the estimated recoverable reserves of crude oil and natural gas are 600 MT and 650 billion cubic meters, respectively.

Since these energy resources are in limited supply, we have to look for alternatives. There are various options and the potential of many of them is being harnessed. These include solar energy, wind energy, hydro energy, tidal energy, geothermal energy and energy from biomass. You would study about these energy resources in detail in Unit 3.

1.4.4 Minerals

Minerals are basic raw materials for many industries. They have diverse uses.

The metallic minerals inc lude iron-ore, copper-ore, chromite, zinc concentrates, gold, manganese ore, bauxite and lead ores. The major non-metallic minerals are limestone, magnesite, dolomite, barytes, kaolin, gypsum, apatite & phosphorite and fluorite. Fig.1.12 shows different mineral resources of India.

Fig.1.12: Mineral resources of India

India is endowed with significant mineral resources. India produces 89 minerals out of which 4 are fuel minerals, 11 metallic, 52 non-metallic and 22 minor minerals. Together, these minerals constitute one-fourth of the world's known mineral resources. India is the world's largest producer of mica. The main mica producing states are Bihar, Andhra Pradesh and Rajasthan. India ranks *third* among the chromite producers of the world. The chromite deposits occur in Bihar, Orissa, Andhra Pradesh, Mysore and Karnataka.

Besides, India ranks *third* in production of coal and lignite and barytes, *fourth* in iron ore, *sixth* in bauxite and manganese ore, *tenth* in aluminium and *eleventh* in crude steel in the world.

Gypsum deposits are found in Tamilnadu and Rajasthan while bauxite occurs in western Bihar, Tamilnadu, Uttar Pradesh, Maharashtra and Karnataka.

1.4.5 Forests

Forests are areas of dominant vegetation. They are also habitats for a large variety of species and wildlife. Many of the diverse life forms are located in dense forests. They are very important resources.

Forests also help in the formation of soil. They are helpful in checking soil erosion. They prevent floods and increase underground water supply. They influence climate by way of increasing humidity of air and providing resistance to winds. They are also useful in reducing the harmful impacts of global warming by acting as a major sink for carbon dioxide which is a greenhouse gas. Forests also play an important role in biogeochemical cycles, i.e. carbon cycle, nitrogen cycle and oxygen cycle.

Forests are very vital resources of the country. They are of diverse types and are treasures of a large variety of products. They are an important economic resource. They are the resource for wood which is an important building material as well as fuel

for many people across different parts of the globe. They also provide fodder, fruits, fiber, medicines, oils, nuts, resins, rubber and raw materials for a variety of things. They are also source of various products such timber, fuel wood etc. Forests are also habitats for a large variety of species and wildlife.

Approximately 27% of the earth is covered with forests. The forests resources differ from country to country. They cover 61% of Indonesia, 58% of Brazil and less than 14% of China. In India, forests cover about 20% of the land.

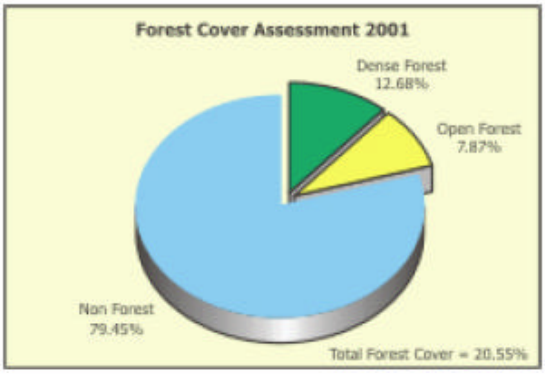
The forest resources of South Asian countries are shown in Table 1.10.

Table 1.10: Forest resources and management in South Asian Countries

	Land area	Forest area 2000					Area change 1990-2000 (total forest)		Volume and above-ground biomass (total forest)		Forest under management plan	
		Natural forest	Forest plantation	Total forest								
	'00 ha	*000 ha*	*000 ha*	*000 ha*	*%*	*ha/ capita*	*000 ha/ year*	*%*	*m^3/ ha*	*t/ ha*	*000 ha*	*%*
	13 017	709	625	1 334	10.2	n.s.	17	1.3	23	39	1 334	100
	4 701	2 995	21	3 016	64.2	1.5	n.s.	n.s.	163	178	699	23
	297 319	31 535	32 578	64 113	21.6	0.1	38	0.1	43	73	46 159	72
	30	1	–	1	3.3	n.s.	n.s.	n.s.	–	–	–	–
	14 300	3 767	133	3 900	27.3	0.2	– 78	– 1.8	100	109	1 010	26
	77 087	1 381	980	2 361	3.1	n.s.	– 39	– 1.5	22	27	–	–
	6 463	1 625	316	1 940	30.0	0.1	– 35	– 1.6	34	59	1 940	100
	412 917	**42 013**	**34 652**	**76 665**	**18.6**	**0.1**	**– 98**	**– 0.1**	**49**	**77**	–	–
	084 746	**431 946**	**115 847**	**547 793**	**17.8**	**0.2**	**– 364**	**– 0.1**	**63**	**82**	–	–

Source: http://www.fao.org/docrep/004/y1997e/y1997eOs.htm

The total forest cover of India is 675,538 km^2 i.e. 20.55% of the geographic area of the country, see Figs.1.13 and 1.14. The break up of this forest cover is as shown below in Table 1.11:



Source: State of Forest Report, 2001

Fig.1.13: Forest Cover

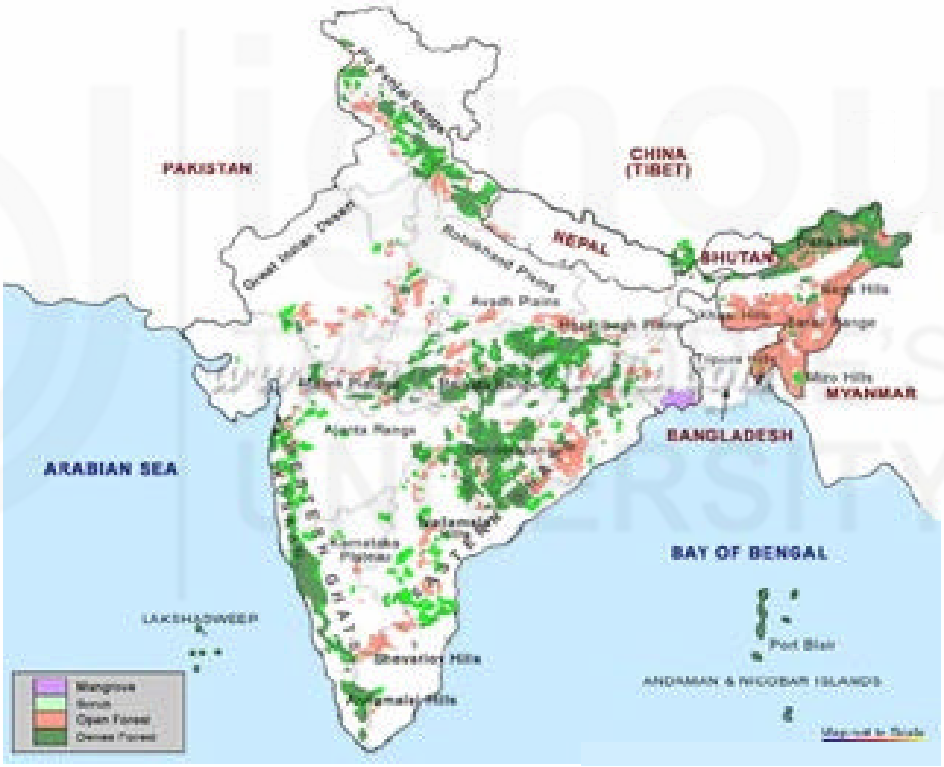
Table 1.11: Forest cover of India

Class	Area (km²)	Percent of Geographic Area
Forest Cover		
a) Dense	416,809	12.68
b) Open	258,729	7.87
Total Forest Cover*	675,538	20.55
Non-forest		
Scrub	47,318	1.44
Total Non-forest**	2,611,725	79.45
Total Geographic Area	**3,287,263**	**100.00**

* Includes 4,482 km² under mangroves (0.14% of country's geographic area)

** Includes Scrub

Source: State of Forest Report, 2001



Source: State of Forest Report, 2001

Fig.1.14: Forest vegetation map

India is fortunate to have diverse forest types. The forests of India can be broadly divided into 16 types: tropical wet evergreen, tropical semi-evergreen, tropical moist deciduous, littoral and swamp, tropical dry deciduous, tropical thorn, tropical dry evergreen, subtropical broad-leaved hill, subtropical pine, subtropical dry evergreen, montane wet temperate, Himalayan moist temperate, Himalayan dry temperate, subalpine, moist alpine scrub and dry alpine scrub. The tropical wet evergreen forests are found in the Western Ghats, Upper Assam and the Andamans. The tropical semi-evergreen forests occur along the western coast and in Assam, the eastern are present in the Andamans, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Mysore and Kerala. The littoral forests are found all along the coast and the swamp forests in the deltas of the larger rivers. The tropical dry deciduous forests occur from the foot of

Dense fo
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the Himalaya to Cape Comorin except in Rajasthan, the Western Ghats and Bengal. The tropical thorn forests grow in a large strip in South Punjab, Rajasthan, the upper Gangetic Plains, the Deccan Plateau and lower peninsular India. The tropical dry evergreen forests are restricted to the Karnataka coast. The subtropical broad-leaves hill forests are limited to the lower slopes of the Himalaya in Bengal and Assam and other hill ranges such as Khasi, Nilgiri and Mahableswar. The subtropical pine forests are found between 1000 and 1800 m throughout the whole length of the Himalaya. The subtropical dry evergreen forests are present in the Bhabar, the Siwalik and the western Himalaya up to about 1000 m. The montane wet temperate forests are found in Madras, Kerala, the eastern Himalayas, Bengal, Assam and Northeast India. The Himalayan moist temperate forests occur between 1400 and 3300 m in Indian-administered Kashmir, Himachal Pradesh, Punjab, Uttar Pradesh, Darjeeling and Sikkim. The Himalayan dry temperate forests occur in Ladakh, Lahol and Chamba. The moist alpine scrub occurs along the entire length of the Himalaya above 3000 m. Dry alpine scrub vegetation is found at the uppermost limit (3500 m) of vegetation in the Himalaya.

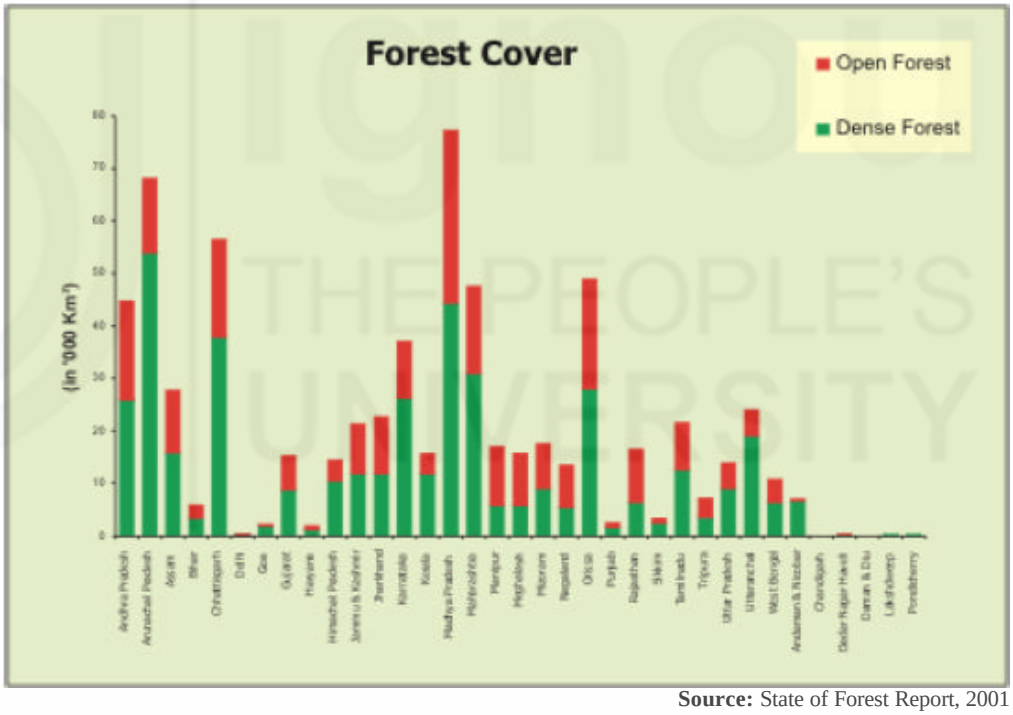
Of the 16 forest types in India, the tropical deciduous form the major forest type of India with 38.2 % of the total forest area. Other predominant forest type is the moist deciduous covering 30.3 % of the forest area of the country. The statewise distribution of forest cover is given in Table 1.12 and Fig.1.15.

Table 1.12: Forest in States/UTs of India

(Area in km^2)

State/UT	Geographic Area	Forest Cover				Scrub
		Dense	Open	Total	Percent	
Andhra Pradesh	275,069	25,827	18,810	44,637	16.23	9,907
Arunachal Pradesh	83,743	53,932	14,113	68,045	81.25	141
Assam	78,438	15,830	11,884	27,714	35.33	224
Bihar	94,163	3,372	2,348	5,720	6.07	122
Chhattisgarh	135,191	37,880	18,568	56,448	41.75	200
Delhi	1,483	38	73	111	7.51	4
Goa	3,702	1,785	310	2,095	56.59	0
Gujarat	196,022	8,673	6,479	15,152	7.73	2,408
Haryana	44,212	1,139	615	1,754	3.97	88
Himachal Pradesh	55,673	10,429	3,931	14,360	25.79	566
Jammu & Kashmir	222,236	11,848	9,389	21,237	9.56	3,087
Jharkhand	79,714	11,787	10,850	22,637	28.40	976
Karnataka	191,791	26,156	10,835	36,991	19.29	3,245
Kerala	38,863	11,772	3,788	15,560	40.04	71
Madhya Pradesh	308,245	44,384	32,881	77,265	25.07	3,452
Maharashtra	307,713	30,894	16,588	47,482	15.43	6,137
Manipur	22,327	5,710	11,216	16,926	75.81	190
Meghalaya	22,429	5,681	9,903	15,584	69.48	259
Mizoram	21,081	8,936	8,558	17,494	82.98	467
Nagaland	16,579	5,393	7,952	13,345	80.49	47
Orissa	155,707	27,972	20,866	48,838	31.36	5,782

Punjab	50,362	1,549	883	2,432	4.83	30
Rajasthan	342,239	6,322	10,045	16,367	4.78	4,925
Sikkim	7,096	2,391	802	3,193	45.00	341
Tamilnadu	130,058	12,499	8,983	21,482	16.52	3,180
Tripura	10,486	3,463	3,602	7,065	67.38	44
Uttar Pradesh	240,928	8,965	4,781	13,746	5.71	678
Uttaranchal	53,483	19,023	4,915	23,938	44.76	598
West Bengal	88,752	6,346	4,347	10,693	12.05	149
Andaman & Nicobar	8,249	6,593	337	6,930	84.01	0
Chandigarh	114	5	4	9	7.51	0
Dadra & Nagar Haveli	491	151	68	219	44.60	0
Daman & Diu	112	2	4	6	5.53	0
Lakshdweep	32	27	0	27	85.91	0
Pondicherry	480	35	1	36	7.45	0
Total	**3,287,263**	**416,809**	**258,729**	**675,538**	**20.55**	**47,318**



Source: State of Forest Report, 2001

Fig.1.15: Forest cover in States and Union Territories

Wetlands

India has a wealth of wetland ecosystems directly or indirectly linked with the river systems like the Ganga, Brahmaputra, Narmada, etc. The wetlands exhibit great ecological diversity and are of great economic, aesthetic and scientific importance. They support fishes, birds and other wild life. They play an important role in flood control, treatment of waste-water, reduction of sediment loads and pollution treatment. A national committee on Wetlands, Mangroves and Coral Reefs has identified 22 wetlands for conservation and management. **Six Indian wetlands have been designated as wetlands of international importance under the Ramsar Convention**.

Mangroves

Mangroves are salt tolerant forest ecosystems. They stabilize the shoreline and act as bulwark against sea erosion. Mangroves are important features of Indian coastline covering a total area of 6740 sq. km. India has nearly seven percent of the world's total mangrove area. Sunderbans in West Bengal is the world's largest mangrove. Fifteen mangrove areas have been identified for conservation and management practices.

1.4.6 Plant Resources

India is home to abundant plant and animal life and has a wide range of climates that accommodate a diversity of species throughout the country. Broadly classified, there are seven major regions for plant and animal life in India: the arid Indus Plain, the Gangetic Plain, the Himalayas, Assam Valley, the Malabar Coast, the peninsular plateau, and the Andaman and Nicobar Islands.

India has an estimated 45,000 species of plants, 33 percent of which are native. There are 15,000 flowering plant species, 6 percent of the world's total. About 3,000 to 4,000 of the total number of plant species are believed to be in danger of extinction.

In the arid areas that adjoin Pakistan, the eastern part of the Indus Plain, most plant life is sparse and herblike. Various thorny species, are common here. Bamboo grows in some areas, and among the few varieties of trees is the palm.

The Gangetic Plain, which has more moisture, supports many types of plant life. Vegetation is especially luxuriant in the southeastern part of the plains region, where the mangrove and the sal, a hardwood timber tree, flourish.

In the Himalayas many varieties of arctic flora are found on the higher slopes. The lower levels of the mountain range support many types of subtropical plant life, notably the orchid. Dense forests remain in the few areas where agriculture and commercial forestry have had little effect. Coniferous trees, including cedar and pine, predominate in the northwestern Himalayan region. On the Himalayas' eastern slopes, tropical and subtropical types of vegetation abound. Here rhododendrons grow to tree height. Among the predominant trees are oak and magnolia.

The Assam Valley features evergreen forests, bamboo, and areas of tall grasses. The Malabar Coast, which receives a large amount of rainfall, is thickly wooded. Evergreens, bamboo, and several varieties of valuable timber trees, including teak, predominate in this region. Extensive tracts of impenetrable jungle are found in the swampy lowlands and along the lower elevations of the Western Ghats. The vegetation of the peninsular plateau is less luxuriant, but thickets of bamboo, palm, and deciduous trees grow throughout the Deccan Plateau. The Andaman and Nicobar Islands have tropical forests, both evergreen and semievergreen.

1.4.7 Wildlife Resources

India is inhabited by a wide variety of animal life, including almost 5,000 species of larger animals. Several species of the cat family – including the tiger, panther, Asiatic lion, Asiatic cheetah, snow leopard, jungle cat, and clouded leopard – live in some areas of India. Most of these species are under threat of extinction. Elephants roam the lower slopes of the central and eastern Himalayan foothills and the remote forests of the southern Deccan Plateau. Other large quadrupeds (four-footed animals) native to India include rhinoceros (under threat of extinction), black bear, wolf, jackal, dhole (wild Asian dog), wild buffalo, wild hog, antelope, and deer. Several species of monkeys life throughout the country.

Various species of wild goats and sheep including ibexes and serows, are found in the Himalayas and other mountainous areas. The pygmy hog, bandicoot rat, and tree

mouse are typical types of smaller native quadrupeds; bats are also abundant. Venomous reptiles, including the cobra, krait, and saltwater snake, are especially numerous in India, and pythons and crocodiles are also found. Tropical birds of India include the parrot, peacock, kingfisher, and heron. The rivers and coastal waters of India rich in fish including many edible varieties.

SAQ 3

What is soil? How is it important as a natural resource?

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SAQ 4

Name some important rivers of Northern India. Also discuss their origin.

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SAQ 5

Discuss some important features of rainfall pattern in India.

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SAQ 6

What are different sources of energy? Why should we look for alternative sources of energy?

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SAQ 7

What are minerals? Give three examples of metallic minerals.

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SAQ 8

Explain the importance of forests as natural resources.

.....

.....

1.5 SUMMARY

In this unit we have discussed natural resources in detail in the beginning the importance and meaning of natural resources was explained. The classification of natural resources into abiotic and biotic resources as well as renewable and non-renewable resources was discussed with the help of appropriate examples. This was followed by a discussion about some general facts, physiogeography, agroclimatic zones and climate of India. Then, various natural resources such as land and soil, water, energy and mineral resources of India were described in detail. The discussion included the distribution, availability and importance of these resources.

1.6 TERMINAL QUESTIONS

1. Discuss the importance of natural resources.
2. Distinguish between renewable and non-renewable resources with the help of examples.
3. Name different geographic regions of India and discuss their important features.
4. How many agro-climatic zones are there in India ? What factors are responsible for their origin?
5. What are different kinds of soils? Comment on their fertility.
6. Name three important river basins of India. Give details about their catchment areas.
7. Discuss various factors a responsible for increasing energy consumption.
8. Where are bauxite deposits located in India?
9. How many types of forests existing India? What is the major forest type present in India?
10. Describe important plant and wildlife resources of India.

Acknowledgement

We thankfully acknowledge Compare Infobase Pvt. Ltd. For various maps included in this unit.

UNIT 2 LAND, SOIL AND WATER

Structure

2.1 INTRODUCTION

So far, you have a fair idea of various natural resources and their importance. You also know that natural resources can be classified as *abiotic* or *biotic* (biological) resources. We will be discussing about different physical natural resources in this unit and Unit 3 while their conservation aspects will be dealt in Unit 4.

We will begin this unit with a description of **land resources**. This would be followed by a discussion on **soil** which is an equally important resource for the production of food and existence of various life forms. We will explain soil profile and describe different types of soil. There will be a brief discussion on soil erosion and the measures required to control soil erosion.

We would then explain various **water resources**. Water is a very-very important resource and existence of life is just not possible without it. Water is abundant on Earth but still its availability is a problem. Why is this so? We would first discuss about the availability of water as ground water and surface runoff. Then, we would focus our discussion on some problems associated with the availability and distribution of water resources. Both the quantity and the quality of water are a matter of concern today. There is an acute water shortage whereas its demand is increasing day-by-day. India too is facing serious problems of water shortages. The water availability in India will be discussed in detail. Various issues related to its distribution and quality have also been raised in this unit.

Objectives

After studying this unit, you should be able to:

- list various land resources and explain their importance;
- describe the uses of soil and list its various horizons;
- discuss various types of soils and their important characteristics;
- give reasons for soil erosion and its degradation;
- explain various measures required to prevent the degradation and erosion of soil;
- highlight the importance of water resources;
- described the sources of surface water and ground water; and
- explain various problems associated with water resources.

2.2 LAND RESOURCES

We abuse land because we regard it as a commodity belonging to us. When we see land as community to which we belong, we may begin to use it with love and respect.

Extensive tropical deforestation is happening every second of the day. Land resources, such as forests, rangelands, croplands, protected areas and wilderness areas are key lands that are coming under increasing stress due to growing population and rapid economic development.

Forests: About 34% of the world's land area is covered with potentially renewable forests. Principle types of these biomes include tropical rainforest, tropical deciduous forest, temperate deciduous forest and ever green conifer forests.

Secondary forests are stands of trees resulting from secondary ecological succession.

Forests provide us with lumber for housing, biomass for fuel, wood, and pulp for paper, medicines, and many other products. Many forest lands are also used for mining, grazing livestock, and recreation.

Rangelands: Almost half of Earth's ice-free land is range land i.e., land that supplies forage or vegetation (grasses, or grass like plants and shrubs) for grazing and browsing animals and that is not intensively managed. Most rangelands are grasslands in semi-arid areas too dry for rain fed croplands. Only 42% of the range lands is used for live stocks. Much of the rest is too dry. Each type of grassland has herbivore carrying capacity. Over grazing occurs when too many grazing animals feed too long and exceed the carrying capacity of grassland.

Protected areas and wilderness areas: Today there are over 1,100 national parks and other protected areas in more than 120 countries. These park and other protected areas have been established to conserve the natural resources and associated biodiversity.

More details of biotic resources and their conservation would be discussed in Blocks 2 and 3, respectively.

SAQ 1

What is a range land?

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SAQ 2

Why are national parks important?

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2.3 SOIL

Soil forms the uppermost layer of land. It is one of the most important natural sources because it plays a central role in food production and in major biogeochemical cycles. It supports major life systems and vegetation, provides fodder, stores and purifies water.

Soil is the main interface between the atmosphere, hydrosphere, lithosphere and biosphere. It contains inorganic and organic materials. The inorganic components may be clay, sand, silt, gravel or stones whereas the organic components are organic wastes and living organisms. It also contains air, water and minerals nutrients.

The formation of soil is a complex and slow process. The time taken may partly depend upon the type of parent material. The formation of one inch (~2.5 cm) of top soil may take 200 to 1200 years depending upon the climatic conditions. However, softer materials are converted to soil in a much smaller time in favourable conditions.

2.3.1 Soil Profile

Soil is formed of many layers which have different colours and composition. These layers are known as **horizons** and they form the **soil profile**. There are five major horizons and they are shown in Fig. 2.1.

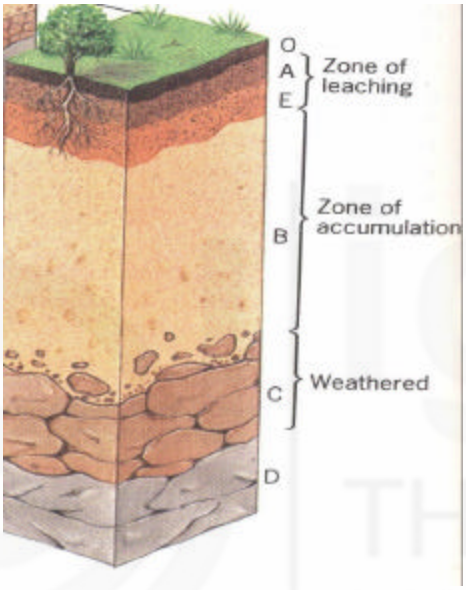

Fig.2.1: Soil profile with five horizons

Note that the uppermost horizon, **O-horizon** is characterized by dark rich colour. It contains organic materials including decomposed or decomposing leafs, twigs and other organic matter.

The next layer, **A horizon** or **top soil** is light black to brown in colour. Its thickness may vary from 2.5 to 60 cms. This zone supports agricultural crops. It is porous and holds moisture. It is rich in inorganic and organic nutrients. This zone (along with the horizon E) is also called the *zone of leaching* because clay, calcium, magnesium and iron are leached towards lower layers by percolation of groundwater.

B horizon or **subsoil** is known as **zone of accumulation**. It is light in colour. This layer is rich in clay, iron oxides, silica, carbonates and other materials which are leached from the upper horizons.

C horizon is a transition zone and contain *partially weathered parent material* whereas **D horizon** is the parent material from which soil is derived.

The type of soil at a particular place is determined by a number of factors such as climate, parent material, type of vegetation, biological organisms etc.

2.3.2 Soil Classification

Soils widely vary in their characteristics and properties. They can be classified into various groups which are discussed below:

i) **Alluvial soils:** These include the deltaic alluvium, calcareous alluvial soils, coastal alluvium, and coastal sands. This is the largest and the most important soil group of India contributing the largest share to the agricultural wealth.

ii) **Black soils:** These vary in depth from shallow to deep. The typical soil derived from the deccan trap is the *regur* or black cotton soil. It is common in Maharashtra, western parts of Madhya Pradesh, parts of Andhra Pradesh, parts of Gujarat and some parts of Tamil Nadu.

iii) **Red soils:** The soils comprise vast areas of Tamil Nadu, Karnataka, Goa, Daman and Diu, south eastern Maharashtra, Madhya Pradesh, Orissa and Chhotanagpur. In the north, it includes the Santhal Paraganas in Bihar, the Birbhum district of West Bengal, the Mirzapur, Jhansi and Hamirpur district of Uttar Pradesh.

The ancient crystalline and metamorphic rocks on weathering have given rise to the red soils. The red color is due to the wide diffusion of iron than to the high proportion of it. They are generally poor in nitrogen, phosphorus and humus. These soils are poorer in lime, potash, iron oxide and phosphorus than the regur soils. Many of the so-called red soils of southern India are not red. On the other hand, some red soils are of the lateritic origin and quite different in nature.

iv) **Laterites and lateritic soils:** Laterite is a formation peculiar in India and some other tropical countries with an intermittently moist climate. It is a vesicular rock composed essentially of a mixture of the hydrated oxides of aluminium and iron with small amounts of manganese oxides, titania etc. It is derived from the atmospheric weathering of several types of rocks. Under the monsoon conditions of alternating wet and dry seasons, the siliceous matter of the rocks is leached away almost completely during weathering.

Laterites are especially well developed on the hill of Karnataka, Kerela, Madhya Pradesh, Eastern Ghat region of Orissa, Maharashtra, West Bengal Tamil Nadu and Assam.

In Tamil Nadu, there are high level and low level laterites formed under peculiar climatic and weather conditions. They are both *in situ* and sedimentary formations are found all along the West coast where rainfall is heavy and humid climate prevails.

On the laterites, at low elevations, paddy is grown and on high elevations tea, cinchona, rubber and coffee are grown. The soils are rich in nutrients and contain 10-20 percent organic matter. The pH is low (3.5-4), and the higher the elevation, the more acidic the soil.

v) **Desert soils:** A large part of the arid region belonging to the western Rajasthan, Haryana, Punjab, lying between the Indus river and the Aravalli range is affected by the desert conditions of geologically recent origin. This part is covered under a mantle of blown sand which, combined with the arid climate results in poor soil development. The most predominant component of the desert sand is quartz in well-rounded grains but feldspar and hornblende grains also occur with a fair proportion of calcareous grains.

The desert proper, owing to the physiographic conditions of its situation, though lying in the track of the south westerly monsoon receives little rain. The sands which cover the area are partly derived from the disintegration of the rocks, but are largely blown in from the coastal regions and the Indus Valley. Some of these soils contain high percentages of soluble salts , high pH, low loss on ignition, a varying percentage of calcium carbonate and are poor in organic matter.

The Rajasthan desert is a vast sandy plain including isolated hills. Though on the whole the tract is sandy, the soil improves in fertility from west and north-west to east and north-east. In many parts, the soils are saline or alkaline, with unfavourable physical conditions and high pH.

vi) **Problem soils:** The problem soils are those which owing to **land** or soil characteristics, cannot be economically used for the cultivation of **crops** without adopting proper reclamation measures. Highly eroded soils (sheet and gully), ravine **lands**, soils on steeply sloping **lands** etc. constitute one set of problem soils. The shallow soil depth, deep gullies, steep and complex slopes are some of the problems which require to be tackled in such areas. Their reclamation may involve massive earth moving operations, terracing, afforestation or **plantation** to maintain permanent cover with grasses, depending upon the intensity of the problem and the nature of the terrain and soil conditions. The potentiality of the **lands**, present **lands** use, cost of operations and other socio economic factors of the regions are some of the factors which have to be taken into consideration.

Acid saline and alkali soils constitute another set of problem soils in the case of which acidity, soluble salts and exchangeable sodium limit the scope of cultivation.

a) **Acid soils.** Although soils having pH below 7 are considered to be acidic from the practical standpoint, those with pH less than 5.5 and which respond to liming may be considered to qualify to be designated as acid soils. In the classification of soils both the percentage base saturation and the pH are used as criteria to distinguish acid soils from non-acid ones.

   Acid soils occur widely in the Himalayan region, the great eastern plains of extra-peninsular India, the peripheral peninsula and the coastal plains, including the Gangetic delta. They are found to occur on different geological formations under varying physiographical, climatic and vegetational environment. In all these regions the rainfall component of the climate appears to have a dominating influence on the formation of acid soils.

   In humid regions, where rainfall is high, the soluble bases formed in the course of weathering of rocks are leached down and carried away by the drainage waters. The continued leaching of soils results in the replacement of calcium, magnesium, potassium and sodium ions by hydrogen ions and the formation of acid soils with low pH. In acid soils the dissolution of aluminosilicate minerals occur and the aluminium ions thus released increase the acidity owing to hydrolysis. Similarly, humus and hydrous oxides contribute to soil acidity at low pH.

b) **Saline and alkali or sodic soils.** In many arid and semi arid areas of India crop production is limited because of salinity or alkalinity or both. It is estimated thet about 7 million hectares in the country have either gone out of cultivation or this area produces low yields of crops. The area in different states is given in Table 2.1.

Table 2.1: The extent of saline and alkali soils in India

State	Area under saline/ alkaline soils (million ha)
Uttar Pradesh	1.280
Gujarat	1.200
West Bengal	0.840
Rajasthan	0.720
Punjab	0.680
Maharashtra	0.528
Haryana	0.520
Karnataka	0.400
Orissa	0.400
Madhya Pradesh	0.240
Andhra Pradesh	0.024
Delhi	0.016
Kerala	0.016
Bihar	0.004
Tamil Nadu	6.872 (or about 7 million hectares)

The soil salinity or alkalinity or both have many adverse effects which are as follows:

1. Causing low yield of crops or crop failure in extreme cases.
2. The limiting of the choice of crops because some crops are sensitive to salinity or alkalinity or both.
3. Rendering the quality of fodder as poor, as at times the fodder grown on alkali soils may contain a high amount of molybdenum and a low amount of zinc, causing nutritional imbalance and diseases among live-stock.
4. Creating difficulties in the construction of buildings and roads and their maintenance.
5. Causing excessive run offs and floods due to low infiltration resulting in damage to crops.

i) Characteristics of Saline Soils

Saline soils normally do not show any change in structure down the profile but are low in humus and the pH is usually below 8.5. A saline soil may contain over 100 tons/acres of salts in the top 4 feet of soil.

Harmful effects of Salinity

Soluble salts can have two types of effect on the growing plants. Specific effects which are due to particular ions being harmful to the crop can be operative at low or high concentration. The general effects of salinity are due to rise in the osmotic pressure of the soil solution around the roots of the crop and this result in dwarf and stunned growth in the plant. Besides these effects, high concentration of salts affects absorption of water and its translocation in the plant system, root activity

and the activity of soil micro-organisms. Amongst the three sodium salts, sodium carbonate is extremely toxic, sodium chloride is intermediate in its effect, while sodium sulphate is least toxic. The salinity of the surfaces soil is predominantly governed by the annual rainfall, while the average salinity of the whole profile is determined by annual temperature.

ii) Characteristics of alkali soils

Alkali soils contain free N_2CO_3 and are alkaline in reaction. Exchangeable Na is more than 15 per cent of the exchangeable bases pH is usually very high.

Saline nature of the soil, high concentration of sodium salts, basin shape topography, faulty drainage and arid nature of the climate accelerate the process of alkalization.

A saline soil contains excess quantity of soluble salts, while alkali soil contains excess quantity of exchangeable Na. A soil which contains an excess of both sodium and soluble salts is termed as saline-alkali soil.

Harmful effects of alkalinity

Harmful effects of high alkalinity are manifested through non-availability of nutrient elements like iron, manganese, boron and phosphate. High pH of alkali soils is due to increase in the concentration of exchange. Na, which in turn modifies the physical conditions of the soil and makes the soil sticky and impermeable and brings out wilting and scorching effect on plants.

2.3.3 Soil Erosion and Soil Degradation

The term **soil erosion** usually refers to the removal of topsoil whereas **soil degradation** means loss of soil fertility without the actual physical removal of soil.

There is a lot of pressure on soil due to increasing population of the world. To meet its increasing food demands, more intensive agriculture is required. Many other human activities such as poor agricultural practices, clearing of forests, overgrazing etc. contribute to the degradation of soil. Soil degradation is also caused by agrochemicals, acid rain, polluted water from industrial and other sources, leaching of materials from sanitary landfills and waste dumps.

Soil erosion is caused by both human activities and natural processes. If the vegetation cover is present, the soil erosion by natural process is minimum. But deforestation, fires and storms expose the soil which gets eroded at a very fast rate. Soil erosion can take place both by water or wind. Rains and floods wash away the soil. Soil erosion is quite significant in arid and semi-arid environments. The high mountain slopes are also prone to soil erosion especially when the vegetation cover is absent.

2.3.4 Soil Conservation

Although soil is theoretically a renewable resource, it takes practically so long to form that it can be looked upon as a non-renewable source. Soil, thus, needs to be conserved.

The best approaches to soil conservation would obviously be on the following lines:

- Maintenance of a protective ground cover of vegetation which may be natural or cultivated, see Fig. 2.2.
- Minimising disturbance to the soil surface.
- Reducing the time of exposure of bare soil.

Fig.2.2: Crop cover

Several practices have been in vogue to achieve the above objectives. Some of these are as follows:

1. **Minimum Tillage:** It reduces the mechanical disruption of soil by not ploughing a field after a crop is harvested. Also, the remaining stalks (e.g. after harvesting wheat) are left in place rather than they are ploughed under, see Fig. 2.3 below. Thus, the soil is not left exposed between two growing seasons.

Fig.2.3: Minimum tillage

2. **Contour Farming:** It involves the planting of crops along level lines that follow the contours of land, rather than up and down slopes. Thus, crops are planted across the direction of water flow on hilly or sloped lands as is shown in Fig. 2.4. It, thus, reduces the flow of water and hence has better water retention. This practice may reduce the soil erosion by 60%.

Fig.2.4: Contour farming

3. **Strip Cropping:** It involves planting alternate crops in large strips, see Fig. 2.5. For example, corn can be alternated with cover crop such alfalfa.

Fig.2.5: Strip cropping

4. **Terracing:** It involves the construction of small earthen embankments on sloped cropland as shown below in Fig. 2.6. It checks water flow and minimizes soil erosion.

Fig.2.6: Terracing

5. **Shelterbelts:** In this practice, long rows of trees as planted which act as windbreaks or **shelterbelts**, see Fig. 2.7. Shelterbelts have many advantages. They minimize the damage caused to crops by windblown dirt particles, reduce the amount of blowing snow, increase soil moisture as well as ground water supplies. Shelterbelts also help in improving irrigation efficiency.

Fig.2.7: Shelterbelts

In addition to the above measures for controlling soil erosion, the following methods can be used to control the degradation of soil.

1. Use of Fertilizers

a) Organic Fertilizers: They include animal dung, sewage and manures. They are helpful in providing soil nutrients (N and P) and organic matter.

Organic fertilizers also improve soil structure, increase water retention and enhance the fertility of the soil. They improve the crop yield and help in reducing the leaching of minerals from the soil by rainwater.

b) Synthetic Fertilizers: They provide nitrogen, potassium and phosphorous. They are helpful in restoring soil fertility. However, when washed with rainwater, these fertilizers cause water pollution.

2. Crop Rotation

It is a very popular and a very old practice throughout the world. It helps to replenish soil nitrogen when leguminous plants are grown for one season after 2-3 year's of the regular cycle of a crop.

SAQ 3

Why is soil an important resource?

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SAQ 4

What are three different types of rocks? How are they formed?

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SAQ 5

What are acid soils? Where do they occur in India?

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SAQ 6

What are various reasons for soil erosion?

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2.4 WATER RESOURCES

Water is the most abundant resource, covering about 71% of the earth's surface. About 97% of the water on Earth is salt water, and the remaining 3% is fresh water. Water helps to maintain the earth's climate and dilutes the environmental pollutants. Essential to all life, water makes up 50% to 97% of the weight of all plants and animals and about 70% of human body. Water is also a vital resource for agriculture, manufacturing, transportation, and countless other human activities. Because of differences in average annual precipitation, some areas of the world have too little fresh water and other have too much. With varying degrees of success, we have attempted to correct some of these imbalances. We have captured fresh water in reservoirs behind dams, transferred fresh water in rivers and streams from one are to another, tapped underground supplies, and attempted to reduce water use, wastage, and contamination.

Despite these efforts, water is one of the most poorly managed resources on the earth. We waste it and pollute it. We also charge too little for making it available, this encourages even greater wastage and pollution of this potentially renewable resource.

2.4.1 Use of Water Resources: Supply and Renewal

Worldwide Supply and Renewal – The world's fixed supply of water in all forms (vapour, liquid, and solid) is enormous. If we could distribute it equally, every person on earth would have 74 billion gallons of water. However, about 97% of the earth's water is found in the oceans and is too salty for drinking, growing crops, and most industrial uses except cooling.

The remaining 3% is fresh water. However, all but 0.003% of this supply is highly polluted, lies too far under the earth's surface to be extracted at an affordable cost, or is locked up in glaciers, polar ice caps, atmosphere, and soil. To put this in measurements that we can understand, if the world's water supply were only 100 litres, our usable supply of fresh water would be only about one-half teaspoon (0.003 litre).

That tiny fraction of usable fresh water still amounts to an average of 2.2 million gallons for each person on earth. This supply is continually collected, purified, and distributed in the natural *hydrological* (water) cycle. This natural recycling and purification process works as long as we don't pollute water faster than it is replenished or overload it with slowly degradable and non- degradable wastes.

Surface-Water Runoff – The fresh water we use comes from two sources: groundwater and surface-water runoff. Precipitation that does not infiltrate into the ground or return to the atmosphere is called **surface water** and becomes **runoff** – fresh water that flows on the earth's surface into nearby streams, rivers, lakes, wetlands and reservoirs. This flow of water is renewed every 12 to 20 days in areas with average precipitation. The land area that delivers runoff, sediment, and water-soluble substances to a major river and its tributaries is called a **watershed** or **drainage basin.**

Surface water can be withdrawn from streams, rivers, lakes, and reservoirs for human activities, but only part of the total annual runoff is available for use. Some of it flows through rivers to the sea too rapidly to be captured and some must be left in streams for wildlife and supply to downstream areas. In some years, the amount of runoff is reduced by below average precipitation.

Ground Water – Some precipitation seeps into the ground. Some of this accumulates as **soil water** and partially fills pores between soil particles and rocks within the upper soil and rock layers of the earth's crust. Most of this water is eventually lost to the atmosphere by evaporation from the upper layers of soil and transpiration from leaves of the plants.

Aquifer in Latin means *water-carrier*.

Under the influence of gravity, some infiltrating water slowly percolates through porous materials deeper into the earth. There, it fills pores and fractures in sponge like, or permeable, layers of sand, gravel, and porous rocks such as sandstone. This area where all available pore spaces are filled with water is called the **zone of saturation**. These porous, water-bearing layers of underground rock are called **aquifers,** and the water in them is known as **groundwater.**

Aquifers are recharged or replenished naturally by precipitation, which percolates downward through soil and rock in what is called a **recharge area**. The recharge process is usually quite slow (it may take decades to hundreds of years) compared to the rapid replenishment of surface water supplies. If the withdrawal rate of an aquifer exceeds its recharge rate, the aquifer is converted from a slowly renewable resource to a non-renewable resource on a human time scale. This is called ***ground water mining***. There are two types of aquifers: **confined** and **unconfined**, see Fig. 2.8. An *unconfined aquifer* or *water-table*, forms when groundwater collects above a layer of impermeable rock or compacted clay. The top of the water-saturated portion of an unconfined aquifer is called the **water table**. Thus, groundwater is the part of

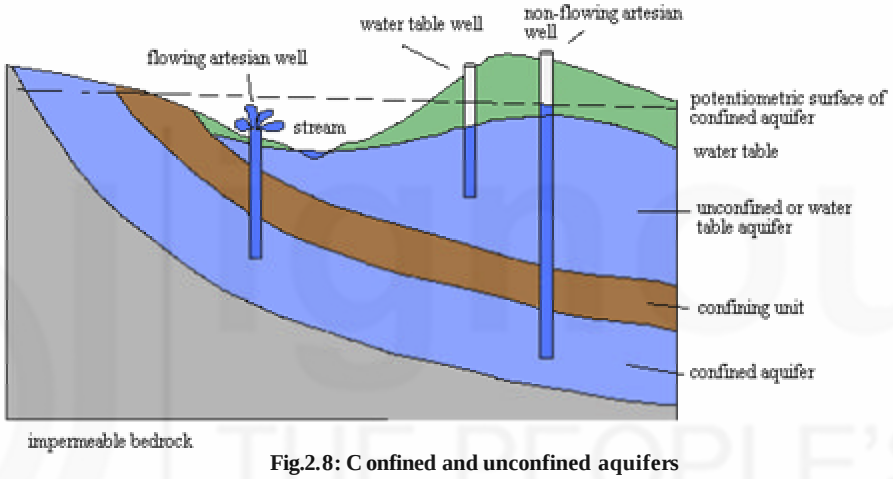

Fig.2.8: C onfined and unconfined aquifers

underground water table in the zone of saturation below the water table. Soil water is the part of underground water above the water table, sometimes called the **zone of aeration**. This water is found within the root zones of most plants. Shallow, unconfined aquifers are recharged by water percolation downward from soil and materials directly above the aquifer. To get water from an unconfined aquifer, a water table is drilled well below the water table into the unconfined aquifer. Then, a pump must be used to bring water to the surface. The water table in an area rises during prolonged wet periods and falls during prolonged drought. The water table also falls when water is pumped out by wells faster than the natural rate of recharge which is called **over drafting**. This creates a waterless volume known as a ***cone of depression*** as shown in Fig. 2.9.

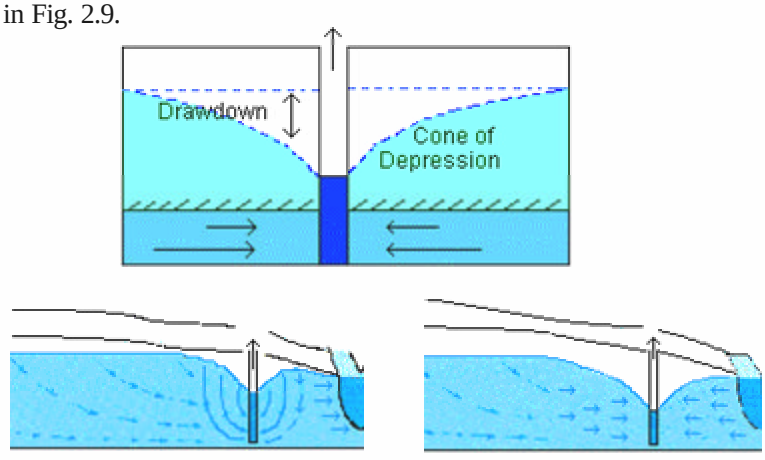

Fig.2.9: Cone of depression

A *confined aquifer* forms when groundwater is sandwiched between two layers of an impermeable rock, such as clay or shale. This type of aquifer is saturated with water under a pressure greater than that of the atmosphere. In some cases, pressure from the weight of water higher in the aquifer is a so great that when a well is drilled into the confined aquifer, water is pushed to the surface without the aid of a pump. Such a well is called a *flowing artesian well.*

With other confined-aquifer wells, called *non flowing artesian wells,* pumps must be used because there isn't enough pressure to force the water all the way to the surface. Recharge areas for confined aquifers can be hundreds of miles away from wells where water is withdrawn. Thus, the rate of natural recharge for such aquifers is not based on local precipitation at the point of withdrawal as it is for unconfined aquifers. These aquifers are also polluted only in their recharge areas.

Annual total water withdrawal and annual average water withdrawal per person may vary considerably among various More Developed Countries (MDC's) and Less Developed Countries (LDC's). Worldwide, almost three-fourths of the water withdrawn each year is used for irrigation. The rest is used in industrial processing, in cooling electric power plants, and in homes and businesses (for public use). However, the uses of withdrawn water vary widely from one country to another.

In developed countries, about three-fourths of the fresh water withdrawn each year comes from rivers, lakes, and reservoirs. The rest comes from groundwater aquifers. Almost 80% of the water withdrawn in the United States is used for cooling electric power plants and for irrigation. Production of food and manufacturing of various products requires large amounts of water, although in most cases, much of this water could be conserved and reused.

Since 1950 total water withdrawal has increased by more than double. This increase has been caused by the increase in population, urbanization, and greater economic activity. In addition to these reasons, the government-subsidized, low water prices also discourage its conservation and reuse.

Worldwide up to 90% of all water withdrawn from rivers and lakes is returned to them for potential reuse. However, about 75% of the water supplied for irrigation is consumed. Between 1985 and 2020, worldwide withdrawal of water for irrigation is projected to get doubled, primarily because of increasing population in LDCs. However, the withdrawal for public use in homes and business is expected to increase fivefold.

2.4.2 Water Resource Problems

i) Too Little Water: The availability of enough fresh water to meet human needs is one of the most serious problems confronting many parts of the world. During 1970's, major drought disasters affected on an average 24.4 million people and killed over 23,000 a year - a trend continuing in the 1980's. A **drought** occurs when an area does not get enough water because of lower than normal precipitation, higher than normal temperatures that increase evaporation, or both.

At least 80 arid and semiarid countries where nearly 40% of the world's population lives, have serious periodic droughts. These countries are mostly located in Asia and Africa, and face great difficulty in growing enough food to support their populations. A prolonged drought affected Africa between 1982 and 1986. It led to widespread starvation and disease and forced at least 10 million people to abandon their homes in a desperate search for food and water.

In many LDCs, poor people spend a good part of their waking hours fetching water, often from polluted streams and rivers. Many women and children walk 10 to 15 miles a day, carrying heavy, water-filled jars.

Reduced average annual precipitation, hig her than normal temperature, or both usually trigger a drought. But rapid population growth and poor land use intensify its effects. In many LDCs, large number of poor people have no choice but to try to survive on drought – prone land. To get enough food and fuel wood, they strip the land of trees, cultivate poor soils, let their livestock overgraze grasslands, and grow crops at higher more erosion-prone elevations. This land degradation increases the severity of long-term drought by reducing the amount of rainfall absorbed and slowly released by vegetation and soils.

In arid and semiarid parts of MDCs, where periodic drought is to be expected, networks of canals and tunnels are often used to withdraw water from rivers and transport it to urban and industrial areas. However, during a prolonged drought, the flow of water in the rivers supplying these urban cases is sharply reduced. The resulting water supply crisis is often viewed as a natural disaster. But, it is actually a human–caused disaster – the result of trying to support too many people in areas that normally have droughts.

Water scarcity is a source of conflict between countries, especially in the arid Middle East. Israel went to war in 1967 partly because Arabian countries were trying to divert surface water from the Jordan river. Part of the reason that Israel continues to occupy the Golan Heights and the West is to ensure its access to water from this river.

Almost 150 of the world's 200 major river systems are shared by at least two countries. Together these countries contain 40% of the world's population, and they often clash over water rights. For example, India and Bangladesh dispute the water rights to the Ganges river, and India and Pakistan dispute water rights to the Indus River.

ii) **Too Much Water:** Some countries have enough annual precipitation but get most of it at one time of the year. In India, for example, 90% of the annual precipitation falls between June and September which is the monsoon season. This downpour runs off so rapidly that most of it cannot be captured and used. The massive runoff also causes periodic flooding.

During the 1970s, major flood disasters affected 15.4 million people, killed an average of 4,700 people per year, and caused tens of billions of dollars property damages. This trend continued in the 1980s.

Floods, like droughts, are usually called natural disasters. But human activities have contributed to the sharp rise in flood deaths and damages since the 1960s. Cultivation of easily erodable land, deforestation, overgrazing, and mining have removed water-absorbing vegetation and soil (see the Case Study below). Urbanization also increases flooding, even with moderate rainfall. It replaces vegetation and soil with highways, parking lots, shopping centers, office buildings, homes, and numerous other structures that lead to rapid runoff of rainwater.

Many poor people have little choice but to live on land subject to severe flooding. Many other people in LDCs and MDCs believe that the benefits of living in flood-prone areas outweigh the risks. Urban areas and croplands often are located on floodplains which are flat areas along the banks of rivers and these are naturally subject to periodic flooding. These usually are level areas with highly fertile topsoil deposited by the rivers. They are also close to water supplies and water transportation routes and are widely used for outdoor recreations.

There are a number of effective ways to prevent or reduce flood damage. Vegetation can be replanted in disturbed areas to reduce runoff. In urban areas, ponds can be built to retain rainwater and release it slowly to rivers. Rainwater can be diverted through storm sewers to holding tanks and ponds for use by the industry.

CASE STUDY: ***Natural and Unnatural Flooding in Bangladesh***

Bangladesh is one of the world's most densely populated countries. It is also one of the world's poorest countries. The country is located on a vast, low-lying delta of shifting islands of silt at the mouths of the Ganges, Brahmaputra, and Meghna Rivers. Its people are accustomed to flooding, after water deposited by annual monsoon rains in the Himalayan mountain ranges of India, Nepal, Bhutan, and Tibet flows downward through rivers to Bangladesh and into the Bay of Bengal.

Bangladesh depends on this annual flooding to grow rice which is its major source of food. The annual deposit of silt in the delta basin also helps soil fertility. Thus, the people of this country are used to moderate annual flooding and need it for their survival. But massive flooding is disastrous. In the past, major floods occurred only once every fifty years or so. But since 1950, the number of large-scale floods has been on an average once every four years. About 300,000 people died in a famine after a flood in 1974.

In the 1980s, floods have become even more severe. In 1988, a massive flood covered 80% of the country's land mass. At least 1500 people were killed by drowning and snakebite and 30 million people – almost one out of four – were left homeless. Hundreds of thousands suffered from diseases such as cholera and typhoid fever from contaminated water and food supplies. Hundreds of thousands would have probably died from famine, in spite of massive international aid.

We usually think of such floods as unpreventable natural disasters. But the increased severity of flooding in Bangladesh is primarily an unnatural disaster caused by little appreciation of watershed management.

Bangladesh's flooding problems begin in the Himalayan watershed, where people depend on wood for fuel. There is a combination of rapid population growth, deforestation, overgrazing, and unsustainable farming on easily erodible steep mountain watershed to absorb water. Instead of being absorbed and released slowly, water from the annual monsoon rain runs off mountainsides rapidly. Then, heavier than monsoon rains cause massive flooding in Bangladesh. This deluge of water also carried with it the unprotected soil, vital to the survival of people in the Himalayas.

Floodplains should be clearly identified, and zoning regulation should prohibit their use for certain types of development. Sellers of property in these areas should be required to provide prospective buyers with information about average flood frequency.

SAQ 7

What is an aquifer? Name its two types.

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SAQ 8

What is a cone of depression? How is it formed?

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iii) Water in the Wrong Place : In some countries, the largest rivers which carry most of the runoff, are far from agricultural and population centers where the water is needed. South America has the largest average annual runoff of any continent. But 60% of this runoff flows through the Amazon – the world's largest river–in areas far from where most people live.

iv) Contaminated Drinking Water: Contaminated drinking water is the most common hazard for people in many parts of the world. In 1983, the World Health Organization estimated that in LDCs, 61% of the people living in rural areas and 26% of the urban dwellers did not have access to safe drinking water. WHO Estimated that at least 5 million people die every year from cholera, dysentery, diarrhoea, and other preventable waterborne diseases. Every day these diseases prematurely kill on an average about 13,700 people. Most of these deaths could be prevented at little cost.

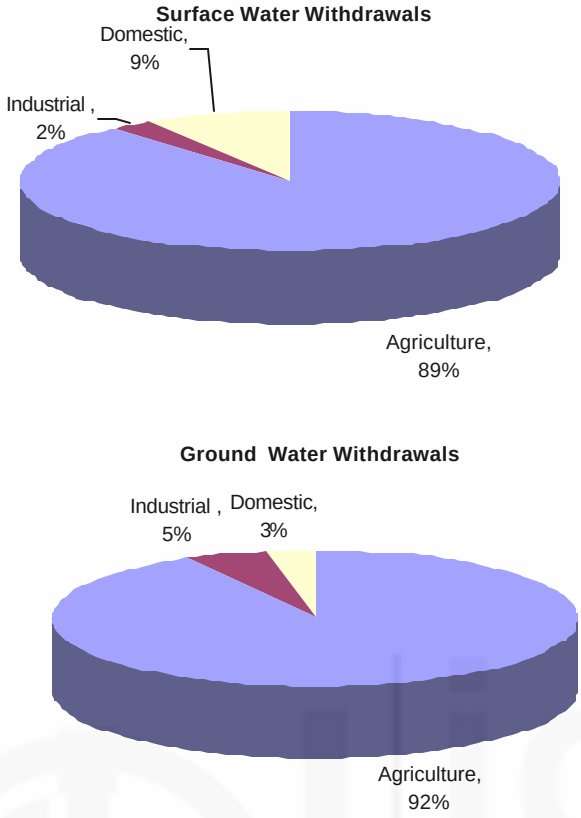
2.4.3 Water Resources and Problems – The Indian Scenario

Water is the elixir of life. Many human activities such as agriculture, industries and domestic use require water. Fig.2.4 shows sectorwise water usage for different activities.

The demand for water resources is growing every day because of increasing urbanization, growing population, increase in industrial and developmental activities. Due to fast economic reforms, many cities and towns are emerging as centers of growth at a very fast rate. The urban population which used to be about 62 million in 1951 has increased to 285 million in 2001 and it is expected to rise to 550 million in the year 2021. Thus, the percentage of urbanization would increase to 41% in the year 2021 as compared to the 17.3% in 1951.

On one side is the increasing demand whereas the ground reality is the decreasing water availability per capita per year. The water availability per capita per year has gone down from 6008 m^3 in 1947 to 2384 m^3 about 50 years time and the utilizable water resources being only 1086 m^3 per capita per year.

The annual average rainfall received by India is 4,000 billion cubic meters (BCM). The rainfall is very uneven in different parts of the country. The precipitation varies from above 9,000 mm in Meghalaya to 100 mm in western Rajasthan. Also, the majority of the rainfall occurs in the monsoon season which lies from June to September; the rainfall in the monsoon season being 3,000 BCM and the remaining 1000 BCM is spread over rest of the year.



Source: India Assessment 2002 – Water Supply and Sanitation

Fig.2.4: Sectorwise water usage

There are still more regional disparities. The water availability also varies from basin to basin as has been illustrated in Unit 1. The utilizable water availability ranges from 18,147 cubic meters in Brahamputra valley to just 180 cubic meters in Sabarmati basin. Rajasthan with 8% of the country's population has to manage with only 1% of the water resources of the country.

Sharing of water is one of the major problems and has been contested at both international and national levels. There are many states in India which are confronting with one other for sharing the water resources since long.

Thus, there is a mismatch between demand and supply and the water resources are under great stress. Not just the quantity, the quality of water has also deteriorated over the years due to pollution from industries, agrochemicals and domestic sources. The other problems of groundwater depletion, water logging, siltation, soil salination further degrade the water quality. Together, all these factors worsen the situation and are a matter of environmental concern. Also, the poor water quality gives rise to many health problems.

Water quality monitoring by various agencies like Central and State Pollution Control Boards. The monitoring under river action plans such as Ganga Action Plan and Yamuna Action Plan has indicated that many of the river water resources are highly polluted.

Safe drinking water is not available to a large proportion of the population. Table 2.2 gives statistics for the availability of drinking water. Many water borne diseases such as *viral hepatitis*, *cholera*, *typhoid*, *dysentery*, *amoebiasis* etc. affect a large number of people. Often, these diseases may turn into epidemics and cause high morbidity and mortality. Lack of proper hygiene and sanitation aggravate the problems still further.

Table 2.2: Availability of drinking water

(in percent)

Sl. No.	States/Union Territories	Tap/Handpump/Tubewell								
		1981			1991			2001		
		Total	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban
1.	Jammu & Kashmir	40.3	28.0	86.7	NA	NA	NA	65.2	54.9	95.7
2.	Himachal Pradesh	44.5	39.6	89.6	77.3	75.5	91.9	88.6	87.5	97.0
3.	Punjab	84.6	81.8	91.1	92.7	92.1	94.2	97.6	96.9	98.9
4.	Chandigarh	991.	94.4	99.4	97.7	98.1	97.7	99.8	99.9	99.8
5.	Uttranchal	*	*	*	*	*	*	86.7	83.083.0	97.8
6.	Haryana	55.1	42.9	90.7	74.3	67.1	93.2	86.1	81.1	97.3
7.	Delhi	93.0	62.3	94.9	95.8	91.0	96.2	97.2	90.1	97.7
8.	Rajasthan	27.1	13.0	78.7	59.0	50.6	86.5	68.2	60.4	93.5
9.	Uttar Pradesh	33.8	25..3	73.2	62.2	56.6	85.8	87.8	85.5	97.2
10.	Bihar	37.6	33.8	66.4	58.8	56.5	73.4	86.6	86.1	91.2
11.	Sikkim	30.3	21.7	71.9	73.1	70.8	92.8	70.7	67.0	97.1
12.	Arunachal Pradesh	43.9	40.2	87.9	70.0	66.9	88.2	77.5	73.7	90.7
13.	Nagaland	45.6	43.4	57.2	53.4	55.6	45.5	46.5	47.5	42.3
14.	Manipur	19.5	12.9	38.7	38.7	33.7	52.1	37.0	29.3	59.4
15.	Mizoram	4.9	3.6	8.8	16.2	12.9	19.9	36.0	23.8	47.8
16.	Tripura	27.3	22.2	67.9	37.2	30.6	71.1	52.5	45.0	85.8
17.	Meghalaya	25.1	14.3	74.4	36.2	26.8	75.4	39.0	29.5	73.5
18.	Assam	NA	NA	NA	45.9	43.3	64.1	58.8	56.8	70.4
19.	West Bengal	69.7	65.8	79.8	82.0	80.3	86.2	88.5	87.0	92.3
20.	Jharkhand	*	*	*	*	*	*	42.6	35.5	68.2
21.	Orissa	14.6	9.5	51.3	39.1	35.3	62.8	64.2	62.9	72.3
22.	Chhattisgarh	*	*	*	*	*	*	70.5	66.2	88.8
23.	Madhya Pradesh	20.2	8.1	66.7	53.4	45.6	79.4	68.4	61.5	88.6
24.	Gujarat	52.4	36.2	86.8	69.8	60.0	87.2	84.1	76.9	95.4
25.	Daman & Diu	54.5	46.4	67.0	71.4	56.9	86.8	96.3	94.9	98.9
26.	Dadra & Nagar Haveli	19.4	16.8	54.3	45.6	41.2	91.0	77.0	70.5	96.1
27.	Maharashtra	42.3	18.3	85.6	68.5	54.0	90.5	79.8	68.4	95.4
28.	Andhra Pradesh	25.9	15.1	63.3	55.1	49.0	73.8	80.1	76.9	90.2
29.	Karnataka	33.9	17.6	74.4	71.7	67.3	81.4	84.6	80.5	92.1
30.	Goa	22.5	8.6	52.3	43.4	30.5	61.7	70.1	58.3	82.1
31.	Lakshadweep	2.2	1.0	3.7	11.9	3.4	18.3	4.6	4.6	4.6
32.	Kerala	12.2	6.3	39.7	18.9	12.2	38.7	23.4	16.9	42.8
33.	Tamil Nadu	43.1	31.0	69.4	67.4	64.3	74.2	85.6	85.3	85.9
34.	Pondicherry	80.6	76.9	84.2	88.8	92.9	86.1	95.9	96.6	95.5
35.	Andaman & Nicobar Islands	51.6	36.3	92.0	67.9	59.4	90.9	76.7	66.8	97.8
All India		**38.2**	**26.5**	**75.1**	**62.3**	**55.5**	**81.4**	**77.9**	**73.2**	**90.0**

N.A. – Not available as no census was carried out in Assam during 1981 and in Jammu & Kashmir during 1991.

* – Created in 2001. Uttaranchal Pradesh, Jharkhand and Chhattisgarh for 1981 and 1991 are included under Uttar Pradesh, Bihar and Madhya Pradesh respectively.

Source: Economic Survey of India (2004)

2.5 SUMMARY

In this unit, we have discussed some physical natural resources such as land, soil and water. Land is an important natural resource. Soil – the upper most layer of land is another vital resource for the production of food materials, fodder, growth of plants, vegetation and micro-organisms. The formation of soil is a very slow process and soil has various layers or horizons. Soils can be of various types each type of the soil has its own unique characteristics. We have discussed various types of soils and their important characteristics. In addition, we have also highlighted important characteristics of problems soils i.e. acid and alkaline soils.

Various factors such as extensive agricultural activities, clearing of forests, over grazing etc. have led to the degradation of soil. Soil erosion is also caused by some natural processes as well as human activities. These factors have been discussed in detail in this unit. However, if proper measures of soils conservation are taken, we can maintain soil fertility and use it as a meaningful resource.

Water is a very essential resource for the existence of life on this planet. Water is present in abundant quantity on earth. Various surface and ground water resources are available. The use of water is ever increasing for agricultural, industrial and domestic purposes. The growing population and developmental activities need more and more water. Although so much water is available on earth, the amount of utilisable water is not matching its demands. There is water shortage in many countries. There are disputes even with a country amongst different states for water sharing.

The quantity as well as the quality of water is a matter of serious concern today. Water pollution is spoiling the water quality and various resources of water are getting polluted today at a very fast rate due to discharge of industrial and agricultural wastes. We all have a responsibility in conserving this precious gift of nature. Various measures are possible for water conservation which will be discussed in detail in Unit 4.

2.6 TERMINAL QUESTIONS

1. What are different horizons of soil? Discuss their main features.
2. How does soil form?
3. Name different types of soils and explain their important features.
4. Explain various practices of protecting soil from degradation and erosion.
5. Explain the following:
   i) surface water
   ii) drainage basin
6. What is a drought? What factors are responsible for it?
7. What are the main reasons for occurrence of floods?
8. Discuss some harmful effects of salinity of water resources.
9. Discuss the factors responsible for water crisis.

UNIT 3 ENERGY AND MINERAL RESOURCES

Structure

3.1 INTRODUCTION

Energy moves the wheel of life. All kinds of processes require energy. Energy can be obtained from various sources which can be divided into non-renewable and renewable resources. In this unit, we would discuss about fossil fuels such as oil, natural gas and coal which are *non-renewable resources.*

However, in view of the limited availability of non-renewable resources, we have to look for alternate sources of energy. These are called *renewable resources*. There are many such resources like solar energy, wind energy hydropower, energy from biomass etc. Some of these are already in use but their real potential still needs to be exploited.

Another category of natural resources is that of **minerals** resources. There are various types of minerals found in the earth's crust. We mine them and modify them to make various items of everyday use. Here, in this unit, we will be describing the types, occurrence and various uses of mineral resources.

All these resources which have been discussed so far are treasures of nature. We should use them judiciously. Since they are in limited supply, there is an urgent need of their conservation. This aspect of conservation of natural resources is dealt in Unit 4 of this Block.

Objectives

After studying this unit, you should be able to:

- describe various sources of energy;
- differentiate between non-renewable and renewable energy resources;
- give examples of renewable energy resources and discuss their importance;
- list some non-renewable energy resources and appreciate the need for their conservation;
- explain the terms minerals and ores;
- give some examples of mineral resources;
- classify mineral resources into metallic and non-metallic minerals; and
- discuss the importance of mineral resources.

3.2 ENERGY RESOURCES

You know that energy resources can be broadly categorized as *non-renewable resources* and *renewable resources*. Here, we would learn more about them.

3.2.1 Non-renewable Energy Sources

The fossil fuel energy sources come under the category of non-renewable energy resources as it took millions of years for their formation. They are also known as **fossil fuels**. *Fossils* are the remains of ancient plant and animal life found on earth, rock, and clay. Fossil fuels are mined for use as an energy source. Fossil fuel energy is stored energy, which is given off when the fuel is burned. Most of the fossil fuel energy is released in the form of heat.

Non renewable energy resources have limited amount of stock available. The regeneration rate of non-renewable energy resources is negligible when compared with the rate of their consumption.

Types of Fossil Fuels

i) **Oil** – Oil is a fossil fuel that is found under the ground and sea in a liquid form. It is collected by drilling a deep well into the ground and then pumping it out. Oil is transported by pipe lines or oil tankers to different places where it will be stored or burned. Oil can be converted into gasoline. Both oil and gasoline are burned in automobiles and in aeroplanes.

ii) **Natural gas** – Natural gas is also a fossil fuel. It is a mixture of gases found under the ground. Natural gas is collected and transported almost the same way oil is. Natural gas is burnt in homes. It is now being used in cars and buses for transportation.

iii) **Coal** – Coal is another fossil fuel that is found under the ground in solid form. Coal is mined and transported by trucks or trains. It is taken to a place where it will be stored or burned.

The Origin of Oil and Gas

Phytoplankton are tiny floating plants called algae. The commonest are golden or brown coloured *diatoms* and *dinoflagellates*. *Zooplankton* are tiny animals which eat the phytoplankton but are themselves the main food for fish and some whales.

Oil (petroleum) and **natural gas** are formed by complex decay processes from microscopic life forms called *phytoplankton* (*phyto* = plant) which floated in the oceans millions of years ago. Just like today's phytoplankton, they harnessed the solar energy and stored it in the form of chemical energy by the process of photosynthesis. When these myriads of tiny floating plants died, they sank to the sea floor and became mixed with mud from distant rivers, and were gradually buried. Over long periods of time, the soft sediments became even more deeply buried and slowly hardened into rocks. Heat from the Earth's interior and the weight of the overlying rocks gradually changed the energy-containing substances present in the plants into liquids and gaseous hydrocarbons. *Hydrocarbons* are compounds made up of carbon and hydrogen atoms. These molecules, being light and mobile, migrated upwards through the rocks but eventually became trapped beneath impermeable rock structure in the Earth's crust. The oil and gas companies around the world know how to find these trapped reservoirs and release their contents by drilling holes into them. Crude oil and gas from these deposits form the basis for the world's largest energy industry i.e. of oil and gas (or petroleum) industry.

Most of oil and gas produced these days comes from underneath the sea bed. As the technology for extraction continues to advance, it becomes possible to extract these resources from deeper and deeper water. This means that new oil and gas fields will continue to be found for some years to come. But the supplies of these resources are limited.

Today, the rocks of the Arabian Gulf area contains by far the greatest amount of hydrocarbon wealth of the world. Saudi Arabia has 35 billion tons of proven oil reserves compared to the United States' 4 billion and Western Europe's 2.2 billion reserves.

The technology for extracting oil is highly expensive whether it is drilling a production well in 100 meters of water, laying sub-sea pipelines or refining the crude oil. Oil and gas are also the base – called *feedstock* – for much of the chemical industry. Almost all plastics are manufactured from this source.

The Origin of Coal

Coal is the most plentiful fossil fuel but it also the most polluting in nature. Like oil and gas, coal also originated from plants which lived tens or hundreds of millions of years ago mostly trees – in low lying swampy areas not much above sea level. As the trees died, they did not decompose (as they normally would, returning the carbon locked in their tissues to the atmosphere). Because of the water-logging, normal decay processes couldn't function. So thick layers of peat built up over thousands of years. These then became covered in sands or mud as the land subsided. As more material accumulated above the peat, water got squeezed out leaving just carbon-rich plant remains. After millions of years, this slowly changed i.e. *metamorphosised* – (like the oil and gas from the plankton) into coal.

Coal reserves of India are shown below in Fig.3.1.

Fig.3.1: Coal reserves in India

3.2.2 Renewable Energy Resources

Renewable energy resources are those sources whose supplies are regenerative and virtually inexhaustible. Among these sources are the sun, wind, water, vegetation, and the heat of the earth. The principal source of the renewable energy is the sun. The most common form of energy is direct sun light. The other renewable energy sources are based on natural environmental cycles, which are energized by the sunrays.

Throughout the human history, these renewable energy resources have been successfully harnessed and used by people. Almost 2,500 years ago, the Greeks designed their homes to use sunlight for heating in winters. Large, south-facing windows were used to collect solar heat, which was stored in massive walls and floors for gradual release throughout the night. The wind has also been used as an energy source for centuries. Some of its early uses include propelling ships and pumping water.

Today's technological advancements have developed more efficient means of harnessing and using renewable energy sources, and these sources are gaining increasing popularity. Existing renewable energy installations are making significant contributions to the global energy supply, and research activities are demonstrating the far-reaching impact that a greater reliance on renewable energy sources could have on the world's energy security.

Renewable energy includes sources of power that are replaceable and often locally accessible. India has the world's largest programmes for renewable energy. In fact, there is a separate Ministry – Ministry of Non-conventional Energy Sources to take care of the development and utilization of these energy sources. The technologies for using various renewable energy resources such as solar energy, solar photovoltaics, wind energy, energy from biomass, geothermal energy etc. are being developed. Let us now study about them in detail.

i) Solar energy – Solar energy is the ultimate source of energy and the other renewable sources of energy in fact originate from solar energy.

The Sun radiates energy across the whole electromagnetic spectrum of which the visible light forms only a small portion. The other types of electromagnetic radiation being radiowaves, microwaves, infra-red radiation, ultraviolet light, X-rays and γ-rays. These radiations correspond to different ranges of energy and hence have different wavelengths. The solar radiation can be used directly to heat buildings (Fig. 3.2) and water amongst its other applications or can be converted to electricity.

Solar energy has many advantages which are as follows:

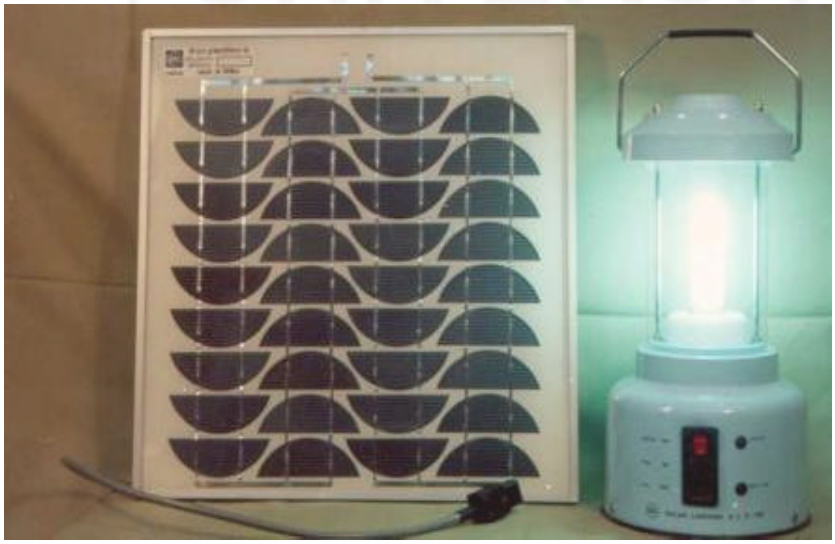
- It is wide spread in nature.
- It is a non-polluting resource.
- Its supply is inexhaustible.
- It is a free resource in the sense that the fuel is free.

India receives solar energy equivalent to over 5000 trillion KW hr per year. Depending upon the location, the incident solar energy in India varies from 4-7 KW hr per m^2.

Solar energy is harnessed in the form of *solar thermal* and *solar photovoltaic* technologies.

(a)

(b)



(c)

Fig.3.2: a) Solar photovoltaic technology; b) 100 KW SPV Power Plant at Jaipura kala, Rajgarh, Madhya Pradesh ; c) Solar lantern

(a) (b)

Fig.3.3: a) Solar cooker; and b) Solar building

Solar thermal energy is used for water heating in domestic and industrial applications, cooking, water desalination and purification, water pumping and power generation (See Fig. 3.3).

Solar photovoltaic cells convert solar energy into electricity. Solar photovoltaic applications include home lighting and street lighting systems, water pumping etc. (See Fig. 3.4).

Fig.3.4: A solar photovoltaic pump

ii) Biomass power – Biomass refers to biological sources of energy like wood and agricultural waste. Bio-mass energy technologies may burn these fuels for heat or power generation (Fig. 3.5) or convert them to liquids (such as alcohol) or gas (such as methane) for later combustion.

Fig.3.5: A biomass power plant in Andhra Pradesh

iii) **Hydro power** – In the hydro-electric dams, the water stored at a higher elevation is a source of potential energy. It is converted to kinetic energy in the turbines and then to electrical energy. These are all forms of external energy. Generally more than 90% of the potential energy of the water can be converted into electrical energy. It is also very easy to start and stop any one of the turbines and there is little energy loss in doing so.

(a) (b)

Fig.3.6: a) A Hydro power dam; and b) A canal based hydro power project

The hydroelectric potential in India is about 600 billion KWh annually whereas the capacity is 150 GWe (15000 MW). The hydro energy resources are mainly located in northern and north-eastern regions. At present, 2700 MW of hydropower has been developed and it is expected that the rest of the potential would be harnessed by 2025-26. The Tenth Plan envisages the addition of 1600 MW new capacity and the Eleventh Plan expects to further add 1930 MW.

iv) **Wind energy** – Wind energy has been traditionally used to lift water for domestic and agricultural needs. Kinetic energy of the wind is converted to electrical energy to meet the above requirements.

Fig.3.7: a) Wind energy use for drinking water supply, and b) A wind farm

India is the fifth largest producer of wind power in the world. The wind power potential is about 45000 MW. Wind energy is being used for water pumping, battery charging and power generation, see Fig. 3.7(a). Wind energy is again a clean renewable energy resource.

Theoretically, a maximum of 60% of wind energy can be converted to electricity but practically wind generators normally convert only 25% of the wind energy to electricity.

Wind speed is the most important factor is the generation of energy from wind mills. Typically, the wind speeds must range from 16-20 kms per hour for economic use of this source of energy. The variability of wind also limits the production of electricity from wind on a continuous basis. Thus, high capacity storage batteries need to be developed.

Also, it is more economical to have 'wind farms' consisting of 50 or more giant wind energy generators rather than individual generators (Fig. 3.7(b)).

v) **Tidal energy** – Ocean and sea waves are caused indirectly by solar energy. The energy of waves is derived from wind energy, which is driven in turn from solar energy. The energy of waves may be converted to mechanical energy and then to electricity.

Fig.3.8: Ocean tides

The gravitational attraction among the earth, moon and sun raises the water levels in oceans and seas. Such tides may range from 1 m to 10 m height. The energy from waves and tides can be harnessed to produce electricity.

vi) **OTEC** (Ocean Thermal Energy Conversion) – It involves the conversion of solar energy stored as heat in the ocean into electrical energy by making use of the temperature difference between the warm surface water and the colder deep water. This temperature could be as much as 22°C. But, this much difference would not be there at all the places. Often, due to smaller temperature differences, the operating efficiency of the OTEC systems is just about 3%. Also, the capital expenditure is large for installing such systems. Therefore, they are not very viable energy options.

vii) **Geothermal power** – Geothermal energy is the energy present as heat (i.e. thermal energy) in the earth's crust; the more readily accessible heat in the upper-most (10 km or so) part of the crust is a potentially useful source of energy, see Fig. 3.9. This heat is a result of the increase in temperature of the earth with increasing depth below the surface.

Fig.3.9: A geothermal well

In most areas, geothermal energy is so diffuse that it cannot be tapped as an energy resource. However, in certain regions, molten magma rises close to the earth's surface and produces hot rock. Where water comes into contact with such hot rocks, it gets superheated (i.e. its temperature rises above 100°C) and can be used as an energy resource.

Geothermal energy makes a small but significant contribution to the total energy requirements. However, it is being extensively used in Iceland, Italy and New Zealand to generate electricity and heat buildings and greenhouses.

SAQ 1

Discuss the difference between renewable and non-renewable energy. Give two examples each for renewable and non-renewable energy sources.

……..

……..

SAQ 2

Give two important uses of natural gas.

……..

……..

SAQ 3

How is energy produced from biomass?

……..

……..

3.2.3 Renewable Biomass as a Versatile Fuel

Biomass is organic plant matter produced by solar energy through photosynthesis. Some of this plant matter can be burned as solid fuel or converted to more convenient gaseous or liquid *Bio fuels.* Biomass supplies supplemental energy by burning of wood and manure and this energy has been used in heating buildings and cooking food.

All biomass fuels have several advantages in common. They can be used in solid, liquid, and gaseous forms for space heating, water heating, producing electricity, and propelling vehicles. Biomass is a renewable energy resource as long as trees and

plants are not harvested faster than they grow back-something that is not being done in most places.

There is no net increase in atmospheric levels of carbon dioxide as long as the rate of removal and burning of trees and plants and loss of below – ground organic matter does not exceed their rate of replenishment. Burning of biomass fuels adds much less sulfur dioxide and nitric oxide to the atmosphere per unit of energy produced than the uncontrolled burning of coal and thus requires fewer pollution controls.

Biomass fuels also share some disadvantages. Without effective land-use control and replanting, widespread removal of trees can deplete soil nutrients and can cause excessive soil erosion, water pollution, flooding and loss of wildlife habitat. Biomass resources also have a high moisture content (15% to 95%), which lowers their net useful energy. The added weight of the moisture makes collecting and hauling wood and other plant materials fairly expensive. Each type of biomass fuel has other specific advantages and disadvantages.

Burning wood and wood wastes. About 80% of the people living in LDCs heat their dwellings and cook their food by burning wood or charcoal obtained from wood.

In MDCs with adequate forests, the burning of wood, wood pellets, and wood wastes to heat homes and to produce steam and electricity in industrial boilers increased rapidly during the 1970s because of increase in the prices of heating oil and electricity. Sweden leads the world in using wood as an energy source, mostly for district heating plants.

Wood has a moderate to high net useful energy yield when collected and burned directly and efficiently near its sources. But in urban areas where wood must be hauled long distances, it can cost home owners more per unit of energy produced than oil and electricity.

Burning of wood releases carbon monoxide, solid particulate matter, and unburned residues that pollute indoor and outdoor air.

Energy plantations– One way to produce biomass fuel is to plant large numbers of fast-growing trees is *biomass-energy plantations* to supply fuelwood. Plantations of oil palms and varieties of Euphorbia plants, which store energy in hydrocarbon compounds (like those in oil), can also be established. After these plants are harvested, their oil-like material can be extracted and either refined to produce gasoline or burned directly in diesel engines. Both types of energy plantations can be established on semiarid land not needed to grow crops, although lack of water probably would limit productivity.

This industrialized approach to biomass production usually requires the heavy use of pesticides and fertilizers, which can pollute drinking supplies and harm wildlife. Conversion of large areas of monoculture energy plantations also reduces biodiversity. In some areas, biomass plantations might compete with food crops for prime farmland. Also, they are likely to have low negative net useful energy yields, as do most conventional crops grown by industrialized agricultural methods.

Burning agricultural and urban wastes – In agricultural areas, crop residues (like inedible, unharvested parts of food crops) and animal manure can be collected and burned or converted to bio fuels. Power plants burning rice husks are operating in India, Sri Lanka, Bangladesh and Nepal. Other crop residues that could be burned include coconut shells, peanut and other nut hulls, and cotton stalks.

In most areas, however, plant residues are widely dispersed. Unless they are harvested along with crops, they require large amounts of energy to collect, dry, and transport to large, centralized power plants. Also, ecologists argue that it makes more sense to use crop residues to feed livestock, retard soil erosion, and fertilize the soil.

An increasing number of cities in Japan, western Europe, and the United States have built incinerators that burn trash and use the heat released to produce electricity or to heat nearby buildings. Some analysts argue that more energy is saved by composting or recycling paper and other organic wastes than by burning them.

Converting soild biomass to liquid and gaseous Bio fuels – Plants, organic wastes, sewage, and other forms of solid biomass can be converted by bacteria and various chemical processes into gaseous and liquid Bio fuels. Their examples being *biogas* (a mixture of 60% methane and 40% carbon dioxide), *liquid methanol* (methyl alcohol or wood alcohol), and *liquid ethanol* (ethyl alcohol or grain alcohol).

In China, bacteria in an estimated 7 million *biogas* digesters convert organic plant and animal wastes in to methane fuel for heating and cooking. After the biogas has been removed, the solid residue left behind can be used as fertilizer on food crops or if contaminated, on non-edible crops such as trees.

Biogas digesters are very efficient. However, they are slow and unpredictable. They don't work well at low temperatures or when contaminated by acids, heavy metals, synthetic detergents, and other industrial effluents. Development of new, more reliable models could change this scenario.

Methane fuel is also produced by underground decomposition of organic matter in the absence of air (anaerobic digestion) in active and closed landfills. The gas is collected by pipes inserted in land fills. The gas is then purified and burned as a fuel. Because methane is a greenhouse gas this recovery would also help show down global warming.

Methane can also be obtained by anaerobic digestion of manure and sludge produced at sewage treatment plants. But collecting and transporting manure for long distances to large, centralized power plants takes energy. Recycling this manure to the land to replace commercial inorganic fertilizer, which requires large amounts of natural gas to produce, would probably save more natural gas.

Some analysts believe that methanol and ethanol can be used as liquid fuels to replace gasoline and diesel fuel when oil becomes too scarce and expensive. Both alcohols can be burned directly as fuel without requiring additives to boost octane ratings.

Currently, emphasis is on using ethanol as an automotive fuel. It can be made from sugar and grain crops (sugarcane, sugar beets, sorghum, and corn) by fermentation and distillation. Pure ethanol can be burned in today's cars with little engine modification. Gasoline can also be mixed with 10% to 23% ethanol to make gasohol. It burns in conventional gasoline engines and is sold as super unleaded or ethanol enriched gasoline.

3.2.4 Bio Fuels and Bio Diesel in India

India has a great potential for the production of bio fuels such as bio-ethanol and bio diesel. India has about 100 varieties of oil seeds. Bio diesel is a renewable fuel made from edible and non-edible vegetable oils. It has been proved to be a good substitute for petroleum diesel.

Oil can be extracted from a number of plants and oilseeds. Some such bio diesel yielding trees are as follows:

1. *Jatropha curcas* or Ratanjot
2. *Pongamia pinnata* or Karanj
3. *Calophyllum inophyllum* or Nagchampa
4. *Hevea brasiliensis* or Rubber Seeds
5. *Calotropis gigantia* or Ark
6. *Euphorbia tirucalli* or Sher
7. *Boswellia ovalifololata*

Table 3.1 gives the production and oil content of some non-edible oil seeds.

Table 3.1: Annual production of some non-edible oilseeds in India

Name of the Plant	Production (MT)	Percentage of Oil
Neem	500	30
Karanja	200	27-39
Kusum	80	34
Ratanjot	--	30-40
Jaoba	--	50
Wild Walnut	--	60-70
Undi	04	50-73
Thumba	100	21

Jatropha curcas is a very promising plant as its 4400 plants per hectare can produce about 1500 litres of oil. It can be grown as a quick yielding plant even in adverse land situations such as on dry and drought prone areas, marginal lands etc. The oil cake left behind after the extraction of the oil from seeds can be used for biogas production and is an excellent organic manure.

Bio diesel contains no petroleum. It can be used either in the pure form or can be blended with petroleum diesel to make a bio diesel blend. Its use in conventional diesel engines leads to reduction in the amount of unburnt hydrocarbons, carbon monoxide and particulate matter.

It has almost nil sulphur, no aromatics and has 10% oxygen content which helps it to burn completely. The Planning Commission (The Government of India) has constituted a committee for 'Development of Bio fuels' which would look after various aspects related to the bio fuels.

SAQ 4

List the disadvantages of biomass fuels.

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SAQ 5

Name the liquid Bio fuels obtained from biomass.

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SAQ 6

What is gasohol?

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3.3 MINERAL RESOURCES

What do cars, spoons, glasses, dishes, beverage cans, coins, electrical wiring, bricks, and side-walks have in common? Few of us make stop to think that these products and many other we use every day, are derived from mineral resources. *Minerals* are non-renewable raw materials extracted from the earth's crust – the upper layer of the lithosphere.

Any naturally occurring inorganic substance found in the earth's crust as a crystalline solid is called a **mineral**. Examples of minerals include *salt* – used to season food, *clay* – used to make dishes and bricks, *silicates* – used to make glass and *sand*, *gravel*, *limestone* and *gypsum* which are used to make concrete. All the minerals cited above are *non-metallic* in nature.

Other important class of minerals is that of metallic minerals from which metals such as iron, aluminum, copper and gold are obtained. An **ore** is a mineral deposit containing enough of a metallic element to permit it to be extracted and sold. The higher the concentration of metal in the ore, the higher is its grade.

These minerals are part of our non-renewable heritage, produced by geologic events over millions of years. Without them the technological civilization it would not have been possible.

Unlike biological resources, the mineral resources cannot be managed to produce a sustained yield. Their supply is limited. We can recycle, reuse and conserve some minerals to make them last longer. But after the high-grade ores and easy-to-get deposits have been tapped, the supply of these minerals will be eventually depleted. Then, it would cost too much to find, process and use what is left.

3.3.1 Origin of Mineral Resources

The rock cycle – A rock is a naturally occurring solid that contains one or more minerals. The largest and slowest of the earth's cyclical processes is the *rock cycle*. It involves the formation and the modification of rocks in the earth's crust and mantle. Three major types of rocks are formed in this cycle: *igneous*, *sedimentary* and *metamorphic*.

i) **Igneous rocks:** They are formed by the cooling, hardening and crystallizing of various kinds of lavas and differ widely in their chemical composition. They chiefly contain feldspars, maphic minerals and quartz. Rocks containing a high proportion of quartz (60-75%) are classified as acidic, whereas those containing less than 50% quartz are classified as basic. The common igneous rocks found in India are the granites (acidic) and basalts or the Deccan Trap (basic).

ii) **Sedimentary rocks:** They are derived from igneous rocks and are formed by the consolidation of fragmentary rock materials and the products of their decomposition deposited by water. The common sedimentary rocks are conglomerate, sandstone, shale and limestone. Alluvial, glacial and Aeolian deposits form the unconsolidated sedimentary rocks.

iii) **Metamorphic rocks:** They are formed from the igneous or sedimentary rocks by the action of intense heat and high pressure or both resulting in considerable change in the texture and mineral composition. The common metamorphic rocks are geneis from granite, quartzite from quartz or sandstone, marble from limestone and slate from shale.

The rock cycle is powered by energy from the sun, heat from the earth's interior, wind, flowing water, and movements of the earths' crust. Mountains, plains, ocean floors, and other geologic features the earth are the results of this geological cycle of destruction and creation of the earth's three basic types of rocks.

Weathering refers to the physical and chemical disintegration and decomposition of rocks which are not under equilibrium under temperature, pressure and moisture conditions on the earth's surface. In the beginning, weathering precedes soil formation, more so in hard rocks. In other words, weathering creates the parent material over which soil formation takes place. Later, weathering, soil formation and development proceed simultaneously. The weathering may be physical or chemical in nature.

3.3.2 Mineral Resource Abundance and Distribution

We have learned how to find and mine concentrated deposits of more than 100 minerals formed by the rock cycle in the earth's continental and oceanic crusts. We convert these minerals into many items of everyday use and then either discard, reuse or recycle them.

We remove concentrated minerals, process and use them, and often disperse them over parts of the earth's surface. It takes millions of years for these dispersed materials to become concentrated by the rock cycle into useful minerals again. Therefore, on a human time scale we classify these minerals as non-renewable resources.

A few minerals, such as gold and silver, occur as free elements. But most minerals are compounds of ten elements and these make up 99.3% of the earth's crust. Only trace amounts of other elements are found in the earth's crust.

Metallic minerals can be classified according to how abundant they are in the earth's crust. Aluminum, iron, magnesium, titanium, manganese, and chromium are abundant metals. Scarce metals include lead, copper, zinc, silver, gold, platinum, molybdenum, and mercury.

Iron makes up 95% of the metals extracted from the earth each year. It is used to make steel. Small amounts of other metals, such as cobalt, manganese, nickel, and chromium, are added to steel to make stainless steel. Stainless steel is an *alloy*. **Alloys** are formed when metals or non-metals are added to metal to modify their properties. A large variety of alloys with desired properties have been in use since ancient times. Their examples being brass, bronze, etc.

The distribution of metallic and non-metallic mineral of the maps of India is shown in Figs.3. 10 and 3.11, respectively.

Fig.3.10: India map showing metal industries

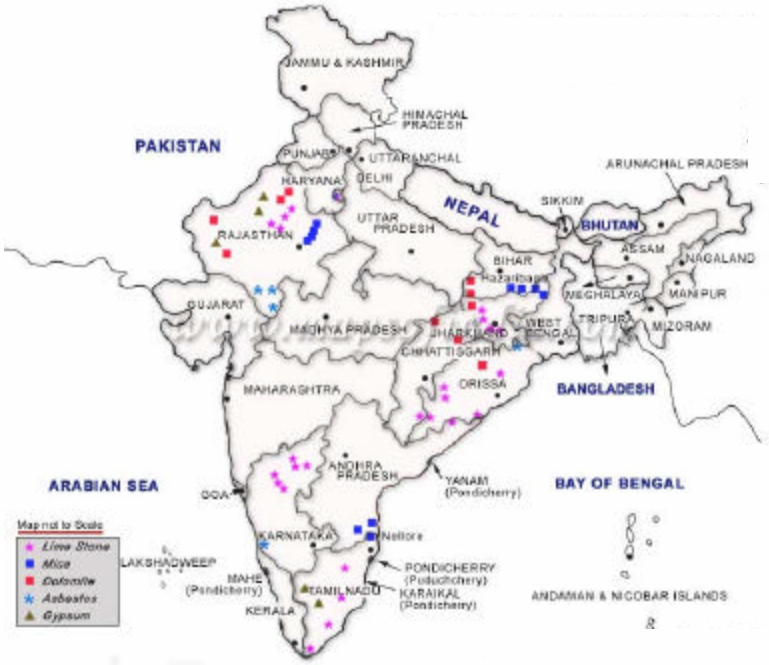

Fig.3.11: Non-metallic minerals in India

The mineral production for some selected minerals is given in Table 3.2.

Table 3.2: Mineral production in India

Mineral	2002-03			2003-04		
	Unit	Quantity	Value (Rs. 000)	Unit	Quantity	(Value in Rs. Crore)
All Minerals	.	.	580659251	.	.	66307.70
Fuel Minerals	.	.	513172449	.	.	53101.10
Coal	Th. tonnes	341248	224262399	M.Tonnes	361	23649.21
Lignite	Th. tonnes	26018	17766340	M.Tonnes	28	1882.51
Natural Gas	M.C.M	29969	87094200	M.C.M	30932	8976.72
Petroleum(Crude)	Th. tonnes	33043	184049510	M.Tonnes	33	18592.66
Metallic Minerals	.	..	45405837	.	.	5519.17
Bauxite	Tonne	9776633	2156553	Th. tonnes	10929	237.88
Chromite	Tonne	3066466	4972513	Th. tonnes	3469	503.92
Copper Conc.	Tonne	153232	2429645	Th. tonnes	143	212.67
Copper Ore	Tonne	3135403	----	.	.	.
Gold	Kg	3049	1391615	Kg	3363	155.92
Gold Ore	Tonne	544378	-----	.	.	.
Iron Ore	Th. tonne	96962	27104479	Th. tonnes	119780	3629.01
Lead & Zinc Ore	Tonne	3095017	-----	.	.	.
Lead Conc.	Tonne	59132	641192	Th. tonnes	73	73.14
Manganese Ore	Tonne	1662004	2455229	Th. tonnes	1734	274.66

Silver	Kg	59502	453694	.	.	.
Zinc Conc.	Tonne	485976	3800067	Th. tonnes	590	420.83
Non-Metallic Minerals	.	.	22080965	.	.	2213.00
Asbestos	Tonne	14340	16923	.	.	.
Barytes	Tonne	675291	325098	Th. tonnes	721	36.95
Calcite	Tonne	114989	33841	.	.	.
Chalk	Tonne	131362	33796	.	.	.
Corundum	Kg	5002	18	.	.	.
Diamond	Carat	84407	396307	Carat	71259	31.81
Diaspore	Tonne	6978	4236	.	.	.
Dolomite	Tonne	3329413	857299	Th. tonnes	3818	82.77
Fireclay	Tonne	463205	50906	Th. tonnes	574	6.34
Fluorite *Concentrates *Graded	 Tonne Tonne	 4198 6296	 32882 9220	.	.	.
Garnet *Abrasive *Gem	 Tonne Kg	 442593 2698	 99067 386	Th. tonnes	472	10.28
Gypsum	Tonne	2842306	394043	Th. tonnes	2854	32.26
Kaolin	Tonne	796758	886513	Th. tonnes	846	95.40
Laterite	Tonne	605661	42272	Th. tonnes	700	6.60
Lime Kankar	Tonne	325960	43338	.	.	.
Limeshell	Tonne	119925	63146	Th. tonnes	134	6.80
Limestone	Th. tonnes	145552	15249436	M. tonnes	154	1534.22
Magnesite	Tonne	272798	318439	Th. tonnes	324	41.23
Mica *Crude *Waste & Scrap	 Kg Kg	 1217054 3401088	 30883 ------	.	.	.
Perlite	Tonne	283	283	.	.	.
Phosphorite	Tonne	1197229	1988280	Th. tonnes	1060	173.91
Pyrophyllite	Tonne	152904	25910	.	.	.
Pyroxenite	Tonne	236791	72140	Th. tonnes	244	8.44
Sand(Others)	Tonne	2135311	110663	Th. tonnes	1773	5.60
Shale	Tonne	1343871	27163	.	.	.
Silica Sand	Tonne	1691055	157476	Th. tonnes	2316	22.93
Sillimanite	Tonne	13674	47301	Th. tonnes	19	6.73
Selenite	Tonne	18761	11944	.	.	.
Slate	Tonne	4775	2644	.	.	.
Steatite	Tonne	675789	330092	Th. tonnes	716	33.91
Wollastonite	Tonne	172510	118994	Th. tonnes	151	10.19

Source: Economic survey, Ministry of Finance, 2003-04.

Over hundreds of millions of years, the geochemical processes have dissolved, transported and deposited elements and their compound unevenly. Consequently, there are large differences between the average crustal abundances of elements and

how much of an elements is found at a particular place. Concentrated deposits of a particular minerals such as iron or copper may exist at some locations. But most deposits contain too little of the desired metal to be economically useable.

3.3.3 The Formation of Minerals

Minerals are formed by several different processes. One is *plate tectonics* i.e. the movements of parts of the earth's crust downward, upward and across one another. Boundaries between the moving plates (faults) are zones where the earth quakes occur and the sites of active volcanoes.

New crust is formed where two plates are drawn apart by movements in the underlying mantle. The theory of plate tectonics explains how the continents have drifted apart over hundreds of millions of year and how some mineral deposits were formed.

Most deposits of metallic ores are formed at the boundaries where tectonic plate separate and where they come together. Where plates separate along the ocean floor, molten igneous rock (magma) comes into contact with cold ocean water. The heated water rises through fractured rocks and leaches metals from them. This hot, mineral-laden water spews out of hydrothermal vents on the earth floor. The dissolved metals are deposited as metal sulphides when the water cools.

At boundaries where tectonic plates come together, igneous rocks saturated with sea water are forced together. The resulting high temperatures and pressures partially melt the rocks to form bodies of magma. This magma may force its way upwards into the crust, cool, and allow minerals to crystallize.

Mineral deposits may also form where plate movements allow magma to rise, penetrate the earth's surface, and form active volcanoes. As the molten igneous rock inside the volcano cools, minerals with high densities crystallize and are found near the top of the rock deposit. Diamonds form when molten rock made up mostly of carbons cools very slowly under enormous pressure.

Many ore deposits are formed by hot waters moving underground within the earth's crust. Hot, circulating ground water dissolves minerals from deeply buried molten rock. When the water reaches rock in areas above or beyond the molten zone, it cools and leaves deposits of minerals.

Sedimentary processes also concentrate minerals in deposits. The processes that weather and erode igneous rocks and deposit them as sediments can remove unwanted materials and leave behind deposits of useful minerals. Weathering and erosion deposit materials in ocean and stream beds at lower elevations. Wind and running water separate these rock particles by density shape and size. Sand and gravel, for example, are sedimentary deposits of fine-grained rock. Sometimes minerals such as gold are found in *placers* in streams. **Placers** are deposits formed when flowing water separates heavier mineral particles from the sediment and drops them on stream beds with little water flow and turbulence.

Some mineral deposits are formed when minerals dissolve in water and then crystallize as the water evaporates. For example, vast underground caverns of limestone are formed when calcium carbonate is dissolved by acidic water seeping downward. The water becomes acidic by dissolution of carbon dioxide from the air and by the passage through some types of soil. As the water evaporates, it leaves deposits of calcium carbonate. When these deposits hang from the ceiling, stalactites are formed.

They are known as salt deposits from above ground when the sun evaporates water from shallow pools of seawater.

3.3.4 Locating and Extracting Mineral Resources

Making Mineral Resources Available – A large amount of energy are needed to mine and process minerals. Several steps are involved in making a mineral resource available for use:

- A deposit containing enough of the desired mineral to make extraction profitable must be found.
- Some form of mining is used to extract the mineral from the deposit.
- The mineral is processed to remove impurities.
- In some cases (especially metallic ores), the purified mineral is converted to a different chemical form by smelting or other chemical processes. For example, aluminum is found in the earth's crust in ore form as aluminum oxide (Al_2O_3). After the ore is purified and melted, electrical current is passed through the molten oxide to convert it to aluminum metal (Al) and oxygen gas (O_2).

In India, The Department of Mines is responsible for the survey and exploration of minerals (other than natural gas and petroleum), for mining and metallurgy of non-ferrous metals such as aluminium, copper, lead, zinc, nickel etc. Its subordinate agencies being Geological Survey of India (GSI) and Indian Bureau of Mines (IBM). GSI is involved in the assessment of geological and regional mineral resources and covers about 94% of the country's area for geological mapping. IBM is responsible for compiling exploration data, mineral maps and other information related to mineral resources.

About 85% of the mineral production is taken care by the public sector enterprises such as National Mineral Development Corporation, Kudremukh Iron Ore Company, Steel Authority of India, National Aluminium Company and Hindustan Copper Ltd. The rock phosphates are mined by the Rajasthan State Mines and Minerals Ltd. whereas the barytes are mined mainly by Andhra Pradesh Mining Development Corporation.

SAQ 7

What are minerals? How are they formed?

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SAQ 8

Name three types of rocks. Give their important characteristics.

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3.4 SUMMARY

In this unit, we have discussed about two important physical natural resources i.e. energy and mineral resources. Both of these are very important from the industrial and economic aspects. The energy can be obtained from various resources. Some of these are renewable resources while the others are non-renewable. The non-renewable resources which were described in this unit were coal, oil and natural gas. These are collectively known as fossil fuels. Since it took thousands of years to form these resources in nature, they are not very easily replaceable. They are being consumed at a very fast rate. Hence, their depletion is a serious concern today. Thus, these resources need to be conserved. Also there is an urgent need to switch over to renewable sources

of energy which include solar energy, biomass, hydro power, wind energy, tidal energy etc. These resources have a great potential to meet the energy requirements. But their full potential is yet to be harnessed.

Minerals form the backbone of various industries. They can be classified as metallic or non-metallic. They are obtained from various types of rocks. India has a large variety of mineral resources. In this unit, we have discussed the abundant and distribution of some important minerals occurring in India. We have also highlighted the importance of these natural resources and ways to use them judiciously.

3.5 TERMINAL QUESTIONS

1. What are fossil fuels? How are they formed?
2. What are the limitations of biogas digesters?
3. How is ethanol produced?
4. What is Bio diesel? How it can be produced?
5. Name two important classes of minerals. Give two examples for each.
6. Discuss the formations of various rocks in nature.
7. Why are mineral resources called as non-renewable resources?

Further Readings

1. http://www.org/opet/articles/art10.htm
2. http://mnes.nic.in/annualreport/2003_2004-English/ch1_pg1.htm
3. http://www.cpcb.nic.in/diesel/ch70902
4. http://www.svlele.com/biodiesel-in-india.htm

UNIT 4 NATURAL RESOURCE CONSERVATION

Structure

4.1 INTRODUCTION

In Units 1, 2 and 3, you have studied about various natural resources in detail. Now, you can appreciate their importance and utility. These resources are very valuable for us. However, their increasing consumption, decreasing availability and their continuous degradation raise the urgent need of their conservation.

Some natural sources are renewable while others are not. Also, these natural resources are not unlimited. Due to their growing demand, they are likely to get exhausted one day and hence we should judiciously use this wealth of nature. In this unit, the conservation of natural resources has been explained in detail. There are many human activities which cause the degradation and depletion of natural resources. The proper management based approach in accordance with the principle of sustainable use is required for the conservation of natural sources to make these resources last longer.

In this unit, we have discussed various aspects leading to over exploitation and degradation of various natural resources. The need for conservation has been highlighted. Certain key issues pertaining to the management of natural resources have been discussed. Finally, the conservation strategies for land, water and energy resources have been described.

Objectives

After studying this unit, you should be able to:

- discuss the reasons of overexploitation of natural resources;
- list various causes of degradation and depletion of natural resources;
- highlight the need for conservation of natural resources;
- describe important issues in natural resource management; and
- explain various measures for the conservation of land, water and energy resources.

4.2 OVEREXPLOITATION OF NATURAL RESOURCES

The human population is increasing at very fast rate and at the same time the human needs are also growing. Hence, more and more resources are required to meet the ever increasing human requirements. But the resources are available in a limited amount. Also, the natural resources on the earth are not distributed evenly. Hence, there is a great pressure on the existing resources. In other words, we can say that these resources are being over exploited. Thus, the resources are being consumed at a very fast rate. The non-renewable resources are being depleted and would exhaust one day. Also, classifying something as a renewable resource, however does not mean that it can not be depleted and that it will always stay renewable. The highest rate at which a renewable resource can be used without decreasing its potential for renewability throughout the world or in a particular area is called sustainable yield. If the natural replacement rate is exceeded, the available supply of a potentially renewable resource begins shrink and this process is known as **environmental degradation**.

If such unsustainability continues, the resources can become non-renewable on a human time scale or some times non-existent. The key of maintaining the supply of a non-renewable resource is to keep its rate of use at or below natural replacement rate (sustained yield).

Today many of the natural resources are being damaged as a result of human activities. Air pollution, water pollution and the problem of solid waste disposal are headlines in newspapers daily. Natural resources like soil, forests and wildlife are in danger because of reckless human action and insensitivity which are stressing and degrading the resources in an unprecedented manner.

Have you heard about the Panda? Only a small number of this species still exists and most of them are under special care. Panda is in danger of becoming extinct because there are only few of them which are surviving. Many species of plants and animals today also are in danger of becoming extinct because they are being hunted and their habitats are being destroyed. Species that are in danger of becoming extinct are called **endangered species**. Population of many species is decreasing, often as a result of human activities. Developers have filled in estuaries and wetlands to build houses and the irrigation and the settlement projects have resulted in the clearing of forests. This leads to population decline as the individual organisms die or move on to new habitats.

Also, there may be thousands of plant species that have not been studied yet, and their uses are unknown. If these species are lost, they are lost forever.

SAQ 1

What do you understand by overexploitation of natural resources?

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SAQ 2

Explain various factors responsible for the degradation of natural resources.

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4.3 DEGRADATION AND DEPLETION OF NATURAL RESOURCES

Several types of environmental degradation can change resources into non-renewable ones and render them unusable. Today, many natural resources are being damaged as a result of human activities. The rapid rate of development and unplanned urbanisation cause air pollution, water pollution, and problem of solid waste disposal. There is too much pressure on land resources also. Forests are shrinking due to expanding greed of humans. Thus, natural resources are being depleted at very fast rate. The problem of their depletion is further worsened by their degradation. Soil, forests, biodiversity – all natural resources are in danger because of human activities. The reasons for depletion and degradation are numerous. Some of them are discussed below.

4.3.1 Land Degradation

The land requirements are increasing heavily due to fast growing population, developmental activities and industrialization. Also, there is an increasing need of food production to feed the increasing human population which requires more and more of agricultural land. Thus, there is an increasing pressure on land resources and they are being over exploited. The quality of land available is also getting degraded due to various reasons. Every day, magazines, news papers, plastic bags, glass bottles, aluminum cans, and glass clippings are thrown away as solid wastes. **Solid wastes** are the unwanted products that are burned, buried and dumped each year all over the world. Solid wastes are being ultimately dumped in sanitary landfills.

In addition to solid waste, toxic waste, biomedical waste and hazardous wastes are also being dumped on land. **Toxic wastes** are chemicals that are by products of industrial processes. Many are known to cause cancer, birth defects, and other health problems. Some waste products are packed in steel drums and are buried underground. If the drums are not sealed properly, the chemicals contained in them leak and pollute both soil and water.

Thus, the vital land resources are heavily threatened particularly in Asian countries.

4.3.2 Deforestation

It is one of the major threats to the natural resources. There are many reasons for deforestation. The increasing population has ever increasing needs for land for agriculture, industries, housing etc. Thus, forests are being cleared for meeting the demand for land. Also, the cutting of trees for fuel wood in hilly and rural areas is common and a major cause of deforestation. Use of wood as a fuel for heating is done both in developing and developed countries. In addition to these two major causes, deforestation results from many other activities. Deforestation has affected the environment in the following ways:

- Cutting of trees from large areas is responsible for the loss of wildlife and increases the surface run off leading to desertification.
- Depletion of grass by livestock (due to overgrazing).
- The erosion of soil results in unproductive lands.
- Elimination of biodiversity due to habitat loss, hunting, pest control and pollution.

4.3.3 Soil Erosion

Much of the land in Asian countries lies on mountain slopes, where fuel for cooking is scarce. The families go higher and higher up into the mountains searching for fuelwood. They cut trees and bring them home, leaving the slope barren. When the rainy season comes, there are no *tree roots to absorb water* and hold the soil in place.

Thus, water washes the soil away. This is called **soil erosion**. Rain washes away the fertile topsoil and the plants are unable to grow on the barren mountains slopes.

Poor farming and forestry practices often result in erosion of top soil. Erosion also occurs when timber in a forest is harvested by a method called **clear-cutting**. By this activity, not only the soil is left unprotected but the habitats of all the organisms which live in or on the trees also get disturbed.

Soil erosion is of much concern because of its consequences on agriculture, which is a major contributor to the India GPD of the Asian countries. Erosion is acute in the hill areas where major rivers originate and critical watersheds are located.

Several indirect and direct factors cause soil erosion in Asian region. These can change soil which is a potentially renewable resource and render it into a non-renewable or an unusable resource. The following factors may lead to erosion of soil.

Factors causing soil erosion

- Covering productive land with water, concrete or buildings to such an extent that the crop growth declines and habitats (places for wildlife to live) are lost.
- Cultivating land without proper soil management – This may lead to reduced crop growth due to soil erosion and depletion of plant nutrients.
- Irrigating cropland without sufficient drainage may lead to excessive building up of water (*water logging*) or salts (*salinization*) in the soil which decreases the growth of crops.
- Removal of water from the underground sources (*aquifers*) and surface water sources.

4.3.4 Water Pollution

Water can be polluted by oil, industrial wastes, sewage, bacteria, sediments, solid wastes, and even heat. Most rivers and lakes are seriously polluted and their water is unfit for use. Rivers Ganga and Yamuna are examples of two such rivers. When power plants use water from rivers for cooling purposes, the water which is returned to the river may be several degrees hotter than it was originally. Organisms in rivers can not adjust to such quick changes of temperature and they may die.

Water pollution in Asian countries also arises from agricultural practices which extensively use agrochemicals and fertilizers. The urbanization and industrialization also results in the release of untreated industrial effluents, dumping of waste and flow of sewage into water ways. Rain washes these chemicals out of the soil and they enter into nearby water resources. Even though water is a renewable resource, it is expensive to clean polluted water, especially the ground water.

4.3.5 Air Pollution

Air pollution is caused by gases emitted from vehicles or power plants which burn fossil fuels. Polluted air may contain carbon monoxide, nitrogen oxides, sulphur dioxide, hydrocarbons, and tiny particles of ash, lead, dust or soot. Some air pollution may occur by natural sources, for example, when gases are released from a volcano. But major reason of air pollution are burning of fossil fuels in power plants and automobiles. The burning of coal to produce electricity releases tons of sulphur dioxide into the atmosphere each year. Sulphur dioxide and nitrogen oxides combine with water vapours in the atmosphere resulting in acid rains.

Air pollution can also be caused by the burning of forests and grasslands. Farmers in Sri Lanka, India, and Bangladesh often clear lands in this way. This burning also releases carbon dioxide into the atmosphere.

Carbon dioxide and other gases present in the atmosphere act like a wall similar to windows of a greenhouse. These gases allow sunlight to pass through them which warms the Earth's surface. Heat and reflected sunlight radiates back, and gets trapped into the atmosphere causing a rise in Earth's temperature. This phenomenon is called **greenhouse effect**.

In addition to carbon dioxide, water vapours, methane, nitrous oxide and CFCs contribute to the greenhouse effect. CFCs are the chlorofluorocarbon compounds which are used as coolants, solvents, and propellants in aerosol cans. CFCs are also affecting the ozone layer of the atmosphere which acts as a protective shield against the harmful UV radiations coming from the Sun. The thinning of ozone layer is referred to as *ozone hole*. The ozone depletion can affect food chains on the Earth and can cause human health effects such as increase in the skin cancers, cataract and suppression of immune system.

Thus, all these factors may lead to change in atmospheric composition and are responsible for undercutting our life supporting atmosphere.

SAQ 3

Why are the land resources degrading? Explain.

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SAQ 4

What is soil erosion? What factors are responsible for the erosion of soil?

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SAQ 5

Discuss the effects of deforestation on environment.

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SAQ 6

How is acid rain caused?

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4.4 NEED FOR CONSERVATION

You have studied in the above section that human activities cause the degradation of natural resources. Pollution of renewable physical resources such as air, water, and soil which makes them unfit for human use. Also, the growing needs of ever increasing population require more and more of natural resources. But the fact is that

the natural resources are limited and so they will exhaust some day. Thus, they will not be lasting for ever. Then, how would human race in the future would survive? Here, we should stop and think seriously.

We should use these resources judiciously and conserve them for future use.

Resource conservation involves *using*, *managing* and *protecting* resources so that they will be available on a sustainable basis for present and future generations. People who actively support this effort are called *conservationists*. Sometimes they are also known as *environmentalists*. Most people are in favour of conserving resources. But they often disagree over which resources are essential and how much of each resource should be conserved for future generations.

4.5 WHAT IS CONSERVATION?

For thousands of years, farmers in steep mountain regions of Nepal, Myanmar, Indonesia, and the Philippines have terraced on the sides of the mountains to grow rice. They learned that terraces prevent soil erosion and hold water needed for rice production. These farmers practice soil and water conservation. Conservation is the wise and careful use of Earth's resources.

There are several strategies for the conservation of natural resources. These are as follows:

1. Reduction in consumption
2. More efficient use of existing resources
3. Substitution of non-renewable resources by renewable ones
4. Development of new materials and newer cleaner technologies
5. Use of more abundant resources in preference to less abundant ones
6. Recycling and Reuse
7. Judicious use of resources with minimum wastage

When humans use natural resources wisely, they can live in harmony with the community and environment around them. Because the human population continues to grow, people are becoming more aware of how important it is to conserve and protect our natural resources. There are so many ways to balance the human need for natural resources with the availability of those resources. How can people clean up the air and water we rely on for life? What can be done about waste disposal?

4.6 KEY ISSUES IN NATURAL RESOURCE MANAGEMENT

Natural resource management aims to provide goods and services, and to maintain essential life-support systems. Natural resource management is not only concerned with the physical or biological functioning of part of the environment (for example, a forest), but also with the allocation of resource products, within the frameworks of particular legal and cultural settings.

Natural resource management has three different dimensions. These are categorized as **ecological**, **economic** and **ethnological** (i.e. social or cultural). If a natural resource is to be used, its use must be physically possible, economically viable and culturally acceptable.

Each of these dimensions is complex and it is therefore not surprising that many texts on resource management concentrate only on one or the other. In practice, however, natural resources have to be managed with regard to all three dimensions: the physical management of the resource has to take place within particular economic and cultural climate. Conversely, the management of natural resources, in order to satisfy

particular economic or social goals, may have effects on the physical or biological nature of the resource.

Many of problems encountered in natural resource management stem from conflicts that develop between different goals. For example, a quest for more food may lead to the intensification of agriculture. This, in turn, can cause landscape change and a loss of scenic beauty as hedges and trees are removed, and may also result in the contamination of rivers by accelerated soil erosion, fertilizers and pesticide residues.

One situation that can cause environmental degradation is the use of **common-property resources** that are owned by no one and available for use by everyone. Most of these are potentially renewable. Their examples being clean air, fish in part of the ocean not under the control of a coastal country, migratory birds, Antarctica, gases of the lower atmosphere, and ozone content of the upper atmosphere.

Abuse or depletion of common property resources is called *tragedy of the commons*. It occurs because each user reasons "If I do not use this resource, some body else will. "The little bit I use or little bit of pollution I create is not enough to matter". When the number of users is small, there is no problem. Eventually, however, the cumulative effect of many people trying to maximize their use of a common-property resource depletes or degrades usable supply. Then no one can make a profit or otherwise benefit from the resource. Therein is the tragedy.

One solution is the reduction of population size and resource use to the point where potentially renewable common-property resources are used at rates below their estimated sustainable yields. Such practice is not easily achieved because people do not like to be told how many children they can have or what types and amounts of resources they can use. Another approach is to determine what is everyone's fair share of the common-property resource and then regulate access to the resource to ensure that annual sustainable yields are not exceeded.

The difficulty is getting the users to agree on what their fair share is. One problem in all these approaches is that it is very difficult and expensive to make reliable estimates of the sustainable yield of a forest, grassland, or the population of a wild animal species. Even if we could do so, sustainable yield can and often do change because of changes in short-term weather, long term climate, unpredictable interactions with humans and other species. These *uncertainties* mean that it is best to use a potentially renewable resource at a rate well below its estimated sustainable yield. This is rarely done because of the strong drive for short-term economic growth and profit regardless of the future consequences.

Another guideline for the management of potentially renewable common property resources, such as national forests owned jointly by the public, is the **principle of multiple use**. According to this principle, these resources should be used for a variety of purposes, such as timbering, mining, grazing, recreation, wildlife preservation, and soil and water conservation.

The problem with multiple uses is that resource managers find it difficult to balance the competing uses because of strong pressure to use these resources for short term economic gain. Often the result is that one use such as timber cutting in buffer zones, become dominant.

SAQ 7

How do we deal with the problem of the tragedy of the commons?

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4.7 LAND RECLAMATION

Reclamation implies rehabilitation of land which has been surface-mined. It involves the restoration of land which has been disturbed by mining activities.

Land reclamation is an integral part of resource management and should be done or planned right at the stage when mining activities are going on rather than after the completion of mining operation. It involves contouring mine spoils and overburden to minimize soil erosion, applying topsoil and fertilizer, planting and maintaining vegetation cover.

4.8 CONSERVATION OF WATER RESOURCES

There is an increasing stress on various water resources and they are degrading at a very fast rate. It is high time that we should take special measures for conserving our water resources. Water is becoming scarcer day by day and the situation is very alarming in many parts of the world. In the year 2000, 1.1 billion people did not have access to clean drinking water. In Africa, 40% of the population does not have the access to water whereas the corresponding figure in Asia is 20%. People, especially women and children have to walk long distances to fetch water.

In order to resolve the water crisis, many measures are being practiced for the conservation of existing water resources. **Water conservation** is the careful use and protection of water resources.

Since water is used in many sectors, improved practices in agriculture, industry and domestic use can reduce water consumption to a great extent and minimize the generation of waste water which make water available for other legitimate use. Some of these are listed below:

A package of strategies can be adopted to conserve water. These water conservation strategies and practices are given below:

- Using sprinklers and drip irrigation methods
- Minimising run off by improving land preparation
- Development of crops which require less water
- Encouraging recycling of water in industries
- Using processes/equipment/ technologies which require lesser amount of water
- Avoiding wastage of water by closing taps when water is not in use
- Repairing leaks
- Using water efficient systems in toilets
- Rain water harvesting

The National Water Policy, 2002 also recognizes the need for well developed information systems at national and state levels and emphasises on inter-basin transfers, artificial recharge, desalination of brackish or sea water and rain water harvesting for increasing utilisable water resources. It also stresses upon watershed management through extensive soil conservation, catchments area treatment, protection of forests and construction of check dams. It is the responsibility of every citizen to minimize the use of water and to protect water bodies from pollution.

SAQ 8

Explain various methods of water conservation.

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4.9 ENERGY CONSERVATION

Although, there is a great potential of renewable resources of energy, it is yet to be exploited meaningfully to substitute for conventional sources of energy. Conservation of existing energy resources is, therefore, the only answer to increase the lifetime of available resources. Conservation of energy is important both from economic as well as environmental point of view. It also reduces the dependence on foreign sources, thus increasing the national energy security. Energy resources such as petroleum (crude oil, natural gas etc.) have led to international tensions and wars between the countries. Energy consumption also influences the international trade and balance of payments. Thus, energy security is very-very essential for a country to be self-reliant.

Since energy has multidimensional uses, various measures in different sectors can be practice to minimize the energy consumption. These are discussed below:

1. Residential and Commercial Measures

Everyone can conserve energy. Even small effects collectively save a large amount of energy. Several initiatives at home, in offices, institutions, hospitals, hotels etc. can reduce energy consumption. These are as follows:

- Switching off electrical appliances when not in use.
- Modification of design of buildings so that they receive more natural light, heat and air.
- Developing more efficient energy gadgets.
- Using energy saver options and regulating devices in air conditions, coolers and in other electrical appliances.
- Using less power consuming bulbs and tubes.
- Proper maintenance of electrical and other power consuming devices.
- Using alternative products whose manufacture requires lesser power consumption.

2. Transportation Measures

Transportation consumes a large amount of energy. A change in transport patterns, requirements and vehicles would significantly alter the energy requirements. Several measures such as follows can contribute to energy conservation in transport sector:

- Improving the design of vehicles to make them more energy efficient and less polluting.
- Use of more energy efficient fuels.
- Using personal car pools rather than single commuting.
- Switching over to efficient public transport systems such as metro trains etc.
- Reducing the number of kilometers to be travelled by proper planning.
- Proper maintenance of vehicles.
- Using good practices while driving.
- Building express ways and high ways.
- Using better traffic management.

3. Industrial Measures

Industries heavily consume energy. Similar to the transport sector, the energy demands can be reduced in industrial sector in many ways. Some of these are listed below:

- Switching off equipment and devices when not in use.
- Using better house keeping practices and planning.
- Using more efficient equipments, instruments and devices.
- Using more energy efficient processes and technologies.

- Substituting and encouraging the use of products whose manufacture requires lesser energy.
- Recycling and using the waste products, heat and waste water in different processes and industries.

SAQ 9

How will you save energy in your homes?

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4.10 SUMMARY

In this unit, we have discussed various reasons for the overexploitation of natural resources. Their over exploitation has in fact led to their degradation and depletion. Various natural resources such as land, soil, water, air etc. are degrading very fast. Various factors leading to the degradation of these resources have been discussed in detail. The need for the conservation of these resources was then highlighted. There are various aspects of natural resource management viz. ecological, economic and ethnological. These have also been explained along with certain other key issues. Finally, the conservation of land, water and energy resources has been discussed in detail.

4.11 TERMINAL QUESTIONS

1. What renewable energy sources are used in your area?
2. What do you understand by environmental degradation?
3. Explain the terms ‘solid waste’ and ‘toxic waste’.
4. Discuss various reasons for the pollution of water resources.
5. What is greenhouse effect? How is it caused?
6. List various strategies for the conservation of natural resources.
7. Describe the industrial measures for the conservation of energy.
8. How can energy be saved in the transport sector?

UNIT 5 INTRODUCTION TO BIODIVERSITY

This universe is the creation of Supreme Power meant for the benefit of all. Individual species must therefore learn to enjoy its benefits by forming a part of the system in close relationship with other species. Let not any one species encroach upon the other's right.

Isavasya Upanishad

Structure

5.1 INTRODUCTION

Biological diversity is the new buzzword, the magic door to international funding and global travelling. We share the earth with million of other living beings. Just as we humans make up one species, there are perhaps five to thirty million other species plants like neem and rice, animals like the elephant and peafowl, and micro-organisms too small to see with the naked eye. India alone has 1,25,000 recorded species, and perhaps many more times that number which are as yet undiscovered. This range of life form is called **biological diversity** or **biodiversity**.

The earth's biodiversity has taken more than 3000 million years to evolve, and today, it forms the basis for survival of the human species and other life forms on our planet. When we speak of global biodiversity we speak of the totality of genetic strains, species and ecosystems in the entire world. Similarly, we can also spe ak of biodiversity at a more localised level, such as in a continent, a region such as South Asia, a country or even a province.

The countries of South Asia have a high biodiversity as it contains vast continental areas covering Bangladesh, Bhutan, India, Nepal and Pakistan as well as islands such as Sri Lanka and the Maldives. This provides the region with a wide range of ecosystem and habitat types. The climate across the region also varies considerably so the extremes of temperature and rainfall are displayed across the region, while the altitude ranges from flat coastal areas to Everest, the highest mountain in the world. The region is also important in terms of in-country endemics, and is consequently important in terms of global biodiversity as well as at the national level for the countries within this region.

"The countries of Asia have great biodiversity importance and richness, ranking with South America as the richest place on earth for variety of living forms. Of the world's 25 recognised biodiversity hot spots, seven are in Asia. These hot spots cover the Western Ghats of India, Sri Lanka, and the eastern Himalayan countries of Nepal, Bhutan and India."

Source: MacKinnon (2002) in Biodiversity Planning in Asia, IUCN.

Our earth and the atmosphere around it contains millions of **species**, in a bewildering array of shapes, sizes and organisational structures. These species occur in a wide range of **ecosystems**, and contain billions of **genes** which make each species, and even individuals within a species, different from one another.

In the present unit you will study as to what biodiversity is, and what are the different levels of biodiversity. You will also study about measures of biodiversity as conservation strategies are based on these measures.

Objectives

After studying this unit, you should be able to:

- define biodiversity;
- explain different levels of biodiversity i.e. genetic diversity, species diversity, ecosystem diversity; and
- describe basis to measure different levels of biodiversity.

5.2 DEFINING BIODIVERSITY

Neologism is a recently coined word or the act of inventing a word or phrase. Additionally it can imply the use of old words in a new sense such as giving new meanings to existing words or phrases.

A portmanteau word (sometimes called a blend or franken word) is a word that is formed by combining two or more words. The meaning of the word was coined by Lewis Carroll.

Biodiversity or **biological diversity** is a neologism and portmanteau word, from **bio** and **diversity**. It is the diversity of and in living nature. Diversity, at its heart, implies the number of different kinds of objects, such as species. However, defining biodiversity or measures of biodiversity, is not so simple.

The term biological diversity, was coined by **Thomas Lovejoy** in 1980, while the word biodiversity itself, was coined by the entomologist **E.O.Wilson** in 1986, in a report for the first American Forum on biological diversity organized by the National Research Council (NRC).

Biological diversity has no single standard definition. One definition holds that biological diversity is a *measure of the relative diversity among organisms present in different ecosystems* "Diversity" in this definition includes diversity within species, among species, and comparative diversity among ecosystems.

Another definition, simpler and clearer, but more challenging, is the *totality of genes, species, and ecosystems of a region*. An advantage of this definition is that it seems to describe most instances of its use, and one possibly unified view of the traditional three levels at which biodiversity has been identified:

- **genetic diversity** – diversity of genes within a species. There is a genetic variability among the populations and the individuals of the same species.
- **species diversity** – diversity among species.
- **ecosystem diversity** – diversity at a higher level of organization, the ecosystem (richness in the different processes to which the genes ultimately contribute). You will study about these concepts in detail in the following sections.

The lattermost definition, which conforms to the traditional five organisation layers in biology, provides additional justification for multilevel approaches.

The 1992 Earth Summit in Rio de Janeiro defined biodiversity as:

> *The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems.*

Wide diversity in terrestrial ecosystems can be seen in South Asia due to the vast variety of natural landforms and climate which have given rise to habitats ranging from tropical to temperate, alpine to desert and coastal to montane. **Freshwater**

aquatic biodiversity abounds in South Asia in natural water bodies such as rivers, lakes, ponds, reservoirs and swamps.

Biodiversity found on Earth today is the result of 3.5 billion years of evolution. Until the emergence of humans, the Earth supported more biodiversity than in any other period in geological history. Since the advent of humans, however, biodiversity has begun a rapid decline, with one species after another suffering extinction.

Estimates of global species diversity vary from 2 million to 100 million species, with a best estimate to somewhere near 12.5 million.

New species are regularly discovered (on an average about three new species of birds each year) and many, though discovered, are not yet classified (an estimate gives that about 40% of freshwater fishes from South America are not classified yet). **Most of the diversity is found in tropical forests**.

Box 5.1: Where does most of the world's biodiversity exist?

Biodiversity is everywhere, in deserts, oceans, freshwater bodies, tropical rainforests, temperate zone forests and your backyard. The rainforests of Central and South America, equatorial Africa, and Southeast Asia may house at least half of the world's species. A large number of plant and animal species call coral reefs – the "rainforests of the seas" – their home. Lakes, estuaries, the deep ocean floor and the soil beneath your feet are also rich in biodiversity, while extreme arctic climates and torrid deserts contain some of the most unusual living organisms.

SAQ 1

Define biodiversity.

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SAQ 2

Who coined the words 'biodiversity' and 'biological diversity'?

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5.3 LEVELS OF BIODIVERSITY

There are three levels of diversity viz. **genetic**, **species** and **ecosystem** diversity. In effect, these levels cannot be separated. Each is important, interacting with and influencing the others. A change at one level can cause changes at the other levels.

5.3.1 Genetic Diversity

Genetic diversity is the "fundamental currency of diversity" that is responsible for variation. This is the diversity of basic units of hereditary information which are passed down generations found within a species (e.g. different varieties of the same species). Genetic diversity underlies the variability (differences) among individuals of a given species. For example no two individuals even in the same family are identical, unless of course they are identical twins with the same genome (i.e. complete genetic makeup). This is true of all species, because any individual resulting from sexual reproduction, except identical twins, has a slightly different combination of genes from another individual. The differences in the genetic makeup of organisms also form the basis for variation within a population, or between populations, of that species. Thus, genetic diversity within a species will increase with the number of individuals of a given species. *It is estimated that there are about 10^9 different genes distributed throughout the world's biota* (i.e. living component).

What are genes? …

Genes are the basic units of heredity in an organism which are passed down by an organism to its offspring. They act as strorehouses of the heritable characteristics of an organism.

1. Genes are made up of a complex organic molecule called **deoxyribonucleic acid (DNA)** which comprises a linear molecule made up of four types of building blocks, or nucleotide bases. A strand of DNA has two strings of nucleotides twisted around each other, with loose attachments between nucleotide pairs.
2. Genetic diversity arises due to the variation in the sequence of nucleotide pairs of DNA strands.
3. In higher organisms, the bulk of DNA is packaged in a linear form within chromosomes located in the cell nuclei of these organisms.
4. Chromosomes occur in pairs in each cell of an organism. One of each pair is inherited from the father while the other is received from the mother. Humans have 23 pairs of chromosomes.

It is genetic diversity that allows a species to adapt to changing environmental conditions such as a lower rainfall, a higher temperature year round, etc. The effective conservation of genetic diversity within a species cannot, however, be achieved by merely conserving the species. This is because the conservation of one or few population(s) of a species cannot lead to conservation of genetic diversity. For example conserving one or more populations of a species may conserve the species as a whole, but may not serve to capture its entire genetic diversity. For example losing even a single population or a group of individuals in a population, may sometimes result in the loss of genetic variation. Sometimes the lost variation of a gene may even be crucial for the future survival of the species in the face of changing environmental conditions.

Box 5.2: The problem of survival among cheetahs

Once quite widespread throughout Asia and Africa, there has been a large reduction of the cheetah's habitat and numbers though it is still seen in widely separated areas of Africa. Recent surveys of cheetah populations have shown that there is almost no genetic variation among individuals, even among those taken from the furthest points of its range. This is due to an evolutionary "bottleneck" caused by the fact that at one point cheetah populations crashed to very low numbers and then expanded from the same stock. As a result cheetahs in the wild, as well as in captivity, show several problems due to inbreeding which is threatening its future survival. The problems encountered are low sperm counts leading to reproductive difficulties, low survival of juveniles, morphological aberrations and high susceptibility to diseases because of low genetic diversity in the immune system. Thus, even when numbers seem relatively adequate for a given species, a low genetic diversity can increase its vulnerability to extinction.

Genetic diversity is, thus, important for the preservation of species diversity, and hence biological diversity. A knowledge of the variability of genes also allows us to understand how closely individuals or species are related to each other. **Genetic diversity between species becomes greater with increasing distance in the relationship of species.** Consequently more distantly related species will represent a higher range of genetic diversity than closely related species. Genetic variability responsible for these different traits, interacts with local environmental conditions to determine the extent to which populations can adopt to environmental changes. Isolated population such as those on ocean: islands or in small patches of habitats cut off from the surrounding environment tend to have less genetic variation, hence more susceptible to extinction.

5.3.2 Species Diversity

Species diversity means the differences between species (both domesticated and wild). It is the most visible component of biodiversity as implied by the word

'species' which literally means outward or visible form. This is why we often tend to describe biological diversity in terms of the number of species in a particular area or at the global level.

Box 5.3: What is a species?

There are many interpretations of what a species really is.

The biological species concept

A biological species as defined by Ernst Mayr are "*groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups*". For example there are some species called **sibling species** that are reproductively isolated although they have extremely minute genetic differences. This definition assumes that a species cannot interbreed with other species due to a variety of isolating mechanisms that are behavioural, physiological, genetic, etc. Thus, according to the biological species concept, individuals within a species have a gene pool available for recombination through sexual reproduction within the group, and is not inhibited by pre- or post-mating reproductive isolation.

The main criticism of this definition is that it applies only to organism (i.e. life forms) that have sexual reproduction, and ignores the fact that some times gene flow occurs between closely related, sympatric species (species whose geographical ranges overlap). For example, significant gene exchange has happened between *bison* and *bus* (domestic cattle). Such occurrences violate the basic notion of the biological species concept. Nevertheless, this definition of a species continues to be widely used even today.

The phylogenetic species concept

Taxonomists (scientists who compare, classify and name organisms) tend to describe a species by studying their physical characteristics and behaviour, and also their genetic and chemical similarities and divergences as a result of evolution. Based on this concept Cracraft proposed the Phylogenetic Species Concept (PSC) in 1983. Here he defines a species as "the smallest diagnostic cluster of individual organisms within which there is parental pattern of ancestry and decent." However, it can be argued that a population, subspecies, stage or a morph can then be elevated to species status. Consequently the number of species recognised becomes highly dependant on the analytical tools used. Even so, the PSC is considered as the most valuable tool for working taxonomists.

There are less widely accepted methods of defining a species such as:

(a) **The evolutionary species concept** which identifies a species as a "lineage (i.e. ancestor descendant sequence of population) evolving separately from others with its own unitary role and tendencies." This is similar to the PSC, without the criterion of interbreeding, but it is less practicable.

(b) **The ecological species concept**: This identifies a species as a population that occupies a distinct ecological niche, whence its reproductive and general biological cohesion over time. This was never widely accepted and is very hard to operationalise.

Source: Primate taxonomy. Groves, 2001.

There are different estimates of extant (i.e. currently existing) species on earth which range from about five to 100 million, but a figure of about **12.5 million** is the most widely accepted. Of these, only about **1.7 million species have been described** as yet. In terms of sheer numbers alone, **insects and micro-organisms are the most abundant life forms on earth**.

The distinct ecological importance of species supports functional diversity and has a direct bearing on the species composition of the site, and therefore on overall

Keystone species play critical role in the ecosystem they inhabit because they affect the abundance and health of many other species. Examples of keystone species include brown algae (Pacific coastal ecosystem), fruit eating bats (south-western deserts) and corals in tropical coastal waters. Their loss may endanger other species.

biodiversity. For example a keystone species will be more important than other species for conserving overall biodiversity. Similarly a species of tree in a tropical rainforest which supports a large number of endemic invertebrate fauna and provides food to vertebrates would make a greater contribution to global biodiversity than an alpine plant in a temperate country which has much less species dependant on it for survival.

Box 5.4: Known species of flora and fauna in the world

	4,500 species of mammals
	10,000 species of birds
	12,000 species of amphibians and reptiles
	22,000 species of fish
	400,000 species of invertebrates (excluding insects)
	960,000 species of insects, approximately 600,000 of which are beetles
	270,000 species of plants
	70,000 species of fungi
	4,000 species of bacteria
	5,000 species of viruses

5.3.3 Ecosystem Diversity

Ecosystem diversity means the variation between different types of ecosystems. Different species of animals, plants and micro-organisms interact with each other and their physical environment (such as water or minerals). Groups of organisms and their nonliving environment, and the interactions between them, form functional dynamic and complex units that are termed ecosystems. These systems help maintain life processes vital for organisms to survive on earth.

Different combinations of species and physical conditions (such as sunlight, climate, soil and water) and their varied interactions give rise to variation among ecosystems. For example, the physical conditions in a coral reef are very different to those in a tropical forest. Accordingly, the species in a coral reef differ from the species in a tropical forest.

Plant and animal communities make up many kinds of ecosystems we are familiar with today – from estuaries, ponds, marshes, coral reefs and other aquatic ecosystems to savannas, prairies, forests, deserts, mountaintops and other terrestrial ecosystems, including neighbourhood parks, school grounds and backyards.

Species are not evenly distributed around the globe. Some ecosystems such as tropical forests and coral reefs are very complex and host a large number of species. Other ecosystems such as deserts and arctic regions have less biodiversity but are equally important.

It is believed that there is a positive relationship between species diversity and an ecosystem's stability and resilience (i.e. ability to resist disturbances).

An ecosystem having higher diversity means the number of species and interactions between them which constitute the food web, is large (Fig.5.1a). In such a situation, the elimination of one species would have little effect on ecosystem balance. In sharp contrast, the number of species in the food web of a simple ecosystem is small (Fig.5.1b). So loss of any one species has far more serious repercussions for the integrity of the ecosystem itself.

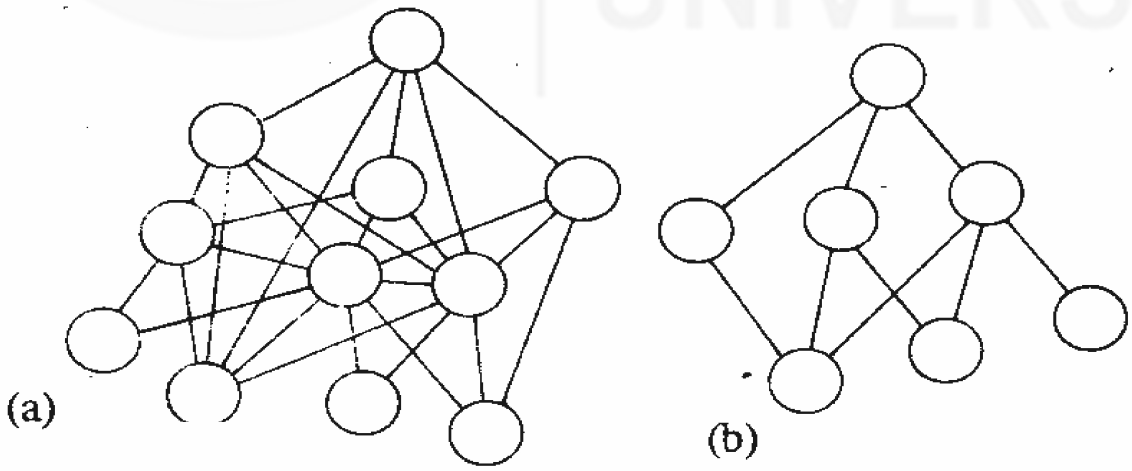

Fig.5.1: The two illustrations give comparative picture of ecosystems with high a) and low b) species diversity. The circles represent organisms. Note the complex linkage in a, and only a few links in b. The increased numbers of links are believed to confer stability to the ecosystems

SAQ 3

By citing an ecosystem, (say tropical forest, or grassland) explain how different levels of diversity are interrelated.

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5.4 MEASURING BIODIVERSITY

Conservation and management of biodiversity require measurement of biodiversity because it is important to make choices about "what, where, and how" to conserve. Measurement can be considered at all three levels of biodiversity: genes, species and ecosystems. As they are all interrelated, however, it is difficult to talk about measures at one level while ignoring the others. It is also difficult to measure biological diversity because there are so many ways of measuring it, and the situation is made more complex because of problems associated with the interpretation of data resulting from the different forms of measurement.

5.4.1 Measuring Species Diversity

The measurement of species diversity provides an important preliminary assessment of overall biodiversity. There are many ways by which species diversity is measured i.e. species richness, taxonomic diversity, taxonomic uniqueness and species-diversity indices.

- **Species richness**

  This is the most widely used measure of species diversity. In simple terms *it is a count of the total number of species in a given area.* It gives equal weightage to all species and does not take into account the number of individuals that represent a particular species. A large number of individuals of a single species will result in greater genetic diversity, and thus positively influence overall biodiversity. Complete counts of species richness of an area are rarely possible, so that the measure of species richness is often based on sampling smaller representative sites within the area to be assessed. Accuracy of sampling is thus important in estimating species richness of a given area.

To describe the complex spatial patterns of biodiversity, ecologists and biogeographers have found it useful to express species richness into four major categories:

1. **Point richness**
2. **Alpha (α) richness,**
3. **Beta (β) richness, and**
4. **Gamma (γ) richness**

Point richness refers to the number of species that can be found at a single point in space.

Alpha (α) richness refers to the number of species found in small, homogenous area. **Alpha diversity** refers to the diversity in a particular area or ecosystem and is usually expressed by the number of species (i.e. species richness) in that ecosystem.

Alpha diversity is characterised by several widespread patterns that are characteristic of most taxa and are strongly correlated with physical environmental gradients. For example,

- Marine and terrestrial environments in tropical regions have more species of higher taxonomic groups than those in higher latitude communities.
- Richness of species in terms of most taxa is positively correlated with habitat structural complexity.
- Structurally simple habitats like open oceans, grasslands, etc. generally support fewer species than structurally complex communities such as forests and coral reefs. In the open oceans maximum richness of most groups is found at depths between 2000-4000 m. In contrast coral species richness peaks at depths between 15-30 m because corals obtain their energy from photosynthetic organisms embedded in their tissues, and are thus confined to the photic zone.
- Island communities are poor in species than comparable mainland communities.

Beta (β) richness refers to the rate of change in species composition across habitats and β **diversity** refers to diversity between the ecosystems.

Gamma (γ) richness refers to the rate of change across larger landscape gradients and **gamma diversity** is a measure of the overall diversity for different ecosystems in a region. Hunter defines gamma diversity as "**geographic-scale species diversity**". Let us make this concept more clear to you by giving an example. Suppose we want to compare diversity of hypothetical species in different ecosystems say I, II and III (Table 5.1).

We can walk a transect in each of these three ecosystems and count the number of species we see, this gives us the alpha diversity for each ecosystem, e.g. α diversity of ecosystem I, II and III is 10,7, and 3 reap. Now, if we examine the change in species diversity between these ecosystems then we are measuring the β diversity, e.g. beta diversity between I and II is 7(representing 5 found in ecosystem I but not in ecosystem II plus 2 species found in ecosystem II but not in I), similarly β diversity between ecosystem II and III is 8 and between ecosystem I and III is 13.

The total number of species for the three ecosystems is 14, which represents the gamma diversity.

Table 5.1: Alpha, beta and gamma diversity for hypothetical species in three different ecosystems

Hypothetical species	Ecosystem-I	Ecosystem-II	Ecosystem-III
A	X		
B	X		
C	X		
D	X		
E	X		
F	X	X	
G	X	X	
H	X	X	
I	X	X	
J	X	X	
K		X	
L		X	X
M			X
N			X
Alpha diversity	10	7	3
Beta diversity	I vs. II (7)	II vs. III (8)	I vs. III (13)
Gamma diversity	14		

- **Taxonomic diversity**

  Taxonomic diversity is relative abundance of a species as well as the ancestor descendant relationships of species to each other. For example, an area with two species of mammals and one species of reptile has greater taxonomic diversity than an area of similar size with only three species of mammals although both have three species each. Similarly, an area with a large number of closely related species is not as diverse as distantly related. It has also been suggested that a site with a large number of higher taxa (which offer greater genetic variation) would possess more taxonomic diversity than a site with more species but less higher taxa.

- **Taxonomic uniqueness**

  The concept of species richness in terms of numbers alone does not take into account the fact that the more distantly related a species is from others, the greater is its contribution to overall biodiversity. For example, two species of *Tuatara* (genus *Sphenodon*) living in New Zealand are the only extant members of the reptile order Rhynchocephalia. Their genetic make-up would, therefore, be unique and very different from their "closest" relatives. It can be expected that such species contribute more towards maintaining a high global biodiversity than species having a large number of very closely related species. Various measures are now being developed to take into account the taxonomic uniqueness of species when assessing biological diversity. For instance, a simple method of assigning taxonomic uniqueness to endemic species is based on the diversity of the genus and the family to which it (the genus) belongs.

- **Species diversity indices**

  From an ecological point of view, species richness alone has limited value. More meaningful measures use the number of different species in a given area (species richness) as well as the relative abundance (in terms of numbers) of individuals in each species. For example, the Shannon-Wiener Index of diversity uses both species richness and the relative abundance of species in its computation of the diversity index.

Shannon-Wiener index

This diversity measure is based on information theory of measure of order (or disorder) within a particular system. For our uses, this order could be characterized by the number and/or the number of individuals in each species, within our sample plot.

By applying these numbers to the Shannon-Wiener equations we can determine what is referred to as the degree of uncertainty. With this number we can then specify our degree of diversity.

$$H' = -\sum_{i=1}^{3} (p_i)(\log_2 p_i)$$

where H' = Information content of sample, Index of species diversity or *Degree of Uncertainty*, s = Number of species, pi = proportion of total sample belonging to i^{th} species.

Alternative Form

An alternative form for Shannon-Wiener index:

$$N_1 = 2^{H'}$$

or

$$N_1 = e^{H'}$$

where N_1 is the number of logarithms used to equally common species for the diversity H'. The equations vary depending on the type of the logarithms used to calculate H'.

Measures of Evenness

The maximum Shannon-Wiener index for a given number of species can be calculated as:

$$H'_{max} = \log_2 S$$

The minimum Shannon-Wiener index for a given data set can be calculated as:

$$H'_{min} = \log N\left(\frac{N - S + 1}{N}\right)[\log(N - S + 1)]$$

where

S is the number of categories or species
N is the total number of observations.

The evenness of the sample can be calculated by the following two equations:

$$J' = \frac{H'}{H'_{max}}$$

or

$$\text{Evenness} = \frac{N_1}{S}$$

According to this index, Area A with four species with four individuals each will have greater species diversity than area B also with four species but with one having 13 individuals while the other three have only one individual each (Fig. 5.2).

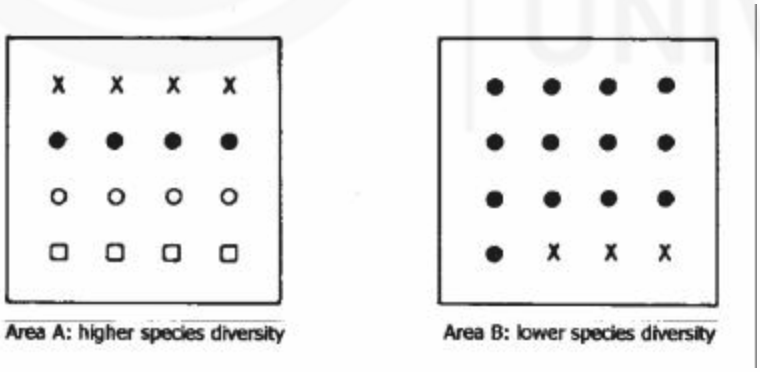

Fig.5.2: A diagram to show the species diversity in two different areas

Base conversion wi th Logarithms

To convert from known log bases to any other log base use

$$\log_b x = \frac{\log_e x}{\log_e b}$$

where **b** is the base value, **log *e*** is the natural logarithm and **x** is value to be transformed. For example to take a log base 2, you would use:

$$\log_2 x = \frac{\log_e x}{\log_e 2}$$

5.4.2 Measuring Genetic Diversity

Genetic diversity needs to be measured through some complicated processes as given below:

- **Protein electrophoresis**

  This method is now being used to measure genetic diversity. Genes contain the information required to produce enzymes – which are proteins – and "dictate" the "code" to other cell organelles to do the actual production. Variations in the

genetic information coding the production of enzymes will therefore show up in the differences of the protein enzymes that the genes "code" for. Protein electrophoresis thus shows the variations in the proteins produced, thereby indicating the diversity of genes that coded for them.

- **Restricted fragment polymorphism**

  This method makes use of a group of enzymes termed restriction enzymes which recognise particular sequence of DNA and act as "molecular scissors" to cut at the beginning and end of these sequences. When DNA from one individual is cut this way, and the resulting fragments are subjected to electrophoresis, the fragments become aligned by length enabling the recognition of a pattern. The analysis of patterns from different individuals permits an assessment of variation in their DNA sequences. Measuring the differing frequencies of the various patterns in a population or species can indicate the genetic diversity within the group.

- **DNA fingerprinting**

  This method makes use of a common, but peculiar, group of DNA sequences known as minisatellites. High levels of variation in the numbers of these repeated units are used in "DNA fingerprinting" to identify relationships that range from distantly related taxonomic groups to closely related individuals within a population.

5.4.3 Measuring Ecosystem Diversity

Measuring ecosystem diversity is not easy, and there is no definite index for its measurement. It is generally assessed by the measure of species diversity in an ecosystem, often based on the diversity of vegetation in a particular area. This may involve the assessment of the number of species in an area as well as their relative abundance. If all species have equal numbers, the area will be more diverse than one in which one, or few, species predominate. Also, an area with more size classes of the vegetation, different trophic levels (i.e. positions of different species in a set of linear feeding relationships) and taxonomic groups will be considered more diverse. Thus, a hypothetical ecosystem with ten species of plants only would be considered less diverse than an area with seven species of plants, two herbivores and one predator. Further, an area with relatively low species diversity, but having a large number of endemics (i.e. species limited to a particular area, such as a country) make an important contribution to overall biodiversity. For example, **small oceanic islands and continental montane regions have relatively low species diversity, but high levels of endemism**.

It also has to be borne in mind that the scale of measurement needs to be given serious consideration when comparing diversity between two different ecosystems. For example 1 m^2 of European chalk grassland can have much more plant species than a comparable area in an Amazonian rainforest! At the scale of 1 km^2, however, the situation will be quite the reverse.

Ecosystem diversity measures based on the species composition of flora, or fauna, or other ecosystem properties, are all equally justifiable: but measures based on different criteria tend to give different results. It is also important to note that diversity measures used for ecological units, such as ecosystems, assume that these units are basically the same in form throughout a wide area and in different places. In reality, however, this is rarely true. These diversity measures cannot, therefore, be effectively used for purposes of generalisation.

SAQ 4

Explain the importance of Shannon-Wiener index with reference to measuring species diversity.

……..…
……...
……...

5.5 SUMMARY

Let us summarize what you have learnt so far:

- The term biological diversity was coined by Thomas Lovejoy in 1980 and the term biodiversity was coined by E.O. Wilson. Biodiversity is a measure of the relative diversity among organisms present in different ecosystems. Biodiversity is the totality of genes, species and ecosystems of a region.
- Biodiversity is diversity of genes and organisms for geneticists; diversity of population of organisms and species for biologists; diversity of durable interaction among species for ecologists.
- There are three levels of diversity i.e. **genetic**, **species** and **ecosystem**. All these levels are interacting and influencing the others.
- Genetic diversity underlies the differences among individuals of a given species. Genetic diversity allows a species to adapt to changing environmental condition. Genetic diversity within a species will increase with the number of individuals of a given species.
- Species diversity is the most visible component of biodiversity. It means the differences between species. There are about 12.5 million species in the World out of which 1.7 million species have been described.
- Variation between different types of ecosystems is called as ecosystem diversity. Different combinations of species and physical conditions and their varied interactions give rise to variation among ecosystems. Some ecosystems such as tropical forests and coral reefs are rich in diversity.
- Measuring biodiversity is very important as conservation and management of biodiversity is based on these measures. It is difficult to measure biological diversity because of the problem related to its interpretations.
- Species diversity can be measured by species richness, taxonomic diversity, taxonomic uniqueness and species diversity index.
- Genetic diversity can be measured by protein electrophoresis, restricted fragment polymorphism and DNA fingerprinting.
- Ecosystem diversity is based on the diversity of vegetation in a particular area. Some ecosystems (e.g. oceanic islands) have relatively low species diversity, but high levels of endemism.

5.6 TERMINAL QUESTIONS

1. Discuss few methods to measure genetic diversity.

   ……

   ……

2. Explain the relationship between species richness and species diversity by citing suitable examples.

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3. List the following five groups or organisms in descending order of biological diversity based on the number of species and their abundance:

   i) Two leopards from one litter in the Wilpattu National Park in Sri Lanka.

   ii) Five leopards and five musk deer from the Pallas Valley in the western Himalayas.

   iii) The individuals each from two species of mangroves in an island of the Maldives.

   iv) One leopard and nine spotted deer from Block I of Ruhuna National Park in Sri Lanka.

   v) Four leopards, four sambar and two grass plants in the Chittagong Hill Tracts in Bangladesh.

      a) Discuss why you listed them in a particular order?

      ……..

      ……..

      ……..

      b) What groups will have the same species richness but can be expected to differ in terms of genetic diversity?

      ……..

      ……..

      ……..

4. List the following systems in descending order of biological diversity

   One acre of:

   i) a tropical rainforest
   ii) a rubber plantation
   iii) a coniferous forest containing several *Pinus* species
   iv) a mixed cultivation of coconut, pepper and cocoa

   Discuss why you gave a particular listing.

   ……

   ……

   ……

UNIT 6 GLOBAL DISTRIBUTION OF BIODIVERSITY

Structure

6.1 INTRODUCTION

The part of the earth where organisms (animals, plants, micro-organisms) live is called the **biosphere**. Distribution of species within biosphere is set by limiting barriers such as large water bodies, land areas and mountains, as well as unfavourable climate regime (light, rainfall, soil conditions). As a consequence of a combination of various physical, climatic and other barriers, plant and animal communities form different biomes. **Thus a biome could be referred to as large ecosystem existing on a macro-scale**. Ecologists call these large, distinct, easily differentiated formations or communities having distinct flora and fauna as **biomes**. Biomes are generally recognised by and named after the dominant plant species or community.

In this Unit we will describe the terrestrial biomes as well as the large aquatic biomes. Seldom the boundaries between two adjacent or neighbouring biomes are discrete or distinct instead they blend with the neighbouring biomes through a transition zone known as '**ecotone**'. This transition zone between two biomes generally has high species diversity and density as compared to any of the neighbouring biomes. In the present Unit we describe the major biomes of the world and also of the Indian region. We describe briefly the physical conditions and biodiversity of specific biomes. In the

present unit you will study about biodiversity hot spots and reasons for variation in biodiversity occurrence across the globe. You will also study about the criteria for identifying biodiversity hot spots.

Objectives

After studying this unit, you should be able to:

- explain the concept of biomes;
- describe the major terrestrial and aquatic biomes of the world and of India;
- explain the relationship between climate of biomes;
- enumerate and analyse the wild life species that occur in the different biogeographic zones of India; and
- list global biodiversity hot spots and reasons for varied biodiversity in different ecosystem/countries and discuss the criteria for identifying global biodiversity hot spots.

6.2 TERRESTRIAL BIOMES OF THE WORLD

Figure 6.1 shows the major terrestrial biomes of the world. As we have said earlier the primary factors that influence the formation of these biomes are climatic, like precipitation, temperature, seasonal extremes and winds. However, topography and light are also important factors. Of all these, precipitation is the chief limiting factor that determines whether a biome would be a forest or a desert or a grassland. **If the average annual precipitation in the region is less than 25 cm the place would be a desert containing little vegetation.** This would be true regardless of average temperature, light and quality of soil. **If a region has moderate average precipitation, around 25-75 cm a year, grasslands would be formed. A region would be a forest if the average annual precipitation is more than 75 cm** . The combination of average temperature and average precipitation, however, decides the type of desert, forest or grassland present in a region.

Box 6.1: Forests and their importance

The word forest is derived for the Latin word 'foris' meaning outside, the reference being to village boundary fence and must have included all uncultivated and uninhabitated land. Today a forest is any land managed for the diverse purpose of forestry whether covered with trees, shrubs, climbers etc. or not. The forest biomes include a complex assemblage of different kinds of biotic communities. Optimum conditions of temperature and ground moisture responsible for the growth of trees contribute greatly to the establishment of forest communit ies. The nature of soil, climate and local topography determine the distribution of trees and their abundance or sparseness in the forest vegetation. Forests may be evergreen or deciduous. They are distinguished on the basis of leaf into broad-leafed or needle-leafed coniferous forests in the case of temperate areas.

India is losing forests at an extremely rapid rate. The data released in mid 1984 by the National Remote Sensing Agency (NRSA) shows that India lost 1.3 million hectares of forests every year in the approximately seven year period between 1972-75 to 1980-82.

The NRSA study classifies the forest cover into three categories closed forests, open or degraded forests and mangrove forests.

For man, forests have been a source of recreation and the dev elopment of his culture and civilisation. Apart from the source of fuelwood, they are raw materials to various wood industries like pulp and paper, composite wood, rayon and other man-made fibres, matches, furniture, shuttles and sport goods. Indian forests also provide many other minor products such as essential oils, medicinal plants, resins and turpentines, lac and shellac, katha and catechu, bidi wrappers, tasser silk, etc.

India and other tropical countries have particularly abundant timber and heartwood resources. Timber accounts for 25% of all photosynthetic materials produced on the earth and about half of the total biomass produced by a forest. Forests have great biological importance as reservoirs of genetic diversity apart from playing an important role in regulating earth's climate.

Forests provide habitat, and food as well as protection to wildlife species against extremes of climate and help in balancing carbon dioxide and oxygen of the atmosphere. Forests enhance local precipitation and improve water holding capacity of soil, regulate water cycle, maintain soil fertility by returning the nutrients to the soil through litter. Forests check soil-erosion, landslides and reduce intensity of flood and droughts. Forests, being home of wildlife are important assets of aesthetic, touristic and cultural value to the society.

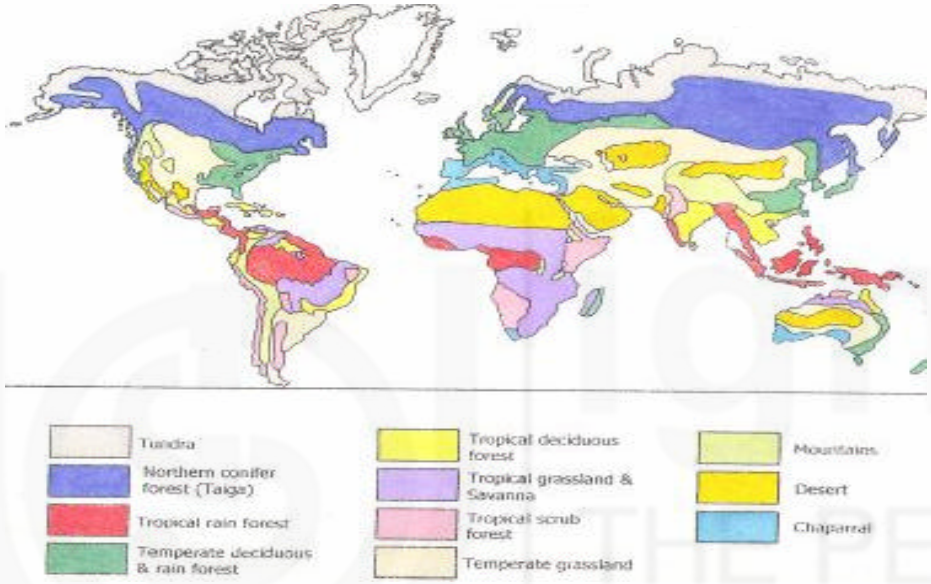

Fig.6.1: The terrestrial biomes of the world can be identified according to the climax vegetation. Note that the taiga and tundra are roughly like a belt around the globe, other biomes have a less continuous distribution

Now let us suppose you had the time and the resources to travel around the world and you plan to start your journey from the north pole towards the equator, let us see in a general way the biomes that you would encounter. You could start your journey of the biomes of the world from the blocks of ice floating on the sea about the north pole. This is a cold barren place. As you travel southwards you would reach arctic tundra where the sea meets the land which represents the northern most biome. As you travel further south towards the equator, the biomes you would pass through would be taiga (coniferous forests), temperate deciduous forests, deserts, grasslands and finally the tropical regions of the planet.

Let us study briefly the main characteristic of each major world biome. Starting with the tundra, which is the least complex of all biomes.

6.2.1 Tundra

The northern most biome on our planet is the arctic tundra. It is a treeless wet circumpolar band between the polar ice caps and the forests to the south. The

predominant plants are lichens, grasses, sedges and dwarf woody plants. Despite the lack of trees, animals are found on land, in air and nearby oceans. Similar communities are found at high mountains of all latitudes forming the alpine tundra. The climate is very cold with a short growing season. The soil is frozen for most part of the year and only the top 0.5 meter melts during the short summers in the arctic tundra (Fig. 6.2). The permanently frozen soil below is known as permafrost. In summer you might see huge herds of caribou, flocks of waterfowls and huge swarms of mosquitoes! With such a harsh climate it is not surprising that only a few kinds of plant and animal species are found here though, in the short growing season moss, lichens, some grasses and fast growing plants dominate the landscapes. Swarms of migratory birds invade the tundra in summer to raise their young and fly south as the summers come to an end. Some of the common permanent residents are musk ox, polar bear, grizzly bear, wolves, snowy owl, arctic hare, weasels, minks, etc. **Tundra is a very fragile ecosystem as the rate of organic matter decomposition is very slow**. On account of harsh climate plants grow very slowly and the tundra takes a long time to recover from any disruptions.

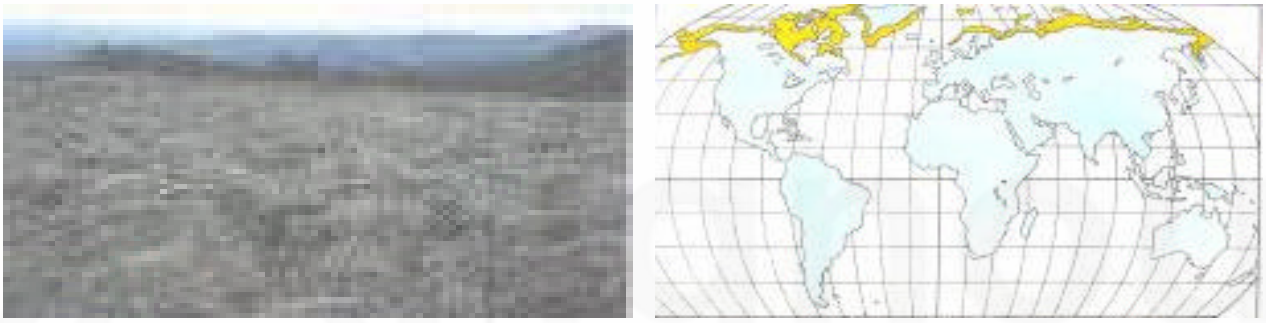

Fig.6.2: Arctic Tundra

6.2.2 Coniferous Forests and Taiga

As you travel south from the tundra you will enter the circumpolar belt of coniferous forests which stretches across North America to Eurasia, this region is called taiga, a world derived from Russian word meaning **'primeval forest'**. **The taiga is a land of lakes, bogs and marshes**. The climate is cold with long winters and short summers. The dominant trees are conifers like spruce, pines and firs (Fig. 6.3) with needle like leaves, that can survive extremely cold winters. Typical animals found in this region include moose, wolves, lynx, bears, gray jays. Many of these rely on their stored body fat for survival during the cold months.

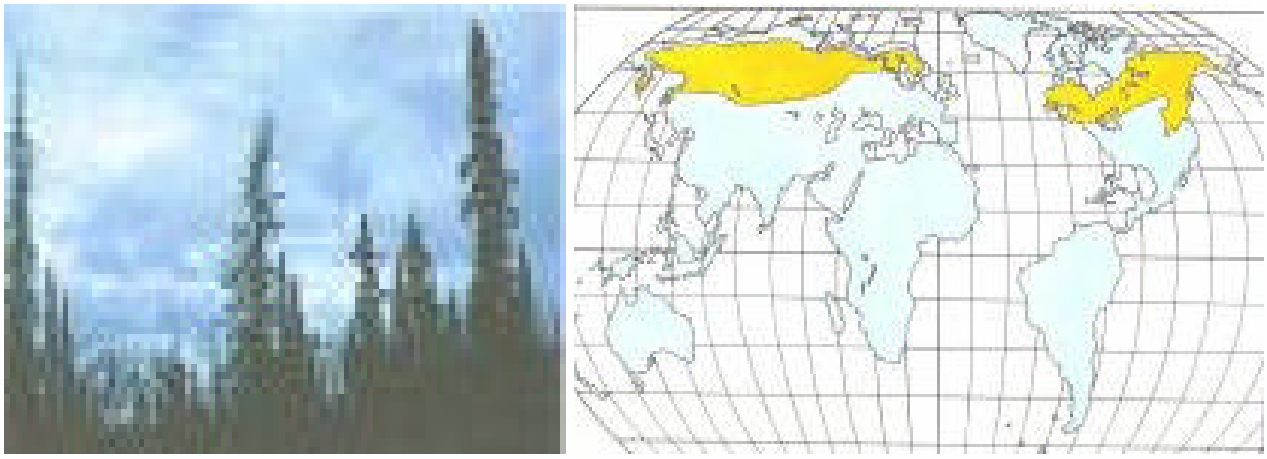

Fig. 6.3: Taiga in summer

6.2.3 Temperate Deciduous Forests

Going south of taiga you would reach the temperate regions of the planet (see Fig. 6.1). These regions experience moderate temperatures on average that change during four distinct seasons. They have long summers, not too severe winters and abundant precipitation spread over the whole year. These regions are dominated by broad leafed deciduous trees such as oak, hickory, maple, poplar, beech, sycamore, etc., that can survive the winter by dropping their leaves and going into a dormant state (Fig. 6.4). Temperate regions are the most productive areas of the world with the best agricultural lands. You would recall that the tundra soils are poor because of extremely slow rate of decomposition of matter but in the temperate regions the decomposition rate is controlled.

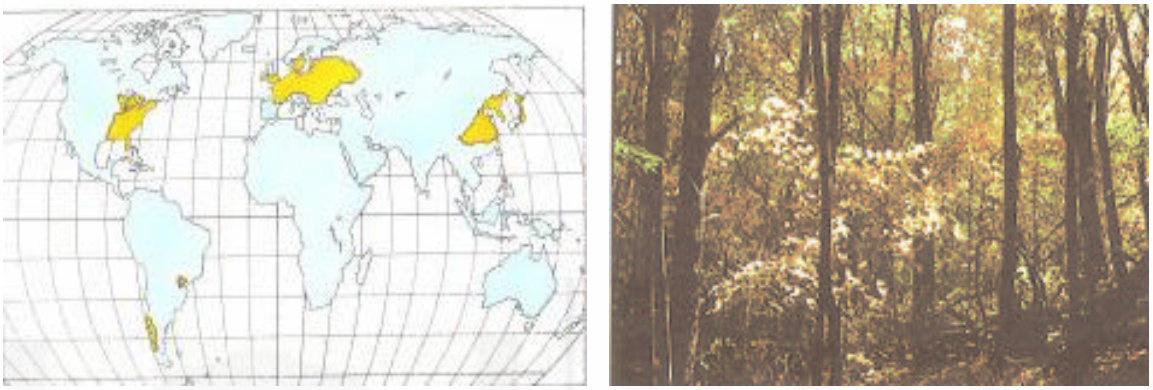

Fig.6.4: Temperate deciduous forests

6.2.4 Temperate Shrublands

These are areas where woody shrubs predominate rather then trees. In regions with a Mediterranean type of climate i.e., hot dry summers and cool wet winters, shrubs grow close together having typically leathery leaves. Remarkably similar shrublands are found in the coastal mountains of California in USA and in Chile; at the tip of Africa and south western Australia. However, in USA such communities are called **chaparral** (Fig. 6.5). Fires are of common occurence and plants and animals have developed adaptations to these special habitat features.

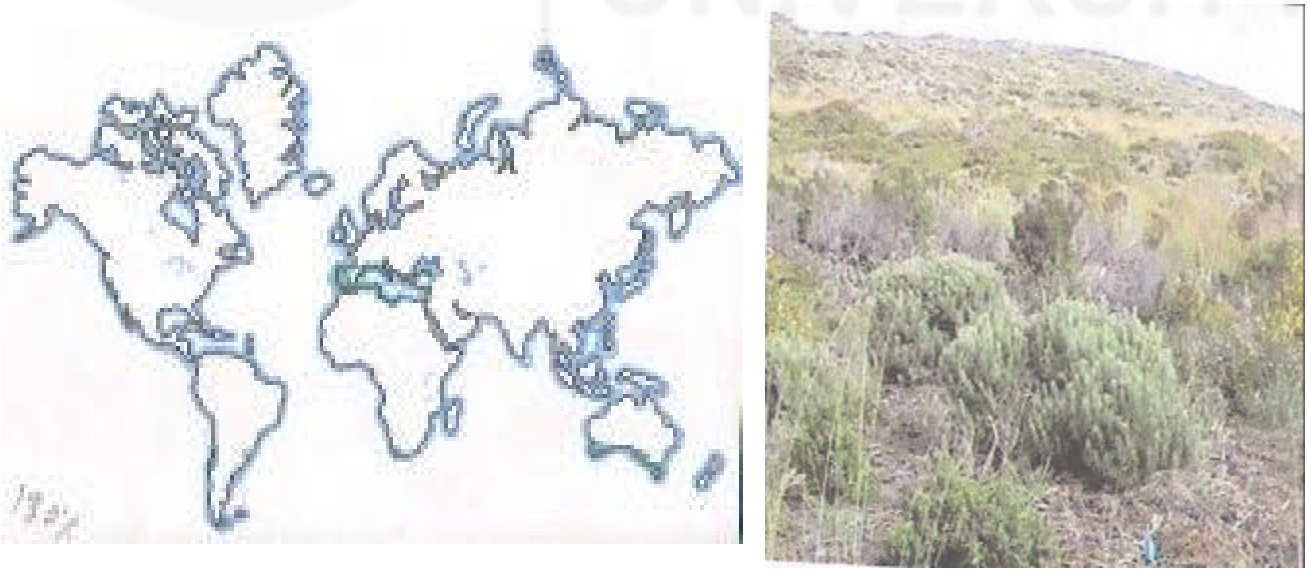

Fig.6.5: Chaparral biome

6.2.5 Grasslands

In the northern hemisphere grasslands are found over large areas in huge plains. Such grasslands are known as **prairie** in North America, **steppes** in Asia and **pampas** in South America (Fig. 6.6). In Australia grasslands cover an area almost equal to the area of the desert in the country.

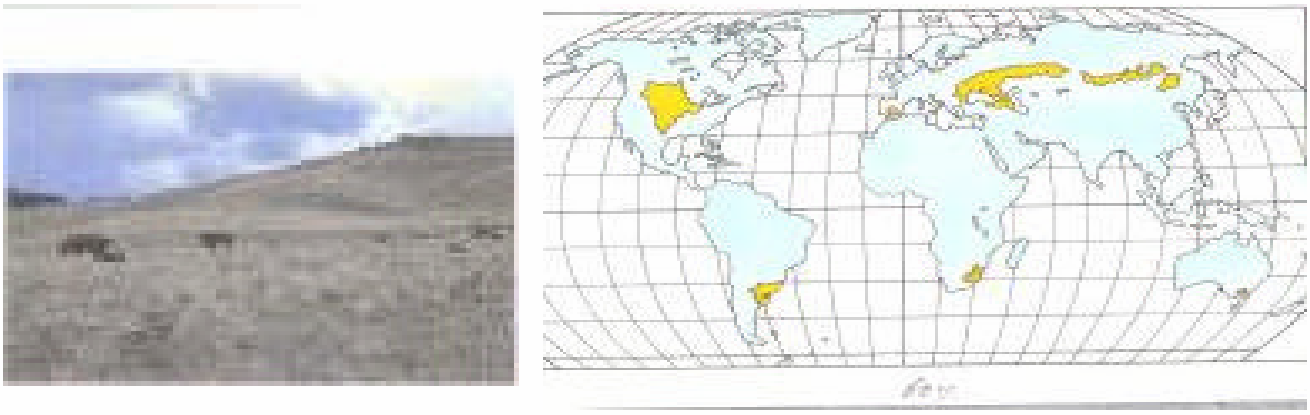

Fig.6.6: A grassland

Grasslands often fade away into deserts. Annual rainfall in areas dominated by grasslands is between 25-100 cm depending on temperature and seasonal distribution – (grasslands occur where rainfall is less to support forest and more than desert). Another factor that prevents penetration of forests into grasslands is the frequent occurrence of natural fires. Grasslands provide natural pastures for grazing animals. The soils under grasslands are rich and fertile. Most of our present day food plants (cereals) have evolved from wild grasses by the process of natural selection and it is one of the most important genetic stock for plant breeding research to develop new food species. Grasslands can be divided into three categories dependin g on the basis of relative height of grasses – tall grasses (1.5-2 m), mid grasses (30-60 cm), short grasses (3-16 cm). Grassland biomes generally support large number of herbivores, whereas carnivores are very few (coyotes, weasels, badgers, foxes, owls and rattlesnakes).

6.2.6 Deserts

In your tour across the temperate zone, you would find some regions lying between mountains and grasslands that are too dry and hostile to life. These are the deserts (Fig.6.7). If you continue to travel southwards as you approach 20^{o} to 30^{o} north and south latitudes you will encounter deserts. Deserts bring up the image of inhospitable places but actually they are quite varied. The world's largest desert is the **Sahara** followed by the **Great Australian desert**. These have the driest environment with less than 30 cm rainfall (sometimes higher but, unevenly distributed). In deserts day temperatures are high, rainfall and humidity is low, but there are cool northern deserts too where winter snows are common e.g. Tibet and Bolinia. However, all deserts exhibit dramatic day and nigh temperature variation. The soil is sandy or salty.

Box 6.2: Cold Deserts

Cold deserts cover a vast area north of the Himalayan ranges forming an ecosystem with exceptionally low temperatures which may reach – 75°C and a mean annual rainfall of 500-800 mm. They occur in a plateau at 4,500 to 6,000 m and fall within the Trans-Himalayan Biogeographic Zone identified by Rodgers and Panwar (1988) which extends into the Tibetan plateau.

These cold deserts of the Indian sub-continent harbour a distinctive insect diversity, the most diverse wild sheep and goat community in the world, the Tibetan wild ass or kiang, the now rare snow leopard and the wolf are among many other species adapted to this exacting environment.

Source: Draft National Biodiversity Action Plan and Strategy of India.

The driest deserts are the Sahara where the rainfall is less than 2 cm per year. They support little life but the less extreme deserts have highly specialised life forms.

Three plant life forms are most adapted to the desert environment.

i) **Annuals** that avoid drought and grow when there is adequate moisture.
ii) **Succulents** – (e.g. cactus), that have adaptation for water storage and avoid water loss.
iii) **Hardy desert shrubs** – having short stem, number of branches and thick leaves.

The animals of deserts are primarily arthropods, reptiles, birds and mammals. Large animals are uncommon. Small rodents are the most common mammals, along with small foxes. Among the herbivores, insects are dominant. A number of insectivorous lizards are very common. However, most animals restrict their activity to early morning or after sunset.

Desert soils are rich in nutrients but water is a serious limiting factor. If water is supplied or made available to desert biomes, they can attain very good production because sunlight is abundant.

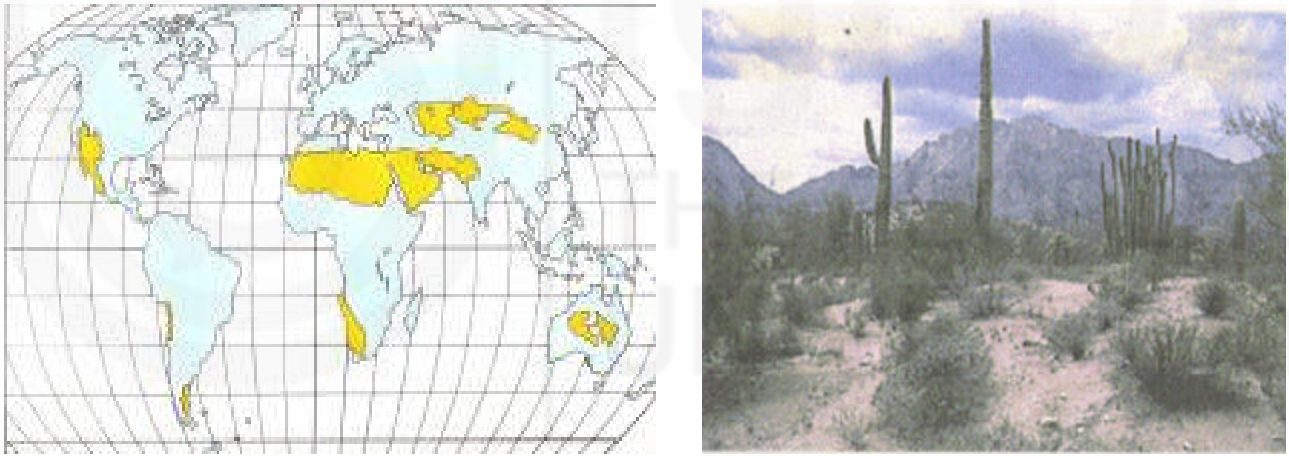

Fig.6.7: A desert

6.2.7 Tropical Savannas

Leaving the deserts as you approach the tropical regions of the earth you will enter the savanna biome, which is a combination of grassland with scattered or clumped trees. These special kinds of grasslands often border tropical rain forests. The climate is warm having 100-150 cm annual rainfall, with prolonged dry season in which fires are common. The rains are erratic.

These grasslands have scattered trees, that do not form canopy in any part of savanna (Fig. 6.8). Trees are up to 20 m height, with thick, deciduous or evergreen leaves. Grasses may attain height of 1-1.5 m and support a great variety of grazing animals.

The largest savanna is found in the African continent. They also occur in Australia and South America and cover nearly 8 percent of the earth's land. The most prominent animals of this biome are large grazing animals such as giraffes, antelopes, elephants, buffalo and predators such as lions and cheetahs.

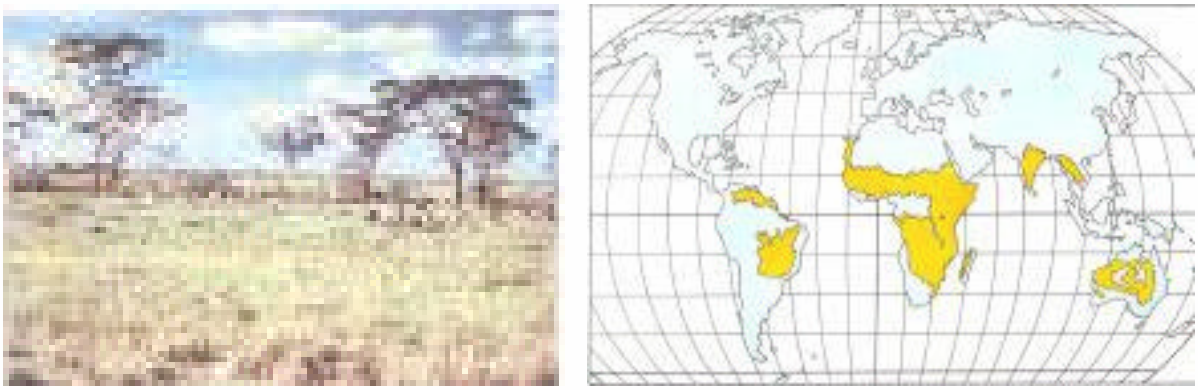

Fig.6.8: The African savanna has typical flat topped *Acacia* and dry grassland

6.2.8 Tropical Deciduous Forests

Before reaching your final destination the equatorial regions, you would encounter the tropical deciduous or seasonal forests. These are also known as monsoon forests found in South East Asia, in Central and South America, Northern Australia, Western Africa and the Pacific. (Fig. 6.9)

Rainfall is high, sometimes higher than tropical rain forests but seasonal. There are pronounced wet and dry periods, and so are winter and summer seasons. The soils are brown in colour and rich in nutrients.

Fig.6.9: Tropical deciduous forest

Vertical stratification in the vegetation is somewhat simple with a single understorey tree layer. The trees loose leaves in one season but ground vegetation remains evergreen. 'Teak' and 'sal' forests are good examples of this type of biome. Trees are of 20-30 m height, sometimes reaching a height over 40 m in this biome. Bamboo is also one of the climax shrubs in these areas.

6.2.9 Tropical Rain Forests

As you approach the equator the climate becomes increasingly hot and seasonal variation in climate decreases resulting in practically the same climate throughout the year. This tropical region abounds with life and thousands of species of plants and animals can be seen, though no species predominates. Tropical rain forests cover about 7 percent of the earth's surface but house approx imately 40 percent of the plant and animal species. Tropical rain forests are found on both sides of the equator in South East Asia, Africa, South and Central America, North East Australia.

Both temperature and humidity are very high and constant. Rainfall exceeds 200 cm a year and is distributed over the year. Soil is nutrient poor because in spite of the high rate of decomposition the nutrients do not remain in the soil. They are absorbed rapidly by plants or the rains wash them away thus making the soil virtually useless for agriculture. There is a distinct stratification of vegetation in rain forests. The dominant plants in these forests are tall, 25-30 meters high with slender trunks that branch only near the tops forming a dense canopy of leathery evergreen leaves. The canopy blocks out most of the light, therefore, the forest floor is fairly open. Whatever the time of the year, some trees are flowering and some bear fruit. Epiphytes and liana are very common (Fig. 6.10).

Wherever there is a gap in the canopy, a thick many layered ground vegetation consisting of bushes, herbs, shrubs, ferns, mosses etc., can be seen. An incredible number of animal species thrive in this biome, many of which have become adapted to life in the specific layers of the canopies and subcanopies. Amongst animal species insects and birds are particularly abundant. On a very small island of six square mile, Barro Colorado, of Panama, there are 20,000 species of insects! There are large varieties of coloured birds such as hornbills, parrots and toucans as well as monkeys and predatory cats that inhabit this most interesting biome.

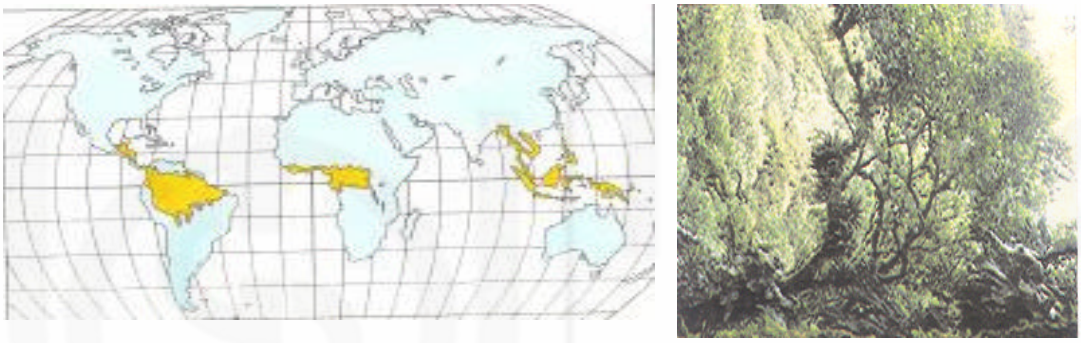

Fig.6.10: Tropical rain forest

Now after studying about biomes, you can understand the altitudinal variation of the biomes. If you look at Fig. 9.11 you would realise that terrestrial biomes tend to be arranged according to particular latitudes in the northern hemisphere. Interestingly at any given geographical location you would find that the climate and vegetation change as the altitude changes. Therefore, we find that at the foot of a mountain there would be complex vegetation and as we go up the slopes of the mountain we find the vegetation becomes sparse till we reach the moss and lichen dominated tundra like regions at the top of the mountain (Fig. 6.11).

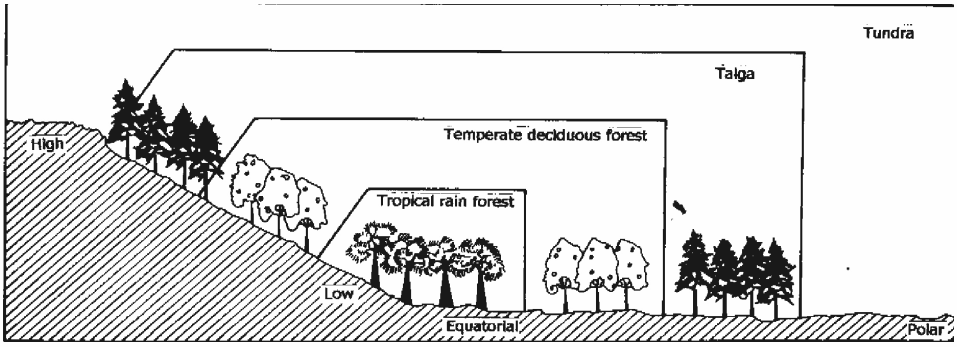

Fig.6.11: The altitudinal variation often mimics the latitudinal variation

SAQ 1

Define a biome and ecotone.

……

……

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SAQ 2

Name the major types of biomes. How do the organisms (flora and fauna) differ in these biomes?

……

……

……

6.3 THE AQUATIC BIOMES

If you look up a world atlas you would notice that most of the earth's surface is covered by the waters of the oceans (about 71%). Beneath the water surface is a fascinating world of a wide variety of habitats and living communities comparable in diversity to the terrestrial biomes but different enough from them to seem to belong to a different world altogether. The main factors affecting the type and numbers of organisms found in aquatic ecosystems are **water salinity** and **depth to which sunlight penetrates**; **amount of dissolved oxygen and temperature of water**.

Salinity levels are used to distinguish the waters on the earth into two categories, freshwater, and marine. We shall first consider the freshwater biomes.

6.3.1 Freshwater Biomes

Low levels of dissolved salts characterise the freshwater biomes. The salt content of fresh water is about 0.005 percent. The freshwater biomes consist of inland bodies of standing water like lakes, reservoirs, ponds and wetlands as well as the flowing waters of the streams and rivers. Their nature does not depend as much on global climate, but on the individual site where they occur.

A lake or a body of standing water can be divided into three zones according to penetration of sunlight in the water body i.e., **littoral**, **limnetic** and **profundal**. Each of these have their own physico-chemical features and characteristic array of living organisms (Fig. 6.12).

The **littoral** zone is the area where light penetrates to the bottom. Aquatic life in the littoral zone consists of free floating and rooted plants, many aquatic insects, snails, amphibians, fish, turtles and water birds.

The open water zone is called the **limnetic** zone. This represents the zone or depth of the water upto which sunlight can penetrate. Phytoplankton along with algal forms, various zooplankton species and fish abound in this zone. The deep water zone lying below the limnetic zone is called **profundal** zone. It is relatively cool and dark, having low dissolved oxygen content and is inhabited by fish which can tolerate such stressful conditions. The bottom of the lake is inhabited by bacteria, fungi, blood worms and other decomposers which live on dead plants, organic matter including remains of animals and their metabolic wastes.

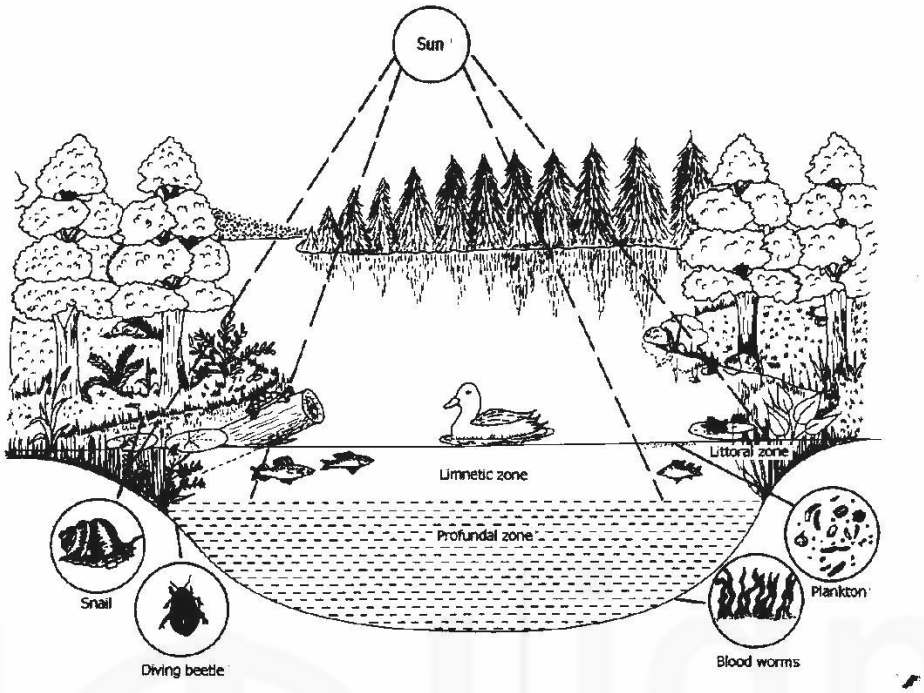


Fig.6.12: Zonation in the lake biome

Precipitation that does not evaporate or penetrate the soil remains on the soil surface resulting in run off which flows down from the mountains in the form of streams and rivers which ultimately discharge into the sea. The downward flow of the river comprises of three phases.

The first phase, when the stream with cold clear water rushes down steep slopes having high dissolved oxygen content. Most organisms which are adapted to cold temperatures and need high amounts of dissolved oxygen are found here. In the second phase the stream flows over gentle slopes and through wider valleys. Here the temperature of water is warmer and supports a wide variety of cold water and warm water fish that require slightly lower dissolved oxygen. At the point where river discharges into sea, the river may divide into many channels, forming the **delta**.

Rivers and brookes which are flowing fresh water bodies differ from lakes and ponds in three major aspects:

1. current is the major controlling and limiting factor,
2. land-water interchange is greater because of the smaller size and depth of moving water systems, and
3. oxygen is always abundant except in case of excessive pollution in river stretches.

Plants and animals living in streams and rivers are usually attached to surfaces. The free swimming animals are exceptionally strong swimmers.

The freshwater and its flora and fauna are utilised as a major communities for recreational purposes and for waste disposal as well as waterways for transport. In this manner we exert a significant impact on freshwater ecosystems.

6.3.2 Marine Biomes

The marine biomes consist of the earth's oceans and its associated areas like the shorelines, islands, reefs and estuaries. The marine waters contain about 3.5 percent

salt, mostly sodium chloride and the organisms inhabiting these waters are profoundly adapted to these salty conditions. As landlivers we generally think of the earth as being mostly land and tend to forget that 71% of the surface of our planet is covered by oceans. In fact, often our planet is referred to as the 'water planet!'.

Oceans

The oceans play a major role in determining the climate and sustaining life on earth. Oceans help to redistribute the solar energy, through ocean currents and evaporation; they are huge reservoirs of carbon dioxide, oxygen and other minerals and help to regulate the ambient temperature and also help in maintaining atmospheric composition and serve as sources of various natural resources.

The world's seas and oceans are all inter-connected forming a World Ocean. The average depth of the ocean is 3.7 km. In some parts of the world the ocean is 11.5 km deep. Compare this with the height of Mount Everest that is 8848 m above sea level.

Fig. 6.13 shows a diagrammatic representation of the vertical and horizontal zonation in the marine environment.

Most marine life is found in the shallower regions of the ocean and seas along the continental shelves, coral reefs and oceanic islands. Life at greater depths is limited by darkness, cold temperatures and pressure. Animal life at great depths comprises mainly of scavengers and predators that feed on the detritus and dead organic matter. The food that supports the large and diverse communities of the ocean is produced in the open water by phytoplankton in upper regions of the ocean where sunlight can reach. The average depth of the lighted zone of the sea is 200 meters in clean areas.

The marine habitat faces destruction due to pollution and resource use. Shorelines and open waters are subject to human activities such as fishing, recreational use, real estate development, garbage and effluent disposal, oil spills, radioactive waste disposal and exploitation of marine natural resources.

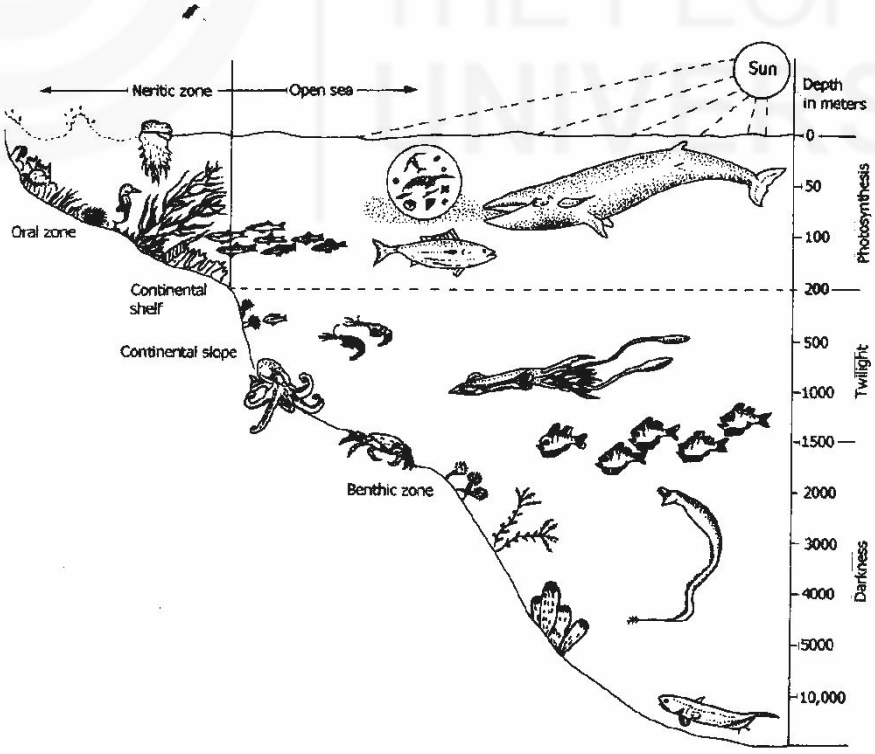


Fig.6.13: Zonation in the ocean

Shorelines, Oceanic Islands and Reefs

Ocean shorelines include rocky coasts and sandy beaches that are particularly rich in diverse life forms. Rocky shorelines support a diversity of organisms that grow attached to some solid substratum. Sandy shorelines provide home to organisms that can live in burrows in sandy substratum.

Oceanic islands are interesting and somewhat specialised biomes. Islands which have broken away from the main continents have similarity of flora and fauna related to the continental source, volcanic and coral islands show results of chance colonization.

Coral reefs form in clear warm tropical seas and are particularly well developed in the South Pacific. They are formed by accumulation in calcarious skeletons of tiny colonial animals called corals over generations. Coral reefs usually form along the shallow submerged shelves and they are limited to a depth up to which sunlight can diffuse. Coral reef communities in terms of species diversity, number of organisms, brilliance of colours and interesting life forms are comparable with tropical forest communities.

Coral reefs are tropical, shallow water ecosystems, largely restricted to the area between the latitudes 30° N and 30° S. These ecosystems are highly productive as a result of efficient recycling, high nutrient retention and a structure which provides habitats for a wide range of organisms.

Coral reefs, largest organic structures built by living creatures, are sometimes hundreds of kilometers long. Due to their abundance of species and great ecological complexity, they are compared to tropical rain forests. But even the latter takes a backseat in view of the parade of exotic life forms on a coral reef. At the phyletic level, coral reefs are more diverse than rain forests and include unique life forms known only in the marine realm.

Source: WCMC, 1992 and World Bank 1997.

Wetlands and Estuaries

Wetlands and estuaries are transitional biomes. Land that remains flooded either part of the year or permanently with fresh or salt water is known as wetland. The internationally accepted definition of wetlands is: **Areas of fen, peatland or water whether natural or artificial, permanent or temporary, static or flowing, fresh, brackish or marine water, the depth of which does not exceed six metres**. Bogs, swamps, marshes are covered by freshwater and found inland. These are known as **island wetlands,** those found on the coast and covered by seawater are known as **coastal wetlands**. Wetlands provide a variety of fish and wildlife and are major breeding, nesting and migration staging areas for water birds and shorebirds. Importance of wetlands cannot be underestimated as they act as traps and filters for water that move through them reducing flooding. As a result, sediments are deposited and chemical interactions in wetlands neutralize and detoxify substances in water and slow seeping of water into the ground helps to replenish underground water reserves.

Estuaries are enclosed or semi closed bodies of water formed where a river meets the sea forming an area of mixed fresh and sea water. Estuaries usually contain rich sediment forming mud flats. Estuaries are very productive areas with high species diversity. They are important nurseries for ocean fish including all economically important fish and molluscs. The estuaries extend inland to form the coastal wetlands. In temperate areas, coastal wetlands usually consist of mix of bays, lagoons and salt marshes, while in tropical areas we find mangrove swamps dominated by mangrove trees, the mangrove forests consist of evergreen, broad – leaf trees growing in brackish water in tropical areas.

SAQ 3

Name the areas of the marine biome and list their characteristics.

……...…

……..

SAQ 4

Name two freshwater biomes. How do the organisms in them differ?

…...……...…

……..

6.4 BIOGEOGRAPHIC REGIONS

Continental-scale biogeographic regions defined by differences in geologic and climatic history which contain distinct assemblage of plants and animals, particularly in higher taxonomic levels. The realm item is of a two letter code.

AA = Australasia
AN = Antarctic
AT = Afrotropics
IM = IndoMalay
NA = Nearctic
NT = Neotropics
OC = Oceania
PA = Palearctic

Biogeographic regions are large areas that contain characteristic assemblages of animals and plants, delineated on account of natural barriers such as oceans, mountains and deserts. A biogeographic region is generally characterised by high levels of species endemism (i.e. species which are restricted to a specific region only).

Box 6.3: Biogeographic realms

Wallace in 1876 proposed six biogeographic regions based on distribution of animals: **Nearctic**, **Neotropical**, **Palearctic**, **Ethiopian**, **Oriental** and **Australian** (Fig. 6.14). Later Udvardy (1975) recognised eight biogeographic realms Nearctic, Palaearctic, Africo-tropical (formerly Ethiopian), Indo-Malayan (formerly Oriental), Oceanian, Australian, Antarctic, and Neotropical. South Asia represents several of these regions. For example the Indian subcontinent and Pakistan fall within the influence of the Palaearctic, Africo-tropical and Indo-Malayan, resulting in high regional biodiversity. Nepal links the Tibetan Plateau with the Indian Subcontinent, and forms a biogeographic corridor between China and India.

Source: Draft National Biodiversity Action Plan and Strategy of India, 2002 and Parajuli and Pokhrel, 2002; Anwar and Shank, 2002.

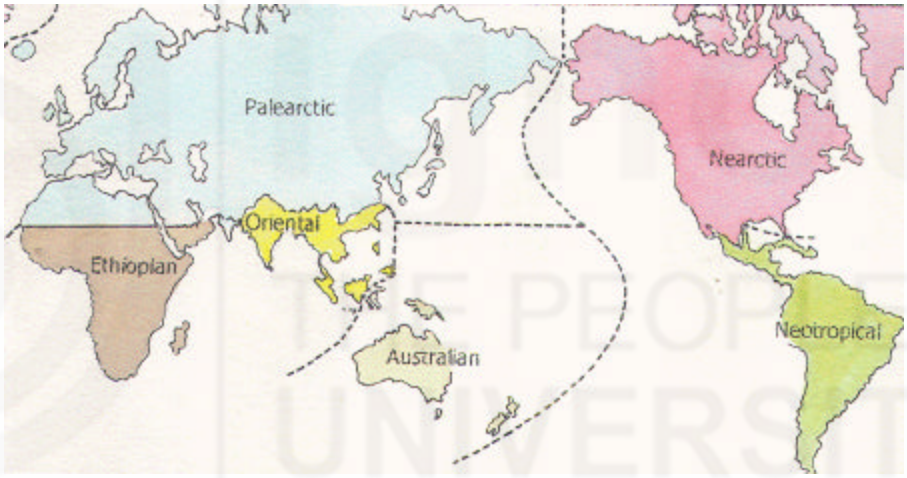


Fig.6.14: The world's zoogeographic regions

Boundaries between biogeographic regions are called "biogeographic lines". Examples are:

- Wallace's line between Southeast Asia and Australia (between Sundaland and Wallaceae), and
- Kangar-Pattini line between India and Myanmar.

The marine environment is three-dimensional with a distinct vertical zonation, each having its distinct associated species. Accordingly in a particular oceanic region, inter-tidal areas, the upper layers of the open ocean and the deep sea have very different assemblage by species.

SAQ 5

Define biogeographic realm.

……...……

……...……

SAQ 6

What is Wallace's line?

……

……

6.5 THE BIOGEOGRAPHIC ZONES OF INDIA AND THEIR BIODIVERSITY

The country has been divided into ten biogeographic zones: *Trans-Himalayas, Himalayas, Indian Desert, Semi-Arid, Western Ghats, Deccan Peninsula, Gangetic Plains, North-East India, Islands, and Coasts.* (Fig. 6.15). This classification was

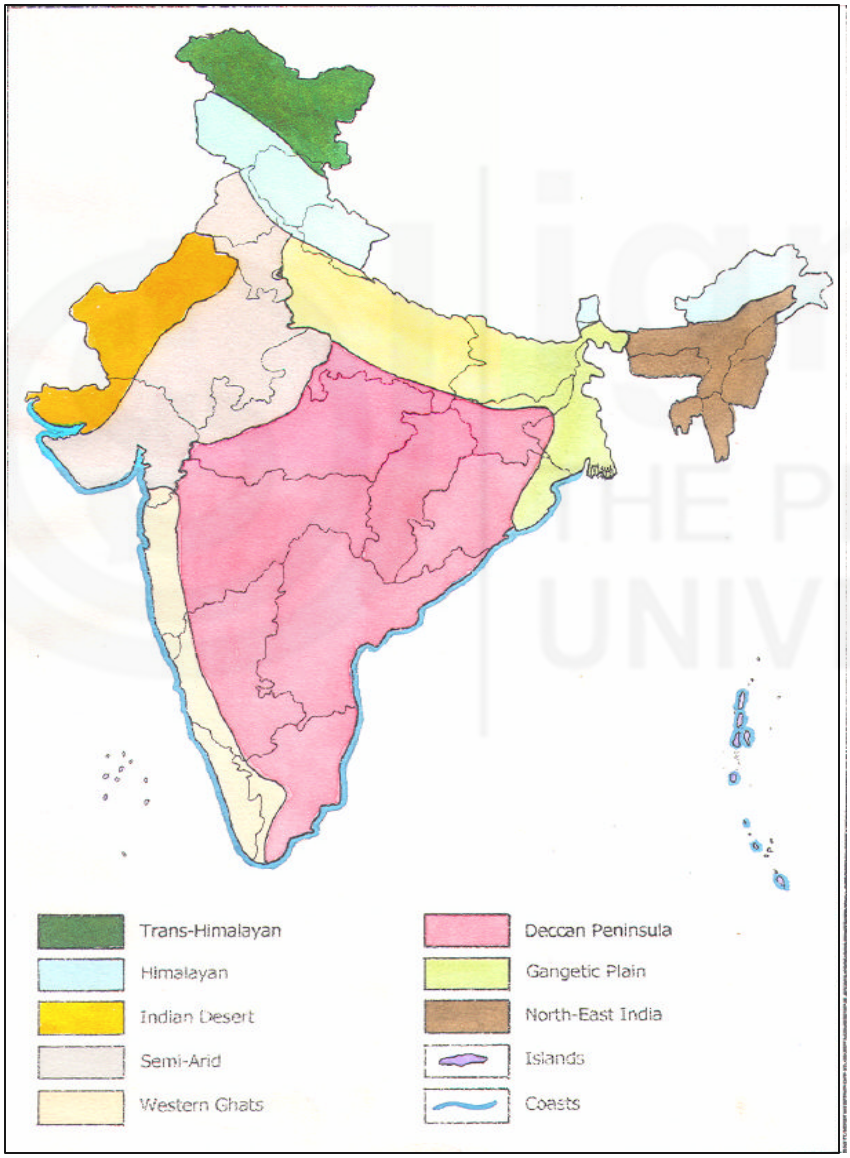


Fig.6.15: The biogeographic zones of India. From: W. A. Rodgers and H.S. Panwar, 1988. Planning a wildlife protectedarea network in India. Vol. 1, Department of Environment, Forests and Wildlife, Govt. of India

developed at the Wildlife institute of India by Rodgers & Panwar (1988) and it is being largely followed. What are these biogeographic zones? These represent the major species groupings. In addition, each of these ten zones indicates a distinctive set of physical, climatic and historical conditions. The Himalayas and Gangetic Plains are examples of two adjacent but obviously extremely different zones.

Table 6.1: Characteristics of biogeographic zones of India (Rodgers and Panwar 1988)

Biogeographical Zone	Biotic Province
A) Palaeoarctic	
1) Trans-Himalayan (Tibetan)	a) Ladakh b) N.W.Himalaya
2) Himalayan	c) W.Himalaya d) Central Himalaya e) East Himalaya
B) Paleotropical: African	
3) Desert	a) Kutch
4) Semi-Arid	b) Thar a) Punjab b) Gujarat-Rajwara
C) Paleotropical: Indo-Malayan	
5) Western Ghats	a) Malabar Coast b) Western Ghats
6) Deccan Peninsula	a) Deccan Plateau (South) 1) Tamil Nadu plains 2) Eastern Ghats (South) 3) Karnataka b) Central Plateau (North) 1) Maharashtra 2) Telangana c) Eastern Plateau 1) Eastern Ghats 2) Chatisgarh & Dandakaranya d) Chhota-Nagpur 1) Chhota Nagpur Plateau 2) Garhjat Hills e) Central Highlands 1) Satpura-Maikal 2) Vidhya-Bagelkhand
7) Gangetic Plain	a) Upper Gangetic Plain b) Lower Gangetic Plain
8) North-East India	a) Brahmaputra Valley b) Assam Hills

Subspecies – A taxonomic subdivision of a species, with some less obvious morphological* differences from the other subspecies and often with a different geographical distribution or ecology, e.g., a species 'A' may have a number of subspecies a_1,a_2,a_3 and so on.

*morphology is the study of structure or form of organisms.

Variety – A taxonomic subdivision of a subspecies, consisting of individuals with uniform characters that have arisen either due to genetic isolation* or due to various cultivation practices.

*genetically isolated group of individuals do not exchange genetic material with the members of other similar group. In other words, two genetically isolated groups of individuals are unable to breed freely.

Endemic species – species confined to a particular region, e.g*., **Azadirachta indica*** (neem) is endemic to Indian sub-continent.

Endangered species – A species is considered endangered when its numbers are so few and/or its habitat is so small that it may become extinct if not given adequate protection.

9) Coasts	a) West Coast b) East Coast
10) Islands	a) Andaman Islands b) Nicobar Islands c) Lakshadweep Islands

Our country, which occupies just two percent of the total land mass, harbours a rich biodiversity comprising of about five percent of the known biodiversity from the world over. The numerical figures of the familiar categories of living organisms would give you a feel of the 'rich biodiversity' that we have in our country. There are about:

81,000 species of animals, including
50,000 species of insects, and
12,00 species of birds,
45,000 species of various other categories of plants, including
15,000 species of flowering plants.[1]

In addition, these species may have several sub-species which in turn may have countless varieties. All these make the wildlife in India one of the richest in the world. The prime reason for such a rich biodiversity is because of the availability of an extraordinary diversity of habitats in India: from the cold and arid high-altitude regions of the trans-Himalayas to the dense, tropical rain forests of south India; from the searingly hot Thar desert in the west to the lush mangrove forests of the eastern coastal areas; and several variations in between. In fact, an entire life time would be inadequate to see the entire range of habitats.

6.5.1 Zone 1: The Trans-Himalayas

This zone has an area of about 1,86,200 sq km[2] and it covers mainly Ladakh and Lahul-Spiti. This zone is much more extensive than the area within India, because of its high altitude mountainous terrain which are between 4,500-6,000m. Taking the toporgraphy into account, the areas comes out to be around 2.6 million sq km.

The Wildlife of the Trans-Himalayas Zone

This zone represents an extremely fragile ecosystem, because of its harsh climatic conditions and the inhospitable terrain. There are three mountain ranges running across this zone in India: Zanskar, Ladakh and Karakoram. Each slope has its own major valley-slope system. Each of these three mountain ranges is very interesting from the biological point of view. To the east, the Ladakh and Zanskar ranges merge into the southern margin of the Tibetan Plateau and the beginning of an internal drainage marsh and lake systems (e.g., Tso Morari). Most of its areas in the north is above the snowline. Siachen Glacier, covering an area of about 1,180 sq km is a major constituent of this area. This, in fact is the largest such area outside the polar region.

The vegetation of Ladakh and Lahul-Spiti is largely a sparse alpine steppe. In addition, several endemic species also occur here. This area within India, alongwith Pakistan and Tibet, has the richest wild sheep and goat communities in the whole world. There are eight distinct species and sub-species of sheep, the familiar ones are: Urial or Shapu, Argali or Nayan, Marco Polo Sheep, Markhor (Fig. 6.16 a-d) and Blue Sheep. The flatter plateaux have a distinct grazing community comprising of Wild

[1] These figures are based on the survey of nearly 70% of the geographical area of the country surveyed so far, survey of remaining areas is continuing.

[2] This area includes 83,808 sq km area of Jammu and Kashmir under illegal possession of Pakistan, and 41,500 sq km area occupied by China since 1962.

Yak, Tibetan Ass, Tibetan Gazelle, Ibex and Tibetan Antelope (see Fig. 6.17a-e). In addition to these herbivores, there is an equally distinctive set of carnivores including Snow Leopard, Indian Wolf, Pallas's Cat, Fox and smaller animals like Marbled Pole Cat, Pika and Marmot (see Fig. 6.18a-d). Of these the Pallas's Cat is endemic to this area. The lakes and marshes too, have a distinctive avifauna including the spectacular Black-necked Crane, which is a migratory bird. Avifauna refers to the birds of an area collectively.

Since this ecosystem has very low primary productivity, the various kinds of animal populations are found in considerable altitudinal migration. Many of the species concentrate in valley areas during winters. The increasing human intrusion is endangering the delicate ecological balance of this extremely fragile ecosystem.

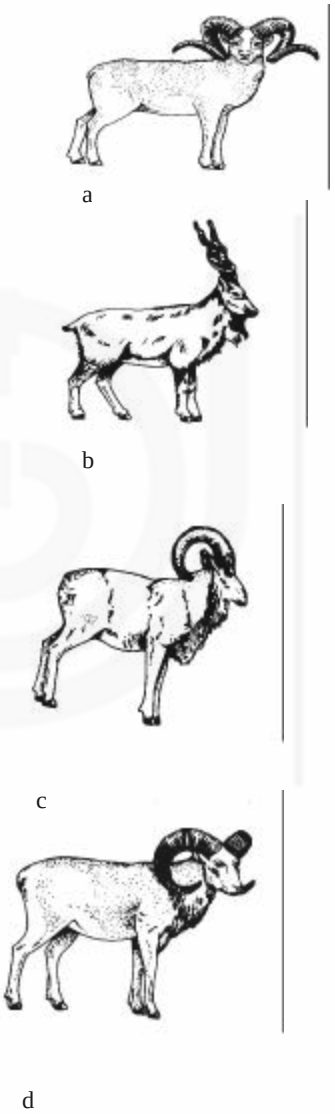


Fig.6.16: Sheep species found in the Trans-Himalayan zone, a) Urial (*Ovis orientalis*), b) Nayan (*Ovis ammon hodgsonii*), c) Marco polo (*Ovis ammon polii*), and d) Markhor (*Capra falconeri*)

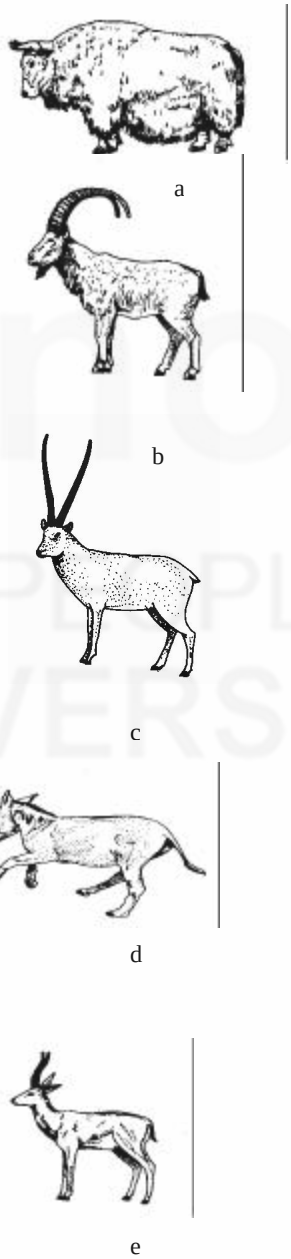
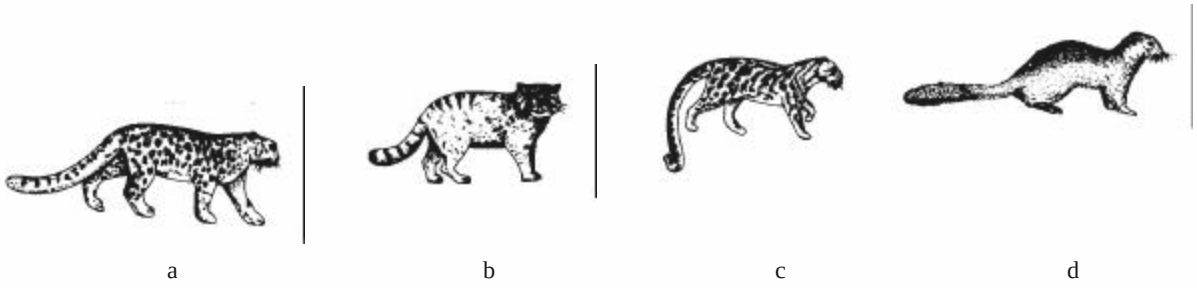


Fig.6.17: Some herbivores of the trans-himalayan zone, a) Wild yak (*Bos grunniens*), b) Gazelle chinkara (*Gazella gazella*), c) Tibetan ass (*Equus hemionus*), d) Ibex (*Capra ibex*) and e) Tibetan antelope (*Pantholops hedgsoni*)



a b c d

Fig.6.18: Some carnivores of the trans-himalayan zone, a) Snow leopard (*Panthera uncia*), b) Pallas's cat (*Felis manul*), c) Marbled pole cat (*Felis marmorata*), and d) Marmot (*Marmot caudate*)

6.5.2 Zone 2: The Himalayas

The Himalayan mountain ranges in India stretch for over 2,000 km from arid Mediterranean areas in the west, to the wet Chinese-Malayan areas in the east. This zone covers an area of 236,300 sq km in India, and forms about seven percent of the country's total land surface. The environment here is extremely harsh, as there are steep slopes, unconsolidated soils and intense rainfall. Moreover, the pressures of human habitation, and the demand for timber, firewood and food are intense. All these factors have led to rapid degradation of this ecosystem that has taken toll of the biological resources occurring here. There are more endangered species in the Himalayas than anywhere else in India.

The Wildlife of the Himalayan Zone

The Himalayan zone is one of the richest areas of India in terms of habitat and species diversity. It shares its boundaries with many other ecosystems. The wildlife is so diverse that we need to look at it along its altitudinal and longitudinal ranges, and also along is east-west axis.

First let us look at the wildlife within the altitudinal and longitudinal range of Himalayas. These are:

i) The **lower sub-tropical foot-hills**. These have typical mixed deciduous community merging into Chir Pine (Fig. 6.19a) and then Ban Oak. The fauna consists largely of Sambar, Muntjac. Wild Boar (Fig. 6.20a-c). Black Bear, Goral (Fig. 6.20d) and Kalij Pheasants. Deciduous community refers to plants that shed their leaves seasonally.

ii) The **temperate areas**. These lie below 3,500 m. This zone has a complex mixture of vegetation types with forests of Maples (Fig. 6.19b) and Walnuts, Moru and Oak (Fig. 6.19c), and a variety of conifers such as the Blue Pine, Fir and Spruce (Fig. 6.19d-g). All these grow in an altitudinal sequence. The fauna consists of Musk Deer (Fig. 6.20e), serow (Fig. 6.20f), Koklas and Monal pheasants. In winters, the high altitude fauna such as Tahr (Fig. 6.20g) move to these areas.

iii) The **sub-alpine area**. This area has forest and scrub vegetation of Birch and Rhododendrons (Fig. 6.19h) interspersed with grasslands with several kinds of herbs. These communities merge into the alpine communities, with sparser cover to over 5,000 m, where only rocks and snow dominate. Here, Musk Deer, Serow and Tahr share the lower ranges with Bharal, and in the west Ibex are more common at higher levels. Along with altitude, the Pheasants of wooded areas give way to the Snowcock. The panther gives way to the Snow Leopard and Wolf. The Black Bear is replaced by Brown Bear.

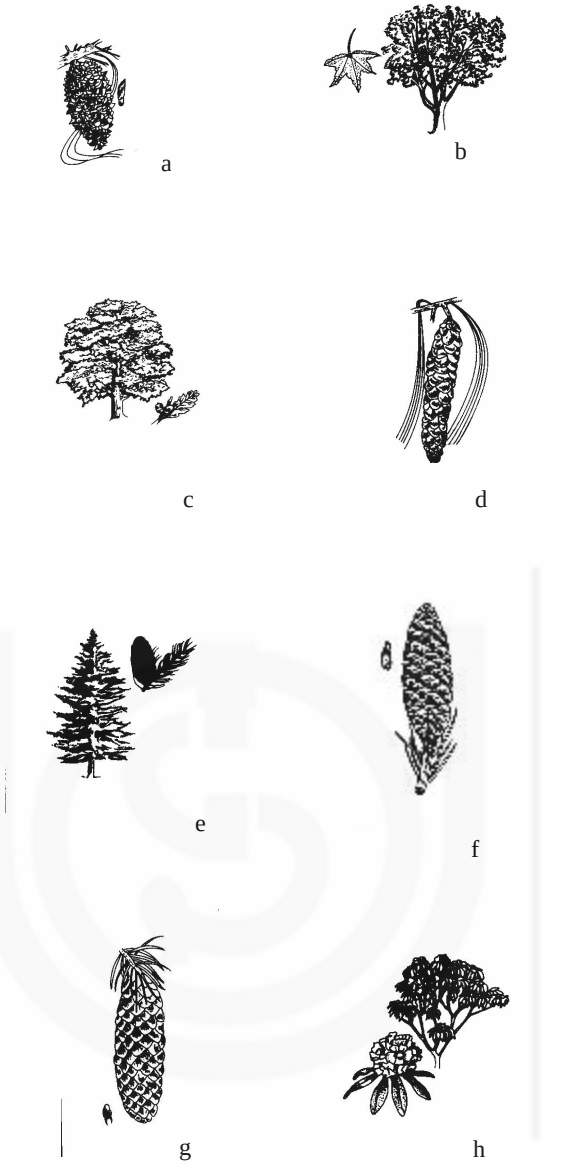


Fig. 6.19: Some representative members of the Himalayan vegetation, a) Chir pine (*Pinus roxburghii*) a cone, b) Maple (*Acer* sp.). c) Oak (*Quercus* sp.). d) Blue pine (*Pinus wallichiana*) a cone, e) Fir (*Abies* sp.). Tree and a cone, f) Spruce (*Pieea smithiana*) found in Western Himalayas, a cone, g) Spruce (*Pieea spinulosa*) from Eastern Himalayas, a cone, h) Rhododendron (*Rhododendron* sp.)

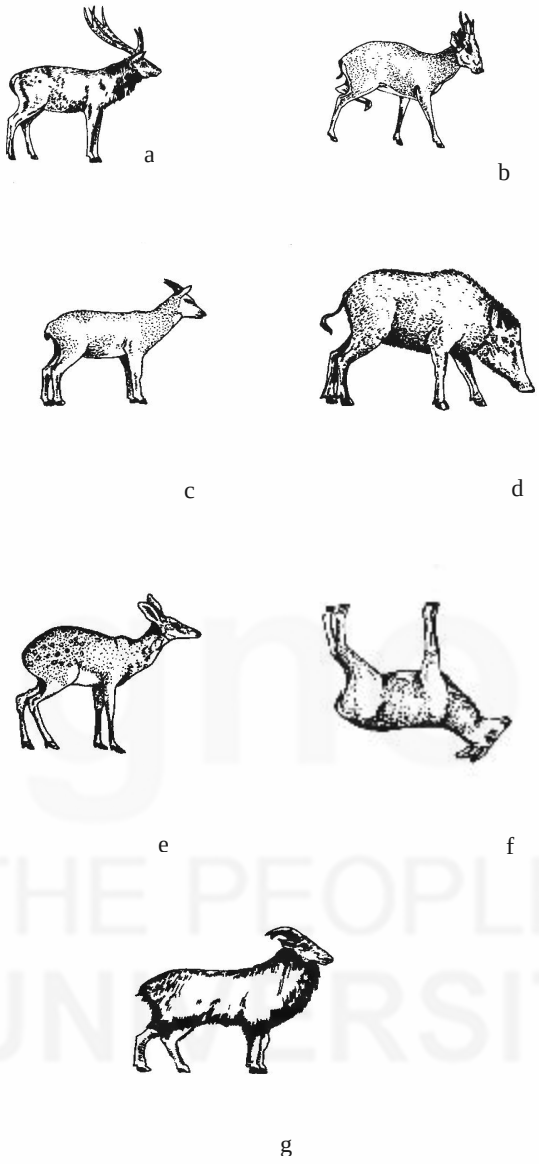


Fig.6.20: Some wildlife species distributed along the altitudinal and longitudinal range of Himalayas, a) Sambar (*Cervus unicolor*), b) Muntjac (*Muntiacus muntjak*), c) Wild boar (*Sus scrofa*), d) Goral (*Nemorhaedus goral*), e) Musk deer (*Moschus moschiferus*), f) Serow (*Capricornis sumatraensis*), and g) Tahr (*Hemitragus jemlabicus*)

On moving along the east-west axis characteristic communities can be seen as well. We divide this axis in three sub zones, i.e., the western, central and the eastern zones.

i) **The Western Zone**: This is a comparatively drier area with Deodars (Fig. 6.21a) and Blue Pines. In addition, there are vast expanses of grassy meadows. Several species of bovids are typical of this area. These include the Bharal, lbex. Markhor, Goral, Serow and Tahr. The Tahr is now missing from Kashmir. The Hangul which is a sub-species of Red Deer is restricted to this area.

ii) **The Central Zone**: There is a poor representation of large herbivores. The lbex, Markhor and Hangul populations have dwindled to nil. The Sikkim Stag is now thought to be extinct in the Indian territory.

a b c

Fig.6.21: a) Deodars, *Cedrus deodara* predominates the western zone of Himalayas, b,c) Orchids constitute characteristic vegetation of the Eastern Himalayan zone, b) *Calanthe triplicata*, and c) *Paphiopedilum spicerianum*

iii) **The Eastern Zone**: The Brown Bear, Bharal and Tahr found in other areas are absent here. Mishmi Takin a herbivore, is found here (Fig. 6.22a). This area has a higher tree line, and supports arboreal forest animal at higher altitudes. The Binturong, Red Panda (Fig. 6.22b) and Lesser Cats are the characteristic eastern faunal elements found here. The Orchids are profuse (two examples shown in Fig. 6.21b,c) and the alpine areas have an abundance of dwarf Rhododendrons that are shrubby.

a b c

Fig.6.22: Some animal species of the Eastern Himalayas, a) Takin (*Budorcas taxicolor*), b) Binturong (*Ailurus fulgens*)

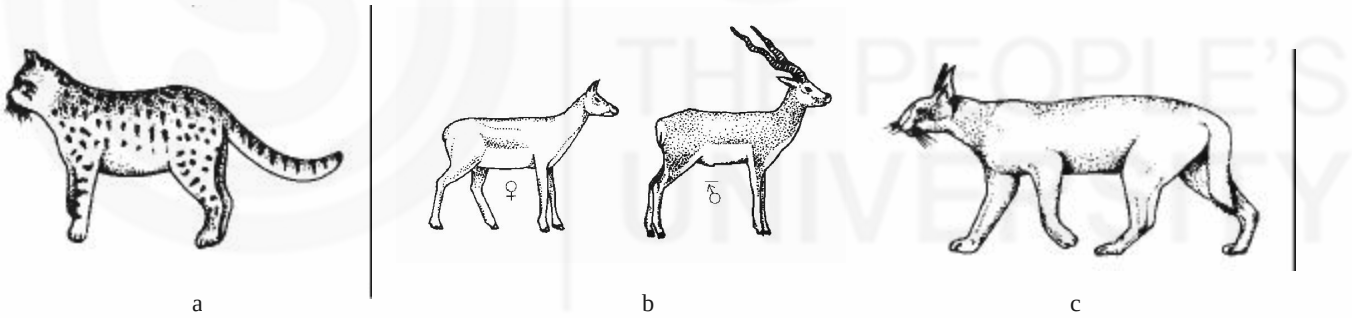
Endemism is high in nearly all groups of plants and animals found here. Though some species are widespread along the Himalayas, others have tiny restricted ranges. In addition to the endemic species there are quite a few endangered species also. As mentioned earlier, this area is regarded as a highly degraded ecosystem. Many large mammals are on the endangered species list. There are indications that the Sikkim Stag is lost from the Indian territory. All evidences indicate that the Tahr may have disappeared from Kashmir as may have the Western Tragopan. The populations of Markhor, Tahr and Serow have dwindled to low densities. The Hangul Stag is virtually restricted to a protected area only.

6.5.3 Zone 3: The Indian Desert

This zone is located in the western part of the country and is also known as the Thar desert. It covers west Gujarat and west Rajasthan. Parts of Punjab and Haryana were once a part of this desert, but the irrigated cultivation has changed the situation there. Biogeographically, the Thar is the eastwards extension of the Sahara-Arabian desert system spread through Iran, Afghanistan, Baluchistan to the India-Pakistan border. Because of the extreme seasonality of rainfall and extreme livestock pressures, it is a fragile ecosystem.

The Wildlife of the Indian Desert

The wildlife of the desert zone is peculiar not because of its great diversity of density, but because of the extraordinary ecological adaptations to the desert conditions. Several of the species are endemic to the Thar Desert. A distinct sub-species of Wild Ass is confined to the Rann of Kutch, its populations in Pakistan have dwindled away. Besides this, the Desert Fox, Desert Cat (Fig.6.23a), Houbara Bustard and some Sand Grouse species are restricted only to the Thar area. This region also has exculsive breeding sites of birds like the Flamingoes (Fig. 6.24a) in the Indian sub-continent breed chiefly in the Rann of Kutch. In addition, there are many species, that are in the endangered species' list. For example, the Chinkara, Blackbuck (Fig. 6.23b), Wolf, Caracal (Fig. 6.23c) and Great Indian Bustard (Fig. 6.24b), have significantly numbered populations in this zone. The plant communities are very peculiar. Within the Rann of Kutch, extensive areas are subjected to saline or brackish flooding every monsoon and there appears a typical salt marsh-salt bush plant community of halophytes. *Prosopis cineraria, Salvadora oleoides* are common trees of Indian deserts. Human inhabitation has modified much of the desert area, and as a result, exotic species as *Prosopis juliflora* (Fig. 6.25) are becoming increasingly widespread.



a b c

Fig.6.23: a) Desert cat (*Felis libyca*), b) Blackbuck (*Antilope cervicarpa*) male (?) and female (?) and c) Caracal (*Felis caracal*)

a b

Fig.6.24: A Falmingo (*Phoenicopterus roseus*). Flamingoes breed exclusively in the deserts, b) The great Indian Bustard (*Choriotis nigriceps*), another bird species associated with the deserts

6.5.4 Zone 4: The Semi-Arid

This zone with an area of 508,000 sq km occupies 15% of the total area in our country. The presence of several grass species and palatable shrubs in these areas has made them a favourite of a vast number of wildlife species. This zone shares common boundary with Western Gujarat and Rajasthan, Maharashtra; and includes areas of Punjab, Haryana and Madhya Pradesh.

The Wildlife of the Semi-Arid Zone

This zone has strong biological links with western Asia, primarily with Pakistan, Iran, Middle-east and Northern Africa. Many of the plants found here show African affinity, e.g., *Acacia* sp., *Anogeissus* sp., *Balanites* sp., *Capparis* sp., and *Grewia* sp. (see Fig. 6.26). One can see pure gregarious forests of *Anogeissus pendula* along the gentler slopes of Aravalli and associated hill ranges. This is the only area where it occurs in this form. Outside this area, *A.pendula* occurs in north Madhya Pradesh, mixed with teak.

Fig.6.25: A twig of *Prosopis juliflora* (Kabuli kikar). It is a moderate-sized, drought-resistant tree distributed widely in this zone

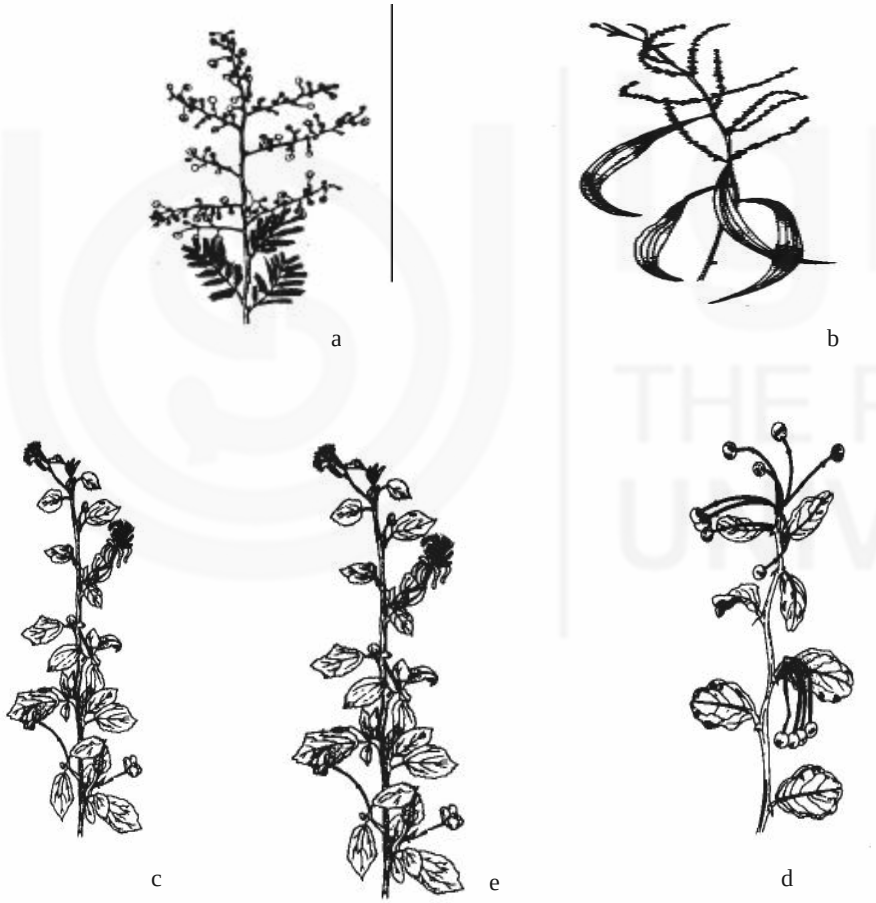
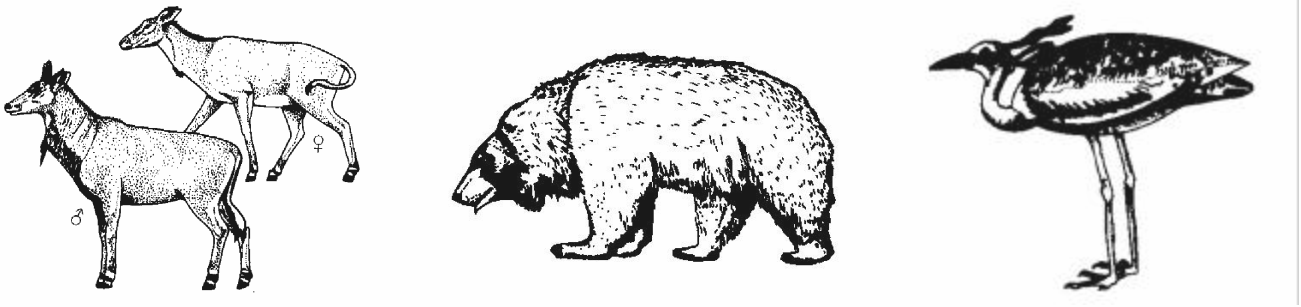


Fig.6.26: Plants of the semi-arid zone, a) *Acacia leucophloea* (Ronj), b) *Acacia auriculiformis* (Australian wattle), c) *Anogeissus pendula* (Dhoy, Siras), d) *Capparis sepiaria* (Kanthari), and e) *Grewia tenax* (Ramchana)



a b c

Fig.6.27: Some faunal elements of the semi-arid zone, a) Nilgai (*Boselaphus tragocamelus*), female (?) and male (?), b) Sloth bear (*Malursus ursinus*), and c) Lesser florican (*Sypheotides indica*)

The fauna consists of larger herbivores – Blackbuck, Chowsingha, Gazelle and Nilgai (Fig. 6.27a). The Sambar is restricted to the wooded hills and Chital to the moist valley areas. Amongst the carnivores, the Asiatic Lion is restricted to a small area in Gujarat whereas Cheetah is now extinct. Many of the species found here are in very low densities, and these are of conservation interest, e.g., Caracal, Jackal, Wolf, Sloth Bear (Fig. 6.27b), Blackbuck, Great Indian Bustard, Lesser Florican (Fig. 6.27c), Flamingoes and both resident and migratory species of waterfowl. The rivers and lakes too have prominent forms such as the Crocodile – Mugger and Gharial, and turtle populations. The largest population of Star Tortoise are seen in this zone.

Meghalaya is known for its botanical value, most of which are high altitude Oak forests of Shillong-Cherrapunji plateaux. The area near Tripura-Mizoram border has exceptional wildlife species diversity with four rare primate species: Hoolock Gibbon, Leaf Monkey and both Pig-tailed and Stump-tailed Macaque.

6.5.5 Zone 5: The Western Ghats

The Western Ghats represent one of the major tropical evergreen forest regions in India. The total area of Western Ghats is about 160,000 sq km. In the west, the zone is bound by the coast and in the east, it shares boundary with the Deccan peninsular zone. The tropical evergreen forests occupy about one third of the total area of this zone. In recent years, a large chunk of the forest cover has been lost and this zone is now of great conservation concern, more so because of its exceptional biological richness. About two-thirds of India's endemic plants are confined to this region. However, the potential of many of these species is yet to be tapped. Besides harbouring diverse biological communities, the forests in this zone also play an important role in maintaining the hydrological cycle.

The Wildlife of Western Ghats

The Western Ghats have a stretch of about 1,500 km, emcompassing a considerable gradient of temperature and rainfall, which produces several species associations. Longitudinally, the Ghats extend from sea-level in the west, rise abruptly to a highly dissected plateau up to 2,700 m in height and then descend, often equally abruptly to the dry Deccan plains below 500 k. This gradient produces a change from evergreen to semi-evergreen to moist deciduous to dry deciduous formations. This enlogated mountain chain has been cut by wide valleys in a few places, preventing dispersal of less mobile species and encouraging local speciation. The major biogeographic barriers or forest gaps are the Moyar Gorge, Palghat Gap and Shencottah Gap

separating the Nilgiri, Anamalai and Agastyamalai mountain blocks. After discussing the overall terrain of this zone let us discuss its plant life.

Out of the 15,000 odd species of flowering plants found in India, about 4,000 or 27% of the total, are found in this zone. And the Western Ghats constitute just 5% of the total land area! Of these 4,000 species, almost half of them (about 18,00 species) are endemic to this region.

We have mentioned earlier about the geographic variation in the 1,500 km stretch of this zone. Likewise, the evergreen forest formation is also not uniform down the length of the Ghats. The distinctive vegetation recognised by their dominant species are described in Table 6.2.

Table 6.2: The major vegetation types occurring along the stretch of the western ghats

S.No.	Vegetation	The Affecting Factors
1.	*Briedelia – Syzygium – Ficus – Terminalia*	Winter temperature and length of dry season
2.	*Memecylon – Syzygium – Actinodaphne*	
3.	*Persea – Holigarna – Diospyros*	
4.	*Dipterocarpus – Mesua – Palaquium*	
5.	*Cullenia – Mesua – Palaquium*	
6.	Montane 'Shola' forest	Higher altitudes
7.	Riverine/Swamp forest, *Myristica* (Fig. 6.28)	Water-logged valleys

Fig.6.28: A twig of *Myristica* along with a fruit

Although these forests have great ecological similarity with the forests in North-east India and Andamans, they are very different in terms of species composition. Of the total 29 species of the timber family Dipterocarpacease, 13 are found only in the Western Ghats and nowhere else. Of these, 4 species are highly localized endemics of conservation concern. One species, *Hopea jacobi* has not been recollected for more than half a century now. These species constitute an exceedingly important genetic stock for timber improvement.

Genera and Species – Genera plural, genus singular. Species same in plural and singular form. In Human beings or *Homo sapiens*, *Homo* refers to the genus and *sapiens* refers to the species. Note the genus is the same but only the species differ in the ancestors of man – *Homo erectus, Homo habillis, Homo kanamensis*.

Now let us have a look at the faunal elements of this zone. This zone has fairly good population of most of the vertebrate species found in Peninsular India, along with an endemic faunal element of its own. The only large mammals missing are the bovid group of Gazelle, Blackbuck, and Nilgai with associated lesser fauna, and the moist grassland fauna of Swamp Deer (Fig. 6.29a) and Buffalo.

Within the vertebrates, endemic taxa are found in all the groups. The proportion of endemic taxa in amphibians is exceptionally large, i.e., almost half the genera and most species are endemic. Some of them are extremely localised. Even the freshwater fish fauna is of interest as endemic taxa, and has affinity to the taxa in north-east India. These have been important in the formulation of Hora's Satpura Hypothesis in the development of Indian biogeographic thought. Several reptiles and bird species are restricted to the Ghats. The Travancore Tortoise and Cane Turtle are two endangered taxa restricted to a small area of Central Western Ghats, also known as the Coorg-Travancore. There are 62 mammal genera in the zone, one of whic h, a rodent is endemic. There are several instances of linkage of biogeographic interest: with the Himalayas, e.g., the Tahr; with North-east India; and with Sri Lanka.

The well known species found exclusively in Western Ghats include the following:

Among Primates – Nilgiri Langur and Lion-tailed Macaque (Fig. 6.29b,c)

Rodents – Plataconthomys, the Spiny Dormouse of the southern ghats.

Squirrels – Several subspecies of Ratufa indica with separate forms in Maharashtra, Mysore, Malabar and Tamil Nadu Ghats. The Grizzled Squirrel is restricted to two localities in the drier Tamil Nadu forest.

Carnivores – Malabar Civet in southern evergreen forests, Rusty spotted Cat in northern deciduous forests.

Ungulates – Nilgiri Tahr (Fig. 6.29d) in Nilgiris to Agastyamalai montane grassland.

Hornbills – Malabar Grey Hornbill (Fig. 6.29e).

In addition to the above endemic species, the other species found are: Tiger, Leopard, Dhole (Fig. 6.29f), Sloth Bear, Indian Elephant and Gaur (Fig. 6.29g).

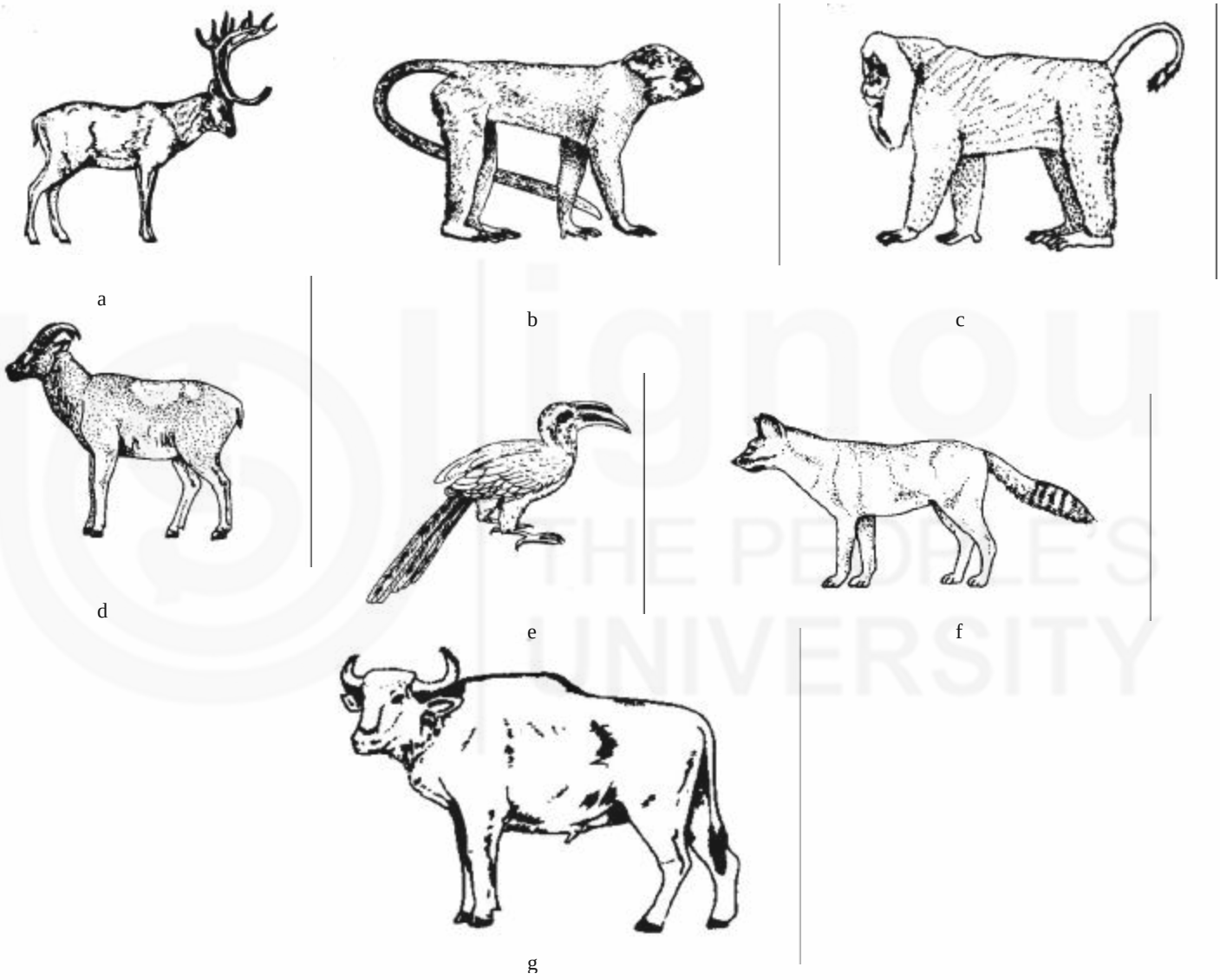


Fig.6.29: The faunal elements of Western Ghats, a) Swamp deer (*Cervus duvauceli*), b) Nilgiri langur (*Presbytis johni*), c) Lion-tailed macaque (*Macaca silenus*), d) Nilgiri Tahr (*Hemitragus hylocrius*), e) Malabar grey hornbill (*Tockus birostris*), f) Dhole (*Cuon alpinus*), and g) Gaur (*Bos gaurus*)

6.5.6 Zone 6: The Deccan Peninsula

This zone covers the largest area in India that amounts to about 43% of the total land mass, and about 1,421,000 sq km area. Though a large area of this zone has been greatly altered by humans, still some forest areas exist, particularly in Madhya Pradesh, Maharashtra and Orissa.

This zone has deciduous forest, thorn forests and degraded shrublands. There are small areas of semi-evergreen forests in the Eastern Ghats and, dry evergreen forests or thorn scrub on the coastal side of the plains of Andhra Pradesh and Tamil Nadu.

The Northern zone has forest dominated by the trees like Sal, especially in the North-east, Teak (Fig. 6.30), and miscellaneous species – (*Terminalia – Anogeissus – Chloroxylon*). The southern half of the zone has dry, thorn forests having *Acaci – Albizzia amara* and *Hardwickia* associations. The natural grasslands are rare.

Fig.6.30: A flowering twig of Teak-*Tectona grandis*

The faunal species are widespread throughout the whole zone, e.g., Chital (Fig. 6.31a), Sambar, Nilgai, Chowsingha, Barking Deer, and Gaur. Some species such as the Blackbuck are restricted to dry open area. Small, relict populations of species also exist, e.g., Elephant (Bihar-Orissa, and Karnataka-Tamil Nadu) and Wild Buffalo (in a small area at the junction of Orissa, M.P. and Maharashtra). The Hard Ground Swamp Deer is now restricted to a single locality in M.P. The Gharial is restricted to a few rivers flowing to the Ganges and one area in the Mahanadi river. Amongst the carnivores, the Rusty Spotted Cat has few small populations in Central India. Low density populations of Wolf are seen in the drier areas. The Tiger, Leopard, Sloth Bear, Gaur, Sambar, Chital, Chowsingha, and Boar are present in sufficiently high densities, particularly in the deciduous areas.

Considering the flora elements, this zone exhibits many interesting features. The Central Hill Ranges mark the beginning of a temperate flora at higher altitudes, and the Eastern Ghats harbour some endemic forms, which inc lude the birds like the Hill Myna (Fig. 6.31b), lesser vertebrates and invertebrates. The valuable, endemic plant resources such as the Red Sanders and Sandalwood are of immediate conservation concern. Similarly, there is also a need for conservation measures for the species – Moist Teak, Southern and Coastal Sal, Umbrella Thorn, and especially Orissa semi-evergreen communities and dry evergreen forest.

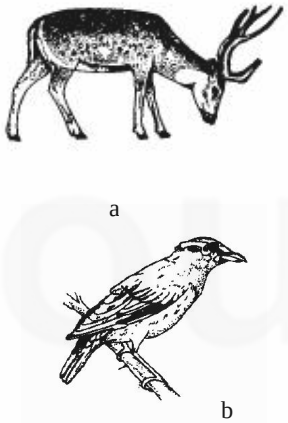


Fig.6.31: a) Chital (*Axis axis*), and b) Hill Myna (*Gracula religiosa*) – found in the Deccan Peninsula

6.5.7 Zone 7: The Gangetic Plain

This zone has one of the most fertile areas in the world, and it supports a dense and growing human population. It covers an area of about 359,400 sq km. The original vegetation found in most of the area is no longer there, as a major portion of this area has been brought under cultivation. This zone is topographically homogeneous for hundreds of kilometers. The only natural vegetation and wildlife is found in the north, in the Shivalik Hills and the adjacent Bhabar and Terai-Duar tracts. This zone has a large number of lakes and seasonal swamps. These have usually escaped drainage. This area is the habitat for migrating waterfowl.

The Wildlife of the Gangetic Plains

Centuries ago, this area was rich in wildlife consisting of Rhinoceros, Elephant, Buffalo and Swamp Deer. With the passage of time, their populations declined and disappeared as more and more area was brought under agriculture. However, small relict populations of Nilgai, Blackbuck nand Chinkara, interspersed with dense cultivation presently exist in the western areas. The northern Terai grasslands have populations of Swamp and Hog Deer (Fig. 6.32a) in a few places. The Rhinoceros, Bengal Florican, and Hispid Hare are found in low numbers in the Eastern Terai of Duras. The Sambar-Chital community if found in the Bhabar forests, with Goral in the areas with steeper slopes. These along with the Kaleej Pheasant shows the beginning of a transition to Himalayan conditions.

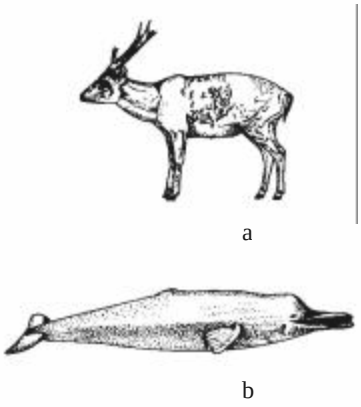
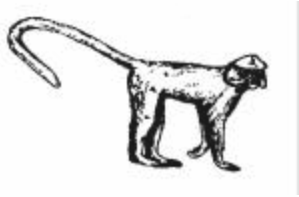


Fig.6.32: a) Hog deer (*Axis porcinus*), b) Gangetic dolphin (*Platanista gangetica*) – found in the gangetic plains

As mentioned earlier, this area is a major winter feeding ground for the migratory waterfowl which occurs in exceptional density and richness here. The wetlands and rivers also contain Crocodile – Mugger and Gharial populations, reflict populations of Gangetic Dolphin (Fig. 6.32b) and a rich, fresh-water turtle community having over 20 species.



a

b

Fig.6.33: a) Golden langur (*Nycticebus coucang*), and b) Hoolock gibbon (*Hylobates hoolock*) found in the North-East India

6.5.8 Zone 8: North-East India

North-East India represents the transition zone between the India, Indo-Malayan and Indo-Chinese regions as well as the meeting point of Himalayan mountains an Peninsular India. It is one of the most important zones in the Indian Subcontinent for its rich biological diversity and a large number of its species are endemic to this zone. It is not only the species of plants that are diverse, but also the animals exhibit a species richness not found anywhere else in the world. It has an area of about 171,423 sq km and includes the states of Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. About 40% of this area is occupied by forests.

The diverse habitat conditions along with the long term geological stability have contributed to the development of endemic plant and animal groups. Many of the species contributing to the biological diversity of North-East India are restricted to the region itself, or to even smaller localised areas such as in the Khasi Hills.

The North-East alone has the original habitat that once was the common habitat of north India. The Brahmaputra valley of this zone contains unique natural vegetation – swamps, grasslands and fringing woodlands and forests. It is in these regions that the full richness of the large herbivore fauna typically found in such grass lands can be seen. The fauna consists of Rhinoceros, Buffalo, Swamp Deer, Hog Deer, Pygmy Hog and Hispid Hare. This area also contains the largest elephant populations. This is also the fly-way for waterfowl and other birds travelling between the warmth of the subcontinent and their summer grounds in Silberia and China. This zone is still poorly explored biologically and many species remain to be discovered and described. There is immense potential for greater biological values to be documented.

The North-Eastern units have biological affinity with the Indo-Chinese and Indo-Malayan areas to the east and south-east. Many species are shared and there is a gradual interchange from one region to the next. Brahmputra river itself is a dispersal barrier for several species of animals as well as of plants. For example, Golden Langur (Fig. 6.33a), Hispid Hare and Pygmy Hog are restricted to the north bank; Hoolock Gibbon (Fig. 6.33b) and Stump-Tail Macaue are restricted to the south bank. Amongst evergreen forest, dominant canopy tree – *Mesua assamica* is found only on the north bank; *Dipterocarpus macrocarpus* and *Shorea assamica* are found only to the south.

Within the Assam Hills, two further gradients of variations exist: an altitudinal gradient, and a rainfall gradient.

1) An altitudinal gradient going from below 300 m at the southern foot of Meghalaya, and to 3200 m in the highest point in the whole province on the Burma border in Manipur. This altitudinal range encompasses tropical evergreen and semi-evergreen forest, tropical moist deciduous forest, subtropical hill forest and temperate forest communities. The higher reaches of Manipur virtually show a sub-alpine shrub community.

2) A rainfall gradient from exposed southern slopes, e.g., in south Meghalaya at Cherrapunji with average annual precipitation of over 11,000 mm, to sheltered rain-shadow slopes with precipitation below 1,500 mm p.a. Of the endemics, members of Magnoliaceae occur in restricted areas, whereas Balsiminaceae has wider distribution.

Meghalaya is known for its botanical value, most of which are high altitude Oak forests of Shillong-Cherrapunji plateaux. The area near Tripura-Mizoram border has exceptional wildlife species diversity with four rare primate species: Hoolock Gibbon, Leaf Monkey and both Pig-tailed and Stump-tailed Macaque.

6.5.9 Zone 9: The Islands

In this category we shall discuss the Andaman and Nicobar group of islands in the Bay of Bengal, and the Lakshadweeps in the Arabian Sea. The Andaman and Nicobar islands are a long group of 348 islands north-south oriented. They have a total land area of about 8,327 sq km, stretching for about 590 km. The Andamans are separated by shallow continental waters from the Burma-India coast, and the Nicobars are separated from the mainland – the Andamans, and also internally from each other by channels of about 800 m depth. These islands are actually the extensions of the Arakan Mountain range of Burma and they have several peaks over 500 m. The Barren and Narcondam Islands are volcanic, and are believed to be still active. The Andamans exhibit biogeographical affinity with Burma. And the Nicobar islands that are about 90 km from Sumatra show strong biogeographic closeness to South-east Asia. The Andaman and Nicobar Islands are one of India's three tropical moist evergreen forest zones. These islands are isolated and show linkages to the east. Their endemic flora and fauna, not found anywhere in India, make them unique in many ways.

The Wildlife of the Andaman and Nicobar Islands

Before discussing the wildlife, we shall briefly look into its biogeogrphic locations. The Andaman group of islands include 324 islands covering about 6,491 sq km area. Most of the area is taken up by the 'Great Andaman' comprising 5 islands separated by creeks. These are: North, Middle, South Andamans; and Baratang and Rutland Islands. Little Andaman is some distance away to the south. The Nicobar group is much smaller with only 24 Islands. It has 3 major subdivisions the North Group; Teressa, Tilangchong, Kamorta; Little Nicobar and Great Nicobar.

The zone possesses a unique kind of plant and animal life exhibiting a high degree of endemism. One finds these islands with impoverished mammal fauna. This may be largely due to the isolation of Andaman and Nicobar islands and the small island size. Amongst mammals, species of rodents and bats dominate. Centuries back, pigs were introduced in these islands and these are now known as the 'Andaman Pigs'. Besides these, some other species like the Spotted Deer, Hog Deer, Barking Deer, Goats, Elephant, Sambar, Leopard and Palm-Civet (Fig. 6.34a) are also present. Some of these species are flourishing very well on these islands, and are believed to be reducing the native fauna that includes certain ground nesting birds and common rat. The indigenous mammal species that need to be conserved include the Nicobar Macaque, also known as the Crab-eating Macaque, and a distinctive race of the widespread Long-tailed Macaque, the Nicobar tree-Shrew, and the Dugong (Fig. 6.34b) found commonly in the coastal waters off the Andamans and Nicobars.

The avifauna consists of 255 distinct taxa of birds, of which 112 are endemic to these islands. Some of the peculiar examples include a mound building bird found in low densities around sandy shores and littoral forests, and the Nicobar Megapode. It is highly endangered. Another interesting endemic avi-species is the Narcondum Hornbill that is restricted to 7 sq km volcanic island 'Narcondum' to the east of the Andamans. The Serpent Eagle, and the 'Andamans' or 'Grey Teal' – a gregarious Duck of brackish and fresh water forest pools, is again restricted to Andamans and is highly endangered. It has been seen that many endemic species are restricted to 'dense evergreen forests' like the Nicobar Pigeon, Andaman Wood Pigeon (Fig. 6.34c), Nicobar Parakeet and the Nicobar Crested Serpent Eagle (Fig. 6.34d). The conservation of these endemic species calls for immediate preservation of their original habitats.

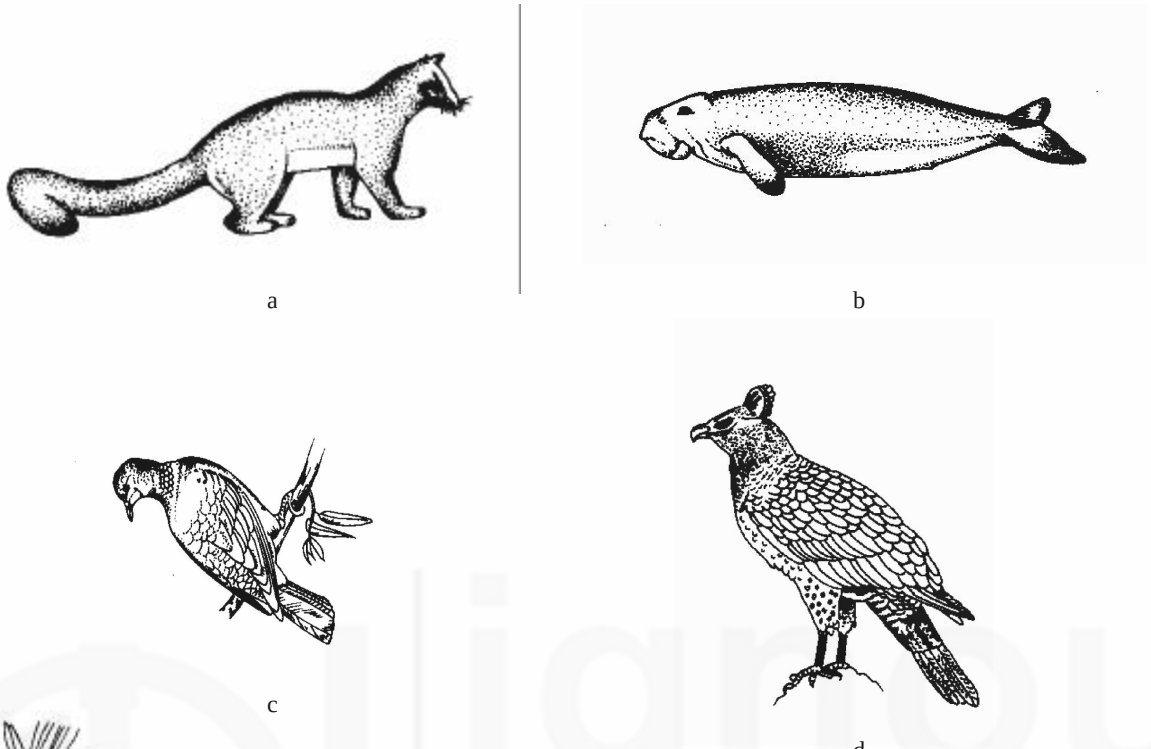


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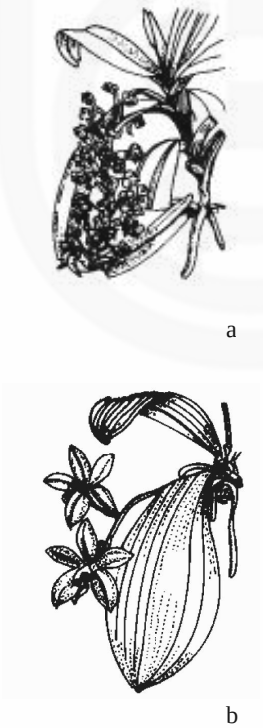
Fig.6.34: Some faunal elements of Andaman and Nicobar Islands, a) Plam-Civet (*Paguma larvata*), b) Dugong (*Dugong dugon*), c) Andaman wood pigeon (*Columba elphinstonii*), and d) Serpent eagle (*Silornis cheela*)



a b

Fig.6.35: Two orchid species of Andaman and Nicobar Islands. a) *Aerides emerici*, b) *Phalaenopsis speciosa*

Reptiles and Amphibia: A large number of reptile and amphibian species are endemic to the islands. Many of these species await to be discovered and the behavioural ecology of many of these birds remains to be understood. Some of the interesting reptile and amphibian species include the salt-water Crocodile that is now restricted only to a few creeks in the north, middle and Little Andaman and Great Nicobar, and on some off-shore islands. The islands have 4 species of Marine Turtle – Green, Ridley, Hawks Bill and Leathery. Of these, the only nesting beach for Leathery Turtle over half of the Green Turtle nesting area is in the Andaman and Nicobar Islands. The small population of Asiatic Box Turtle – a fresh water turtle, is a cause of concern.

The fish and coral life: The Andaman and Nicobar Islands show a variety of coastal variations such as the mangrove estuaries, sandy and muddy shores, coral reefs, lagoons, and marine cliffs. These waters are said to have the richest fish and coral communities in India. Several species of Dolphins are present and Whale sightings are frequent.

Plants: Out of the 15,000 species of flowering plants found in India, some 2,200 species are found in these islands (two such species are shown in Fig. 6.35). Over 200 are strict endemics. Further, 1,300 species are found nowhere else in India, and these show closeness to the species of Burma, Malaysia and the Indonesian region. It implies that about 10% of India's 15,000 flowering plant species are restricted to the 8,000 sq km area of Andaman and Nicobar forests. Extensive data on the extent of forest cover in the region glaringly point out that the forest cover of Andamans has been reduced to half in the past 100 years. At this rate, about 20% of the total species, that is, about 400 species will disappear in coming times. And remember, these are found nowhere else in India!

The seven major categories of forest vegetation described by Champion and Seth[3], (1968) are: Evergreen Forests: Semi-evergreen forests; Hill Top Stunted Evergreen Forests; Moist Deciduous Forest, Swamp Forest and Mangrove Forests. In addition, there are some non-forest plant communities found on the beach strands – fresh water ponds and rocky cliffs. The Barren Island – a volcanic island – has a grass-scrubland cover. Smaller islets have grass-spray sclerophyllous scrub. Many species of Andamans show affinities with Burma and North-East India. The Dipterocarpaceae is one such example with no affinity to its South Indian counterparts.

The Nicobars have affinities with Indonesia. They lack Dipterocarps, but have a high diversity of tree-ferns and Palms. The Orchid flora of Great Nicobar further lend support to their affinities with their Indonesian counterparts. Out of the 36 species recorded, 21 are known nowhere in India except this region. Twenty of these species are restricted to the forests, and one is found on open hill-top rocky grassland in the forest hills.

The great biological resources of the Andamans have prompted the authorities to develop permanent field stations of the Botanical and Zoological Surveys of India in Port Blair.

The Lakshadweep Islands or Arabian Sea Islands

These islands comprise of some 25 islets, forming three main groups: Amindivi Islands in the north; Laccadive or Cannanore Islands in the centre, and Minicoy Island – a solitary island of about 175 km towards the south. These islands are of coral origin and have a typical reef lagoon system. They have a total land area of about 109 sq km including reef, bar and islets. Only 10 islands have permanently settled populations consisting of more than 25,000 people. The population density works out to be high, about 870 people per sq km. Now most islands are planted with coconuts and not much natural vegetation is left. The major environmental threats to these fragile ecosystems include: the setting up of a cement factory that would use the fossil reef limestone commercial inshore fishing, and the demands put by tourism on the local resources.

Some of the smaller islands show a typical coralline rock-sand beach littoral vegetation of *Pandanus – Casuarina* and *Thespesia*. The reefs have excellent examples of tropical inshore marine ecosystems needing immediate protection. The shallow sea lagoons have marine angiosperm pastures that are Dugong's feeding grounds. These islands are also major feeding grounds for Turtles and there are some Green Turtle nesting sites also. Several oceanic bird species have resting sites on uninhabited islets, e.g., Brown-winged Tern, Noddy Tern, White capped Noddy, Lesser Crested Tern and Sooty Tern. Some sea birds are so peculiar that they have chosen only two islets as their nesting sites. These are Pitti and Baliapani. Despite a ban on the collection of the eggs of these birds, people continue to illegally collect them.

6.5.10 Zone 10: The Coasts

India has a vast coastal stretch of about 5689 km (Srinivasan, 1969)[4]. On the west, the Arabian Sea washes the shores of Gujarat, Maharashtra, Goa, Karnataka and Kerala States. On the east, the Bay of Bengal washes the coasts of Sunderbans in West Bengal, Orissa, Andhra Pradesh and Tamil Nadu states. The southern promontory of Indian Peninsula is bathed by the Gulf of Manaar and Indian Ocean, along the coasts of southern portions of Tamil Nadu.

[3] Champion H.G. & Seth, S.K. 1968. Forest Types of India, Government of India Press, New Delhi.

[4] Srinivasan, K.S. 1969. Phycologia Indica. Vol-I and II. Botanical Survey of India, Calcutta.

The Wildlife of Coasts

The geology of coasts is very varied and accordingly, five main communities have been described:

a) Mangroves – that have a variety of community types from seaward to landward facing areas of estuaries, lagoons and deltas.

b) Sandy beaches, including raised beaches and distinctive plant communities such as *Casuarina – Calophyllum – Pandanus*.

c) Mud flats with a range of successional stages to completely terrestrial vegetation.

d) Raised corals and rocky coast lines.

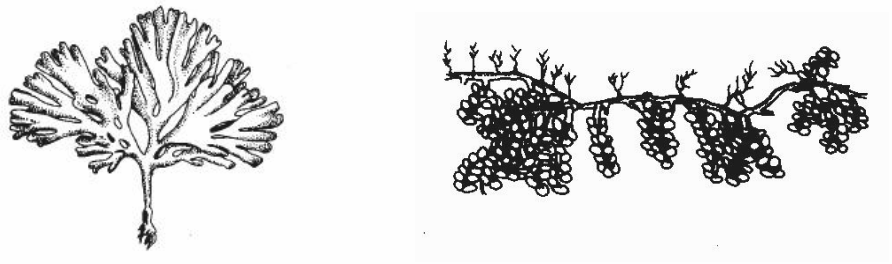
e) Marine angiosperm pastures.

Some of the interesting coastal wildlife species include: Dugong; Hump-back Dolphin of estuarine turbid waters; Estuarine or salt-water Crocodile; Olive Ridley, Green, Hawksbill, Leather and Loggerhead sea Turtles; the Estuarine Turtle – *Batagur basker* of Sunderbans and the huge Soft-shell Estuarine Turtle; *Pelochelys birbornii* off the Utkal-bengal Coast fish – mud skippers or semi-terrestrial Gobies, small Crabs in association with Anemones; avifaunal communities of mangrove, mud flats and lagoons. In the higher regions of mangroves, there are Spotted Deer, Pigs, Monitor Lizards, Monkeys, and the Sunderban Tiger.

India harbours some of the best mangrove swamps in the world, of which the largest stretch of mangroves in the country lies in the Sunderbans in West Bengal in an area of 4200 sq km. The predominant mangrove species are *Avicennia officinalis, Exceocaria agallocha, Heritiera formes, Rhizophora mucronata* (Fig. 6.36a) and *Xylocarpus granatum.* The region harbours a number of Molluscs, Polychaetes and Honeybees. The main species found in the west coastal regions in the states of Gujarat, Maharashtra, Goa, Karnatka and Kerala are: *Avicennia marinar, A.officinalis, Ceriops tegal, Salvadora persica,* (Fig. 6.36b), *Rhizophora mucronata, Sonneratia alba, Acanthus illiciiolius* and *Heritiera littoralis*. Coastal mangroves also occur in the states of Orissa, Andhra Pradesh and Tamil Nadu on the eastern coast. The dominant species in this region include *Burguiera cylindrical, B.Parviflora, Rhizophora mucronata, Phoenix palmosa,Avicennia officinalis, A.marina* and *Ceriops tagal*. In addition, a large variety of phytoplankton and sea weeds occur all along the coasts (two forms shown in Fig. 6.37).

a b

Fig.6.36: Two commonly seen plants found along the Indian coasts, a) A twig of *Salvadora persica*, commonly known as 'Pilu', b) *Rhizophora* sp. Note the two plantlets (arrows) germinated on the mother plant itself



a b

Fig.6.37: Luxuriantly growing marine algae constitute a major portion of the coastal vegetation, a) ***Stoechospermum marginatum*****, b)** ***Caulerpa peltata***

Associated with the coasts are the coral reefs. We shall consider them as part of the coastal ecosystems. The coral reefs are formed by the calcareous skeletons of stony coral polyps that house the corals, which are soft-bodied, radially symmetrical marine invertebrates. Each individual of a colony is called a polyp. Millions of coral skeletons cemented together over a period ranging from thousands to millions of years give rise to such reefs, which often reach great depths and even run continuously for hundred of kilometers at a stretch. The coral reefs too exhibit rich biological diversity. A variety of fishes also known as Coral Reef Fishes are found in this habitat.

Coral reefs are divided into three major types.

i) **Fringing reefs** are the most common type. They project seawards from the shore and surround island and the continental land masses.

ii) **Barrier reefs**, though similar to fringing reefs, are separated from the landmass by shallow lagoons.

iii) **Atolls** are common in the Indo-Pacific region. They rest on the summits of submerged volcanoes and they are usually oval or circular with a central lagoon.

SAQ 9

How many biogeographical regions are there in India?

……..

……..

SAQ 10

Complete the table given below:

……..

……..

Sl.No.	Biogeogrphic Zones of our Country	The Physical conditions

6.6 BIODIVERSITY HOT SPOTS

Hot spots are areas that are extremely rich in species, have high endemism and are under constant threat.

An endemic species is one that is restricted to a given area that can be a mountain top, a river, a country or continent according to usage.

Box 6.4: Biodiversity hot spots

Myers (1988) identified 18 regions or "Hot spots" around the world. Interestingly these areas contain nearly 50,000 endemic plant species, or 20% of the world's plant species, in just 746,000 km^2, or 0.5% of the Earth's total land surface. A subsequent study done by the World Conservation Monitoring Centre, U.K. identified 21 "hot spots". A more recent study by Conservation International, which carries forward the work of Myers, has identified 25 global "biodiversity hot spots". These 25 hot spots cover only 1.4 percent of the Earth's land surface but contain about 44% of all vascular plants and 35% of vertebrates (excluding fishes), and 96% of the world's most threatened primate species. Among the 25 hot spots of the world two are found in India extending into neighbouring countries – the Western Ghats/Sri Lanka and the Indo-burma region (covering the Eastern Himalayas) (Fig. 6.38). These areas are rich in floral wealth and endemism, not only in flowering plants but also in reptiles, amphibians, swallow tailed butterflies and mammals.

Fig.6.38: Biodiversity hot spots in India extending into neighbouring countries

Overall, 241 centres of Plant Diversity have been identified and Ethiopia represents one of the eight major centres of crop plant diversity in the entire world. More classes to have, the Indian sub-continent bears traces of having produced a considerable component of the major crops that are used in the world today. India has been named, among the world's 12 Vavilovian Centre's of origin and diversification of cultivated plants known as the "Hindustan Centre of Origin of Crop Plants" by Vavilov in 1951.

6.6.1 Differences between Regions

Biodiversity is not uniformly distributed across the globe. Some areas are very rich in biodiversity, while others are less so. Comparison of species richness of different geographical regions of the earth indicates that species diversity increases in warm areas and decreases with increasing latitude. For example, amphibians are generally absent at high latitudes although a salamander species can be found in the Arctic circle. Reptile species diversity increases towards the subtropics and tropics, and the diversity of birds and mammals also increases towards the equator. As such, tropical areas have more species in a given land area than a similar sized area in the temperate zone. There is also some indication that gross genetic diversity is higher in some tropical species compared with related temperate species.

Diversity is also greater in areas of high rainfall compared with drier areas, although the relationship between precipitation and diversity is not straightforward. However, the relationship is most apparent in areas of climatic extremes, such as arid areas where species diversity is relatively low. In terrestrial ecosystems diversity generally decreases with increasing altitude although in some tropical forests, diversity is higher at mid-altitudes-giving rise to what is called a "mid-altitude bulge". In coastal aquatic environments biodiversity declines when salinity declines from normal sea water (i.e. salinity 35 ppt). In contrast, biodiversity declines in fresh water habitats when salinity levels are >2ppt. (parts per thousand).

6.6.2 Differences between Ecosystems

Some ecosystems possess relatively large number of species as compared to others. This is particularly true of tropical forests which exhibit a very rich-biodiversity. For example, the 13.7 km^2 area comprising the La Selva Forest Reserve in Costa Rica (a tropical forest) contains almost 1500 plant species, which is more than the total number of plant species found in the 243,500 km^2 area comprising the whole of Great Britain.

Tropical moist forests are believed to be the richest terrestrial ecosystems on earth. In the marine environment, coral reefs also possess extremely rich biodiversity. It is now suspected, however, that the richness of species diversity on sea floor may be equal or even greater than coral reefs.

6.6.3 Differences between Countries

Some countries are richer in biodiversity than others. Generally, the economically poor developing countries in tropical areas are richer in biodiversity than developed countries in temperate areas.

Countries that lie along the equatorial zone can have enormous numbers of species. Venezuela has 15,000 and 25,000 plant species; Brazil has as many as 55,000 flowering plant species; Tanzania has 10,000 and Indonesia has 20,000. In terms of examples of flowering plant diversity in the countries of South Asia, India has 7000 species which is over 45% of the Indian flora; Pakistan has 5700 species, Nepal has 6500 species and Sri Lanka although small in size has 3500 species of flowering plants which is the highest diversity per unit area for the Asian region. About a quarter of these species are also endemic to the country.

Small tropical oceanic islands have relatively fewer species due to their isolation, but they generally possess large number of endemics. Mauritius has a native flora of 878 higher plant species, of which 329 are endemic.

Countries rich in diversity are called mega diversity countries. India is among the world's mega-diversity countries. The mega-diversity countries deserve special international attention for conservation of the earth's biological diversity.

Box 6.5: India: A megabiodiversity country

Why India is one of the mega-diversity countries. India has a rich and varied heritage of biodiversity:

- 2 hot spots out of 25 global biodiversity hot spots listed by Myers are in India with its neighbouring countries i.e. Western Ghats/Sri Lanka and the Indo-Burma region (covering the Eastern Himalayas).
- The endemics of Indian biodiversity is high about 33% of the country's recorded flora are endemic to the country. Of the 49,219 plant species, 5150 are endemic and distributed into 141 genera under 47 families corresponding to about 30% of the world's recorded flora.

Green Nations

Plants, insects anything mentioned in a biology text book qualifies as a bioresource. Countries with vast bioresources are called Mega-Diverse.

Mega Diverse countries

Eighteen countries that control 70 precent of the world's bioresources have got together: India, China, Zaire, Indonesia, Columbia, Mexico, Ecuador, Kenya, Peru, Venezuela, Costa Rica, Bolivia, Malaysia, Madagascar. Philippines, South Africa, Congo and conservation priority in the selection of countries is based on species richness and species endemism

- India has 26 recognised endemic centres that are home to nearly a third of all the flowering plants identified and described to date.
- India has two major realms called the Palaeretic and the Indo-Malayan and three biomes i.e. tropical humid forests, tropical deciduous forests and the warm deserts/semi-deserts.
- India has ten biogeographic regions.
- India is one of the 12 centres of origin of cultivated plants.

6.7 CRITERIA FOR IDENTIFYING BIODIVERSITY HOT SPOTS

Conservation priority in the selection of countries is based on species richness and species endemism.

6.7.1 Selection According to Species Richness

A simple method used to identify areas of high conservation priority is the selection of countries according to highest species richness. Among the top 12 countries identified this way based on the assessment of vertebrates, swallow-tailed butterflies and higher plants are Mexico, Columbia, Ecuador, Peru, Brazil, Zaire, Madagascar, China, India, Malaysia, Indonesia and Australia. It is estimated that 70% of the species diversity in the world is found within these countries.

This method, however, involves species inventory within a geopolitical boundary, and fails to take into account the uniqueness of the fauna and flora of each country or region in question. As a result, there is considerable overlap of species between adjacent regions (or countries) that are prioritised for conservation action. For example, most mammalian species listed for Ecuador are also found in Peru. If both countries are prioritised for conservation, therefore, the same species will be conserved in both.

6.7.2 Selection According to Endemic Species Richness

An alternative approach has been to identify areas with the highest number of endemics or species with a restricted geographical range. Assessments of this nature have been very often done at a country level (single country endemics) rather than in some identifiable region in a country (site or area endemics). It is relevant that single country endemic species are given high conservation priority at the global level because they are unique. If such species are lost, they can never be replaced. Here again, prioritising is done at the country level.

Myer's work on identification of global hot spots is an important step towards determining areas where conservation requirements are greatest, and where the potential benefits from conservation measures should be maximised at a global level.

The essential criterion to be met with in qualifying as a global "hot spot" is the

i) presence of at least 0.5% of 1,500 of the world's 300,000 vascular plant species as endemics.

ii) the threat criterion which decrees that a hot spot should have lost 70% or more of its natural vegetation,

iii) the presence of mammals, birds, reptiles and amphibians and their endemism serve as a back-up to further facilitate comparison among the "hot-spots".

Some of these hot spots span two or more countries as exemplified by the Western Ghats/Sri Lanka hot spot.

Although the hot spot analysis is as yet for terrestrial areas, efforts are under way to identify conservation priorities for marine species. Other efforts for priority setting for areas of conservation value have been carried out via Birdlife International's Endemic Bird Areas and IUCN/WWF International's Centres of Plant Diversity and Endemism.

SAQ 8

Why India is considered as one of the megadiversity countries?

……..……..

……..……..

SAQ 9

Explain the criteria in prioritization of global biodiversity hot spots.

……..

……..……..

6.8 SUMMARY

In this unit, you have studied that:

- Biomes are climatically distinct regions having specific plant and animal species. Very broadly the biomes of the world can be divided into terrestrial and aquatic.
- There are 10 major terrestrial biomes and these are named after the dominant vegetation of the region.
- The northern most extremely cold land biome is the **tundra** which is dominated by low lying cold resistant plant species. The **taiga** is a biome dominated by coniferous trees and is found like a circumpolar belt on the continents in the northern hemisphere. **Temperate shrublands** occur in coastal regions marked by winter rainfall and summer droughts and are dominated by evergreens adapted to these conditions. **Grasslands** occur where the rainfall is more than deserts but less to support forests. **Deserts** have hot days and cold nights with very little rainfall. The tropical regions with maximum plant and animal species are the **tropical rainforests** where high temperate and rainfall permit plants to grow throughout the year.
- The aquatic biomes of the world can be classified as fresh water and marine according to the salinity of the water. The fresh waters biomes are the stream, rivers and lakes and animals and plant species are adapted accordingly.
- The marine biomes consist of the oceans, coastal regions and islands. The distribution of animals and plants is limited by availability of light and nutrients. Some specialised marine biomes are the coral reefs, estuaries and wetlands.
- The Indian subcontinent has a lot of variation in climate, soil type and therefore, in vegetation. This is the reason why all the biome types of the world find a representation here.
- India has been divided into ten biogeographic zones viz; Trans-Himalayas, Himalayas, Indian Desert, Semi-arid, Western Ghats, Deccan Peninsula, Gangetic Plains, North East India, Islands and Coasts. Each of these zones has certain geographical as well as biological peculiarities. Some of the biological elements are characteristically found in certain zones only and no where else.

- Biodiversity hot spots are areas that are extremely rich in species, have high endemism and are under constant threat. Today, there are 25 hot spots in the world; 2 of which are found in India extending into neighbouring countries. The Western Ghats/Sri Lanka and the Indo-Burma region (covering the Eastern Himalayas).
- India is among the world's mega diversity countries because of various reasons, viz. 2 hot spots, 26 recognised endemic centres, two major realms, three biomes and ten biogeographic regions.
- High conservation priority of countries is according to highest species richness and highest endemism.

6.9 TERMINAL QUESTIONS

1. List the factors that affect the distribution of biological diversity.

   ……...……..…….

   ……

   ……

2. Which of the biomes that you learnt about would you expect to find in your country? Discuss the main differences in biodiversity (abundance and species richness) that you would expect to find in similar sized areas of the following types of biomes:

   - Rain forest
   - Coniferous forest
   - Hot deserts
   - Savanna

   ……

   ……

   ……

3. Make a table listing the physical conditions and the plants and animals (list species where possible as well as different groups of animals and plants) in a:

   - tropical rain forest
   - tropical monsoon forest
   - temperate deciduous forest
   - taiga or the northern coniferous (boreal) forest
   - chaparrals (evergreen scierophylls forest)
   - tundra
   - savanna grassland
   - temperate grassland
   - tropical hot desert
   - mid latitude desert

   As far as possible list species in your country for biomes that occur there.

   ……

   ……

   ……

4. Which biome in you opinion would have the largest number of:

   - reptile species
   - amphibian species
   - large herbivorous mammals
   - bird species
   - endemics (at the national level)
   - insects

   ……

   ……..……...…

   ……

5. What broad group of animals would you expect to do best in both a desert as well as a tropical rain forest? State why?

   ……

   ……..……...…

   ……

6. Which of the Conservation International's 25 hot spots are nearest to where you live?

   ……

   ……..……...…

   ……

7. Circle the correct responses in the following multiple-choice questions:

   i) According to the Wallace the species in the:

      a) Nearctic Region is similar to those in the Neotropical Region.
      b) Palearctic Region is similar to those in the Ethiopian Region.
      c) Oriental Region is similar to those in the Indian subcontinent.

   ii) Which response is false out of the following?

      a) Tropical moist forests are the most diverse ecosystems on earth at the phyletic level.
      b) Coral reefs are almost as diverse in terms of species as tropical forests.
      c) The deep sea is very high in species that are not yet discovered.
      d) The deep sea floor may prove to equal tropical forests in species richness in the future with more data coming in.

   iii) Countries differ in terms of biodiversity. Generally:

      a) Developing countries in the tropics are poorer in biodiversity than developed countries in temperate areas.
      b) Countries in equatorial areas will have higher biodiversity than countries at high latitudes.
      c) Small tropical oceanic islands have very high biodiversity.
      d) Small oceanic islands have small floras and low endemism.

iv) A biodiversity hot spot is best defined as an area with:

a) High endemism and high species diversity coupled with threats to the habitat.
b) A large number of threatened species whatever the extent of overall biodiversity.
c) Extremes of daytime temperate.
d) "Mega diversity" in terms of species.

v) In your opinion the best way of conserving the earth's biodiversity is to conserve species in the countries:

a) Identified as mega diversity countries.
b) With the highest number of single country endemics.
c) With the highest number of species that are of commercial importance.
d) That are rich in species though poor in endemics.

UNIT 7 THE VALUE OF BIODIVERSITY

Structure

7.1 INTRODUCTION

Today, there is widespread concern for conservation of wild animals and plants. One might wonder why there is so much concern about protecting other species when our own species is facing poverty and starvation? The truth is, poverty and starvation, and several other ills facing humans are often the result of the destruction of biodiversity. Though we seldom realise it, biological diversity and its components are the very basis of human survival providing food, energy, medicine, ecosystem sources, scientific insights and cultural sustenance to over six billion people.

Understanding the value of biological diversity is vital to maintain the enormous range of genes, species and ecosystems that the earth supports. This can be looked at in many ways. One way would be to understand the "resource" or "use" value of various components of biodiversity which are used by humans. Biodiversity has also, however, great "non-resource" or "non-use" value such as maintaining ecosystem functions. Biodiversity can also be viewed in terms of economic and non-economic values. The economic value of a biological resource may be broken down into a range of use and non-use values that are of direct or indirect benefit of humans.

In the present unit, you will study about 'use' values and 'valuation' (economics) of biodiversity. After studying this unit, you will appreciate the fact that there can be no true and long lasting development if we continue to erode habitat and species diversity.

Objectives

After studying this unit, you should be able to:

- explain the value of diversity in terms of direct vs. indirect use, extractive vs. non-extractive use and resource vs. non-resource use;
- appreciate the concept of valuation of biodiversity and its relationship to environmental accounting; and
- describe the emerging trends of biodiversity valuation.

7.2 USE VALUES OF BIODIVERSITY

Despite its importance, determining the value or worth of biodiversity is complex and often a cause for debate. This is largely due to the fact that the worth placed on biodiversity is a reflection of underlying human values, and **these values vary dramatically both among societies and individuals**. The perspective of rural versus urban dwellers towards wildlife is one example. People that don't live with elephants on a daily basis, appreciate elephants for their sheer size, charisma, and intelligence. However, those who live near elephants tend to perceive them as a threat to people,

crops and property. **Values are also dynamic; they change over time, and they depend on a specific situation**. Both the diversity of values towards a species and the changes in values over time can be examined in the case of vultures in India. Once widespread throughout India, vultures are getting depleted.

The value of biodiversity is often divided into two main categories:

- **UTILITARIAN** (also known as instrumental, extrinsic, or use) value, and
- **INTRINSIC** (also know as inherent) value.

A living thing's **utilitarian value** is determined by its use of function. Usually utilitarian value is measured in terms of its use for humans, such as for medicine or food. However, it can also represent the value of an organism to other living things or its ecological value; native bees, for example, serve as pollinators for many plants. In contrast, **intrinsic value** describes the inherent worth of an organism, independent of its value to anyone or anything else. In other words, all living things have a right to exist – regardless of their utilitarian value.

Determining the value or worth of biodiversity is complex. Economists typically subdivide utilitarian or use values of biodiversity into **direct use value** for those goods that are consumed directly, such as food or timber, and **indirect use value** for those services that support the items that are consumed, including ecosystem functions like nutrient cycling.

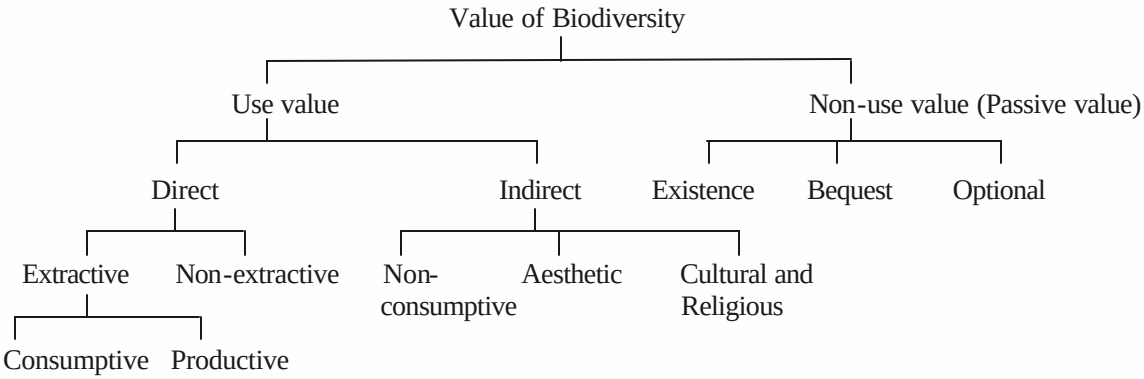
There are several less tangible values that are sometimes called **non-use or passive values**, for things that we don't use but would consider as a loss if they were to disappear; these include **existence value**, the value of knowing something exists even if you will never use it or see it, and **bequest value**, the value of knowing something will be there for future generations (*Moran* and *Pearce* 1994). **Potential or Option value** refers to the use that something may have in the future; sometimes this is included as a use value, we have chosen to include it within the passive values here based on its abstract nature. The components included within the category of "utilitarian" values vary somewhat in the literature for example, some authors classify spiritual, cultural, and aesthetic values as indirect use values, while others consider them to be non-use values, differentiated from indirect use values – such as nutrient cycling – because spiritual, cultural, and aesthetic values for biodiversity are not essential to human survival. Still others consider these values as separate categories entirely. In this Unit, we include spiritual, cultural and aesthetic values as a subset of indirect values or services, as they provide a service by enriching our lives (Table 7.1).

Table 7.1: Categories of values of biodiversity

Direct Use Value (Goods)	**Indirect Use Value (Services)**	**Non-Use Values**	
Food, medicine, building material, fibre, fuel	Atmospheric and climate regulation, pollination, nutrient recycling	Potential (or Option Value)	Future value either as a good or a service
	Cultural, Spiritual, and Aesthetic	Existence Value	Value of knowing something exists
		Bequest Value	Value of knowing that something will be there for future generations

Note: Some authors choose to differentiate Cultural, Spiritual, Aesthetic, and Non-Use Values from those services that provide basic survival needs such as the air we breathe.

Classification of values of diversity is provided in a key form below for your easy understanding.



7.2.1 Direct Use Value

Direct use values are for those goods that are ensured directly e.g. food and timber. Maintaining a wide range of components of biological diversity can be of direct use, especially in the fields of agriculture, medicine and industry. Direct use can involve the use of forests, wetlands or other ecosystems for timber extraction, collection of non-timber products, fishing, etc. Direct use values could be due to **extractive use** where resources are extracted and consumed, or due to **non-extractive use** when there is no extraction or removal of the resource that is used (e.g. bird watching, scientific research in an ecosystem, etc.). However, the difference between extractive and non-extractive use is sometimes fine and hard to define. Various types of direct use values are discussed below:

- **Extractive use**

  This includes **direct use** such as harvesting of wild plant species for use as food, fuel, fodder, fibre, shelter or medicine and hunting animals for food or sport and fisheries.

  In terms of ecosystems, forests have been converted for agriculture and settlements, wetlands have been drained and reclaimed for various uses and coral reefs have been used for extraction of corals for producing lime.

  Sometimes, in the case of species for which there are no substitutes (such as tigers, whales, and bluefin tuna), their prices increase exponentially as the resource becomes more and more scarce due to extraction. This in turn increases the incentives to extract such resources due to the high prices they fetch. Thus, the price and demand keep increasing until the species in question is on the brink of extinction or finally becomes extinct. A case in point is the stock of western bluefin tuna, which has declined to less than 20% of its 1970 level, while its price has increased 20 fold. Ecosystems that contain economic value in the form of minerals, wildlife, wood and land have resulted in the final destruction of the ecosystem due to excessive extractive use.

  Extractive use can be further divided as **consumptive use values** and **productive use values**.

  i) Consumptive use values

  This means the **non-market value of natural products such as firewood, game and fodder that do not pass through a market or product preparation**. Indigenous people in developing countries still basically rely on wild and traditionally cultivated plant species to supply a wide range of their needs in terms of food, fibre, skins and feathers for clothing, fuelwood, wood for houses, medicinal plants, etc. The products of subsistence hunting and

gathering go largely unmarketed, but although these resources have no financial value, as they are not sold and have no cash price, they do have economic value as they are of importance to society.

ii) Productive use values

This is the **value of natural products harvested through commercial logging, agriculture or fisheries and medicines that generated products that are of commercial value**. Logs still account for a significant proportion of world trade, although there is a trend towards value-added processing in the timber industry in developing countries. The export of timber in log form is increasingly being restricted, partly to retain wood within the country for further processing, and partly as a conservation measure.

This also includes the commercial value of products prepared using biological resources as opposed to subsistence use when they are directly consumed. For example, taxol from the Pacific yew tree yields medicines that are used for treating cancer; enzymes from leech saliva is used to produce medicines that dissolve blood clots during micro-surgery.

- **Non-extractive use values**

Some activities that make use of biological resources, without involving their extraction or destruction, denote non-extractive use of biological resources. This includes ecotourism, which involves a direct 'transaction' between people and biological resources and fall into the category of direct use values. However, as it does not involve destruction or a change in the resource – in this case the natural areas visited by tourists – it can be classed as a non-extractive use. You will study about ecotourism in detail in Block 3 of this course. Likewise, scientific research in natural areas, bird watching and plant breeding are some other examples of non-extractive use of biodiversity.

'Ecotourism' is defined by IUCN – the World Conservation Union's Ecotourism Programme as **"environmentally responsible travel and visitation to relatively undisturbed natural areas, in order to enjoy and appreciate nature (and any accompanying cultural features – both past and present), that promotes conservation, has low visitor impact, and provides for beneficially active socio-economic involvement of the local populations."** (Ceballos-Lascurain, 1993).

7.2.2 Indirect Use Value

Indirect use value is for those services that support the items that are consumed. You will study about various indirect use values in this section.

Non-consumptive value

This is concerned more with nature's services which also make vital contributions to the welfare of society and to ecological processes without which our planet would be uninhabitable. Biodiversity contributes to varied ecosystem services that include numerous invisible but essential services. These are the recycling of elements such as carbon, oxygen and nitrogen and other nutrients, decomposition and waste dissipation, productivity and carbon storage, soil formation and fertility generation, reduction of soil salinity, water recharge, maintenance and raising of water table, enhancement of water and air quality etc. Other indirect uses including pollination, gene flow, carbon sequestration, absorption and breakdown of pollutants (in land, air and water), maintaining soil fertility by soil microflora, are important services provided by biodiversity. Biodiversity also acts as a buffer against excessive variation in weather, climate and other natural events (e.g. through flood control, storm protection, drought control etc.) and many more that are outside the control of human beings.

Box 7.1: Carbon sequestration

With increasing atmospheric levels of CO_2 (375 ppm) due to expanding use of fossil fuels managing carbon is need of the hour. Carbon sequestration is the novel way to manage carbon.

Carbon sequestration refers to the provision of long-term storage of carbon in the terrestrial communities/ecosystems or the oceans so that carbon dioxide buildup (the principal greenhouse gas) in the atmosphere gets reduced or slows down. In some cases, this is accomplished by maintaining or enhancing natural processes.

Carbon sequestration can be done by following methods:

- **Enhancing the Natural Terrestrial Cycle**: Identifying ways to enhance carbon sequestration of the terrestrial biosphere through CO_2 removal from the atmosphere by vegetation and storage in biomass and soils.
- **Carbon Sequestration in the Oceans**: Enhancing the net oceanic uptake from the atmosphere by fertilization of phytoplankton with nutrients, and injecting CO_2 to ocean depths greater than 1000 meters.
- **Sequencing Genomes of Micro-organisms for Carbon Management**: Sequencing the genomes of microbes that produce fuels such as methane and hydrogen or aid in carbon sequestration, to allow an evaluation of their potential use to produce, for example, methane or hydrogen from either fossil fuels or other carbonaceous sources, including biomass or even some waste products.

Forests play a valuable function in capturing and slowly releasing huge amounts of water during non-rainy period, prevents soil erosion, and flooding. They also have a cooling effect on the environment due to evapo-transpiration, which in turn serves to recycle large amounts of water, and thereby help to ameliorate (improve) and maintain the microclimate. Similarly, in an estuary shellfish and other organisms can filter a large volume of water, thereby "cleansing" the water.

Box 7.2: Mountain forest ecosystem as life support systems

Mountains and their forest ecosystems are regarded as the water towers of the world. A good example is the extraordinarily massive Himalayan Mountains which have shaped the climate of the Indian subcontinent, also provide water and soil to the Gangetic plains. The important ecosystem services of the Western Himalayan forests to the people in the Gangetic plains are:

1. maintaining water flow in rivers and lakes which contributes to pollution control and helps maintain aquatic diversity and soil and water storage.
2. controlling flood peaks and erosion.
3. contributing to rapid soil formation, particularly in oak forests, thus nursing crop-fields both in hills and plains by providing soil and nutrients.
4. carbon sequestration and climate stabilization.
5. prevention and slope sterilization of landside sites through the process of
6. succession in which nitrogen fixing woody species play an important role.

Source: Western Himalayas, Ecoregion Draft BSAP, 2002 cited in the Indian NSBAP. Draft of 2002.

Pollination is a vital operation carried out by insects, mostly independent of humans. Most of our important crops rely on pollination by insects; and bees are the most important group in this respect.

We know that bacteria shaped the early atmosphere of the earth, and that life began with the decrease of atmospheric CO_2 and the increase of oxygen around 3.8 billion years ago. Micro-organisms continue to play a major role in the maintenance of the biosphere and global ecology through various biogeochemical cycles, and by performing a critical function in the circulation of matter. For example,

- algae and cyanobacteria, especially those in the oceans fix about 40% of the carbon fixed by photosynthesis on earth.
- the earth's nitrogen cycle is dependent on bacteria for nitrogen fixation, oxidation of ammonia, nitrification and nitrate reduction.
- the sulphur cycle is dependent on bacteria for the reduction of sulphate into hydrogen sulphide, oxidation of sulphides to sulphur, and conversion of sulphur to sulphates.

Aesthetic value

The aesthetic value of biodiversity can be easily understood by us when we experience the beauty of nature. The appreciation of the aesthetic aspect of biodiversity is reflected in the trouble people take to maintain their home gardens, and the number of people throughout the world who visit national parks, botanical and zoological gardens, aquaria and places where one can experience natural landscapes or view diverse species.

There are compelling arguments for the maintenance of biological diversity for its aesthetic appeal, but this too has limited force, as aesthetic value is subjective and may differ between individuals and societies. Accordingly, one could justify discarding some organisms that are not visible or are not of aesthetic value. Further, genetic diversity does not have an aesthetic appeal. Thus, aesthetic criteria can be applied only to some species and the ecosystem aspects of biodiversity.

Even so, regardless of individuals aesthetic judgements, it is undoubtedly the case that humans very strongly favour variety in food, clothing, construction and art. This need is particularly evident in the human perception of the natural world, and biological diversity is held to be highly desirable. This is not a mere notion, but a need that is very deeply felt, and a fundamental part of the spiritual life of many people around the world. Research has shown that proximity to being near natural surroundings relieves work stress, while people who worked in closed environments and were surrounded by only artificial structures experienced greater work stress and ill health. For example, the importance of a natural area to people living in cities is perhaps why the Sanjay National Park on the outskirts of Mumbai receives a colossal traffic of 1.5 million tourists every year.

Cultural and religious values

Wildlife has influenced language, art, religion and social customs of many societies worldwide, and wild animals figure prominently in many cultures even today. In all cultures of world, species and nature have inspired songs, superstitious beliefs, stories and folktales, and dance and drama, poetry, traditional crafts, local and national cuisines, local rituals, names of places, and even family and Christian names. The cultural value of biodiversity in human societies is often expressed in the respect for life forms or symbols of components of biodiversity. In some countries the tiger, lion, lizard, turtles and bison are part of religious and spiritual beliefs. For instance, the hanuman langur (*Semnopithecus entellus*) is considered sacred in India, and the elephant assumes considerable cultural significance in Sri Lanka. Hunting is also sometimes closely related to social practices, and in some societies of Africa, a man's social worth is determined by his ability as a hunter.

In some countries, seasonal changes in hunting techniques (e.g. individual hunting in the wet season and cooperative hunting in the wet season and cooperative hunting of

game in the dry season) may determine the location of where camps are pitched, grouping patterns, social rapport and material exchange. In some local cultures the behaviour of species gives rural people an important indication of events that are of social, environmental or agricultural significance.

The cost of replacing these indirect uses of biodiversity, even if it were technically possible, would be so high as to render it impossible to duplicate. We also do not know how to quantify these services comprehensively, mainly because most ecosystem services are so poorly understood even now.

Examples of non-resource use and cultural significance of biodiversity are given below:

- *Ficus religiosa* is of paramount significance for Buddhists in Sri Lanka and is venerated although the tree is not used as a bioresource.
- In India some species such as the peafowl are icons of cultural heritages and is held sacred as the mount or vehicles of the God Murugan.
- For some fishermen the sighting of dolphins indicate the arrival of the much awaited tune which sustains their livelihoods.
- A tribal community in India interprets the sighting of red ants before the monsoons as an indication of the early onset of rains.
- In some tribes of Africa it is a cultural requirement for boys to hunt a lion to prove reaching manhood.
- In rural Sri Lanka the sound of a house gecko portends various occurrences in the near future.
- In the northwestern frontier province of Pakistan, the Pukhtoons, or majority population, is divided into many tribes, and their dialects, customs and traditions vary depending on the ecology and geography of the area.
- In Nepal different species and sites have various cultural linkages in terms of symbolic value.
- In Bhutan most people in the community of Phobjikha, revere the globally threatened black-necked cranes (*Grus nigricollis*)
- In India the *Endlagatte Punnam* festival celebrates diversity of crops when food prepared from their farms are offered to the village goddess in gratitude for showering her blessings for a diverse harvest.

Economists are, however, increasingly attempting to place values on such indirect uses of biodiversity. Since **indirect use values** do not enter directly into human preferences and are often widely and freely available, their value is often ignored and not incorporated into development decisions or national budgets. However, as natural habitats and resources decline, their ecological processes and functions will become scarcer, and their economic values will become more recognised until eventually mechanisms are designed for marketing these services. For instance, there is an increased trend towards establishing user changes for freshwater supply and disposal in developed countries as this commodity becomes, more scarce for human use. For example sectors such as agriculture, industry and hydro generation requiring a clean accessible supply of water are taxed in China to compensate communities whose development options are constrained by the need to maintain watersheds.

Ethical values

The ethical values of biodiversity highlights the intrinsic value of biodiversity for its own sake and it is independent of the varied economic, social and cultural uses of the

large number of species discovered by human communities. It underscores the fact that humans are only one of the millions of species that inhabit the earth, while each species is unique and is the result of evolutionary processes without human intervention, so that every species has a natural right to exist.

However, it is also difficult to maintain all of the existing biological diversity for purely ethical reasons. Whilst the killing of any living organism, or a particular species may be morally unacceptable to some people, there are problems in extending this argument to the conservation of biological diversity. As you have studied earlier, any individual organism that is not genetically identical to another represents a distinct component of biodiversity, and according to ethical arguments it is difficult to justify the destruction of any facet of biodiversity. It is easy to understand the objection to the killing of a charismatic species such as an elephant on ethical grounds, but it can be argued that ethically it is equally objectionable to eat rice which is grown from genetically diverse seeds or to destroy pests and disease causing organisms as we are reducing genetic diversity! However it may be more difficult to justify this on ethical grounds.

Even so, the fact remains that ethical values are a powerful tool against the destruction of biological diversity. In practice, this argument is often supported using the **precautionary principle**. For example, we may argue that it is unethical to destroy something that is of current or future use to others. This brings us to the **"stewardship argument"** which builds on the principle of **inter-generational responsibility**. This means that we are responsible to see that future generations can enjoy the same resources that we do. This concept may be well accepted in the developed world, but it may mean little to an **economically deprived person** faced with the difficult prospect of survival in a developing country.

7.2.3 Non-use Value

Values for those things/organisms/entities – that we don't use but would consider as a loss if they were to disappear. These include **potential or option value, bequest value** and **existence value.**

- **Optional use values**

  Optional values are associated with potential use in the future. Accordingly one opts to conserve biodiversity based on the hope that it could be used directly or indirectly in the future, perhaps as a source of genetic material, for pharmaceuticals, crop enhancement, etc. There are many indications that some societies or people are willing to pay an additional sum, over and above what a future use value of a biological resource in worth, in order to guarantee the future access to the resource. For example, when species go extinct their potential is never discovered and we may have lost that very thing that is essential to save millions of lives, enhance food production or provide the ability to resist future diseases and pest attacks. But once lost, these resources will remain unknown and undiscovered forever.

  This consideration necessitates leaving our options open to have access to certain gene pools that may be of use in the future, especially in the face of climate change, as maximum genetic diversity promoted maximum flexibility of species and ecosystems to respond to changes in climate.

- **Bequest value**

  Sometimes people derive satisfaction from the fact that conserved biodiversity may benefit other individuals in the future, giving a bequest value of biodiversity.

- **Existence value**

  There may also be non-use existence values for components of biological diversity due to the value placed on biodiversity purely based on its continued existence, irrespective of whether or not it will ever be used.

  Sometimes individuals gain a benefit by the mere knowledge that a particular component of biodiversity exists. For instance, people who donate money to a conservation organisation may never expect to ever visit the habitat, or use the species, which the organisation aims to conserve. Hence, they derive satisfaction simply by the fact of the continued survival of the species or habitat in question.

SAQ 1

Classify biodiversity values according to their use.

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…….

SAQ 2

Differentiate between extractive and non-extractive use by citing suitable examples.

……...……...

…….....

SAQ 3

Spiritual, cultural and aesthetic values can be classified as indirect use values or non-use values. Substantiate your answer.

……...…

……..

SAQ 4

What is the difference between potential value and bequest value of biodiversity?

……..

……..

7.3 BIODIVERSITY AND ECONOMICS

With the survival and well-being of humans beings so heavily dependent on biodiversity, its economic value assumes considerable importance. For instance the economic value of ecosystem services and components of biodiversity is estimated at around US $ 33 billion, which is about 1.8 times more than the world's GNP. Another example is the pharmaceutical industry which still depends largely on wild bioresources; in India alone around 660 wild species are involved in all-India trade. Throughout the world, tourism based on appreciation of nature is growing, and it constitutes a major income earner for many countries of South Asia.

Economic valuation should also show the economic costs associated with the loss or degradation of biodiversity and its components. This will include on and off-site loss of subsistence, loss or decrease of employment, loss of income and foreign exchange earnings and the cost of replacing or mitigating the loss of bioresources and ecosystem functions. For example

- agriculture, forestry and fisheries account for 26 percent of total GDP and 70 percent of total employment in Vietnam. Despite the significance of this,

improper use of natural resources and management patterns threaten Vietnam's continued economic viability.

- The 1997-98 Indonesian forest fires cost the country around US $ 10 billion due to the impact of transportation breakdown, loss of crops and timber, decline in tourism, health care, and others.
- ecosystem degradation costs Australia about US $ 500 billion annually because of reduced production and nutrient loss.
- in South Asia the losses due to land degradation and desertification are US $ 10 billion, and about US $ 700 million in North East Asia according to Economic and Social Commission for Asia and the Pacific (ESCAP) reports.

However, according to conventional principles of economic analysis it is necessary that a resource is used for it to acquire a value. **Consequently economists traditionally value biological resources in terms of their direct uses, the raw materials they supply for human production and consumption.** For example, a living tree can only be valued in terms of the price it would fetch in the market place as timber; natural forest will be valued based on timber value; coastal and marine ecosystems are valued in terms of fisheries. This disregards all those vital services and functions of biodiversity that are not directly seen or perceived. Consequently they are taken for granted although irreplaceable and vital to sustain local economies.

Species and genetic material have long been exchanged in Asian markets (e.g. rice, timber and fish, utensils, cloth, etc) but there has been failure to give a value for the services provided by natural systems which therefore remain "worthless" in market terms. For example, the disruption in natural water regulation due to forest loss in the central highlands of Vietnam accounts for around 50 percent of seasonal fluctuations in rice production. It is important to recognize the vital importance of biodiversity services for local/national economy apart from sustaining life support systems.

Box 7.3: Biodiversity contributions to development

This aspect of biodiversity services is only now beginning to be understood. They include the following examples:

- storing ground water (through soil biodiversity's role in maintaining soil structure and, thus, water-holding capacity) and regulating water release to ensure consistency and predictability in crop production;
- protecting fish nursery areas, thereby sustaining inshore stocks of marine products;
- protecting coastlines against damage and reducing the impact of natural disasters on life and property;
- protecting watersheds for downstream hydroelectric, irrigation and water supply installations;
- controlling soil erosion and recycling nutrients;
- providing a natural sink and treatment for wastes and restoring health and productivity to wastelands;
- controlling salination in soils and water;
- preventing and reversing desertification; and providing for tourism and recreation.

Source: Emerton, 2002.

Thus new approaches to economic assessment are required to ensure that economic values incorporate both monetary and non-monetary expressions of biodiversity value. Accordingly, a given habitat or species should have many different use and non-use values. For instance a rain forest may have values through contribution to watershed protection, carbon storage and soil conservation as well as values due to ecotourism, timber extraction, optional use and existence values based on ethical and/or aesthetic values. Many countries (particularly islands) in South Asia have long coastlines which combined with a tropical climate provide a multitude of coastal and offshore marine ecosystems such as estuaries, coral reefs, mangroves, sea grass beds, sandy beaches, rocky beaches and lagoons. Mangroves and coral reefs play a critical role by protecting the shore during hurricanes and storms.

7.3.1 Valuation of Biodiversity

Serious research in this field has only been recently initiated and the methodologies for valuation are still evolving. Important valuation work is being carried out in various pilot projects and monetary values are being given to biodiversity services. Practical tools are needed, however, to bring biodiversity into the economy – especially in the countries of South Asia. Part of the problem in valuation of biodiversity is that biodiversity services are often almost invisible and the loss or disruption of services are difficult to identify. Due to the resilience of nature, the loss of production with market implications of a magnitude that will awaken a political response may also become apparent only when the natural system is near total collapse.

A growing literature in applied economics is demonstrating that techniques are available for obtaining concrete estimates of the value of many different facets of the environment. This includes the more **intangible** (i.e. not directly observed) aspects of environmental quality, such as clean water, clean air and better scenic views. These methods can be applied to biodiversity, but are subject to major limitations and problems of interpretation. One of the major difficulties is that these methods are based on the premise that value is determined by human willingness to pay. The range of human values are very broad and consequently difficult to measure. For example, many people place an 'existence value' on certain natural resources that they will never personally see or experience.

Valuation of biological resources includes the process of deriving a monetary value to the things that are not sold in the market. Examples are the value given to fuelwood gathered in the forest, water filtration provided in a wetland or biological resource that may supply new medicines in the future. Valuation is essential for a "social cost-benefit" analysis of biodiversity (i.e. analyzing the costs and benefits of maintaining biodiversity for a society), and is linked to **"environmental accounting"** which means the modification of national accounts to take into consideration the economic role of the environment. Many countries in the world are now attempting this. It is believed that over 25 countries have experimented with environmental accounting over the past 20 years and a few European countries have already set up physical accounting systems that are routinely complied and applied to economic and environmental policy making. Biodiversity valuation can contribute to constructing environmental accounts at the national level.

7.3.2 Future Directions in Biodiversity Valuation

The methods that can be used for valuing biodiversity are still evolving at the global level, but studies have been done on how biodiversity values can be incorporated into the process of decision making for investment projects. In carrying out valuation studies, it is necessary to emphasize the importance of adopting appropriate criteria and methods and focusing on values that are of relevance to the respective countries. In this regard, however, we need to be able to see the distinction between valuing only individual biological resources and valuing biological diversity (i.e. the existence of a

range of variation in biological resources, whether measured quantitatively or qualitatively).

A balanced approach to understanding the values of biodiversity in the context of ecosystem services should be based on the understanding that people in all countries and regions depend daily on ecosystem services from terrestrial as well as aquatic habitats for managing their lives. This underscores the need to value and conserve the natural ecosystems of all countries and regions rather than only on biodiversity hot-spots or charismatic species. Identification and recognition of ecosystem services is therefore required at various scales from local to regional, national and global.

Overall, while it is evident that neither ethical nor aesthetic arguments alone provide sufficient grounds for attempting to maintain all the earth's existing biological diversity. A more general and practical approach recognizes that different but equally valid values (resource values, optional values, ethical and aesthetic values, etc.) can assume importance in different cases, and together can provide an overwhelmingly powerful case for the conservation of the earth's biodiversity.

In current practice, many of the arguments used to justify the conservation of biodiversity stress the benefits, both economic and otherwise, from the sustainable use of biological resources. However, arguments for biodiversity conservation on economic grounds alone is insuffcient to ensure its long term preservation. It is a fact that aesthetic, moral or other values are just as valid and necessary as financial values to justify the conservation of biodiversity.

SAQ 5

How biodiversity valuation is significant in biodiversity conservation?

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……

SAQ 6

What important considerations should be undertaken in valuation of biodiversity?

……

……

……

7.4 SUMMARY

Let us summarise what you have learnt so far:

- Biodiversity has great value, but determining the value or worth of biodiversity is complex.
- The value of biodiversity is often divided into two main categories i.e. **intrinsic** or **inherent value** and **extrinsic** or **utilitarian** value. Intrinsic value describes the worth of an organism, independent of its value to anyone or anything else. Utilitarian value refers to something's value as determined by its use or function.
- Values can also be classified as '**use values**' and **'non use'** or **passive values.**
- Use values can be direct or indirect. Direct use values are for those goods that are consumed directly, such as food or timber and indirect use value are for those services that support the items that are consumed, including ecosystem functions like nutrient cycling.

- Non-use or passive values are for those entities that we don't use but would consider as a loss if they were to disappear. These include **existence value, bequest value** and **option value.**
- Spiritual, cultural and aesthetic values are classified as indirect use values or non-use values by different people.
- Economic value of biodiversity is of paramount importance. Economic valuation reflects the interaction between loss/degradation of biodiversity and the economic costs. Economic valuation is an integral part of biodiversity assessment.
- Valuation is essential for a 'social-cost benefit' analysis of biodiversity and is linked to environmental accounting.
- Biodiversity valuation planning requires that the benefits provided by genes, species and ecosystems, and the costs of their loss and all forms of capital must be fully valued.

7.5 TERMINAL QUESTIONS

1. Make a list of direct and indirect use of the biodiversity that you think you could see in a nearby coral reef ecosystem, forest, urban system or agricultural system. State separately the extractive uses and non-extractive uses that could be listed under direct use.

   ……

   ……

   ……

2. From the information that you have gathered on coral reefs in your units up to now match column A with the uses in column B in the table below.

Column A	Column B
Aspects of biodiversity in the coral reefs of the Maldivian islands	Values of biodiversity
A highly productive specialised habitat that forms the nursery grounds of fish and other species of economic value	Direct extractive use value Direct non-extractive use value Indirect use value
Contains species that are important to the national food fishery industry	Optional use value Aesthetic value Existence value
The coral reefs protect the shore from wave action preventing coastal erosion	
Contains a very high species diversity	
Is of very high aesthetic value due to the parade of organisms that one can see under water	
The corals provide specialised niches to a variety of reef inhabitants	
It is now seen that coral reefs contain organisms that yield medicinal compounds	
Contains many reef fishes that are exported as	

ornamental fish Has great potential for ecotourism Coral damage has occurred due to uncontrolled tourism A site of several research projects	

3. List the different aspects that should be taken into account when valuing the biodiversity of a mangrove ecosystem, coral reef ecosystem and a rain forest.

   …….

   …….

   …….

4. What factors (from the list you generate) do you think should be taken into consideration during environmental accounting?

   …….

   …….

   …….

UNIT 8 RESOURCE USE OF BIODIVERSITY

Structure

8.1 INTRODUCTION

Biodiversity is multiple resource based offering us a range of products, materials and services. Our survival and well being of man-kind is directly dependent on biodiversity. Biodiversity produces goods and services for the most fundamental of our needs – clean air, fresh water, food, medicines and shelter. It also provides people with recreational, psychological, emotional and spiritual enjoyment. Some people believe we should protect and restore biodiversity because of its benefits to us. Others believe that we have a moral responsibility to protect biodiversity simply because all organisms have value, whether or not we understand their benefits to us.

In this unit, you will study about importance of biodiversity as products (food, energy, medicines, drugs) and as services (ecosystem regulation).

Objectives

After studying this unit, you should be able to:

- explain the importance of biodiversity in providing goods and services;
- discuss the importance of biodiversity in providing plant and animal food including the fisheries industry;
- explain the use of genetic resources, wood products in timber trade, biomass as energy and industrial raw material;
- describe medicinal and ornamental uses of biodiversity;
- appreciate the significance of biodiversity in ecosystem balancing by nutrient cycling, climate regulation, drought and food control, air and water purification; and
- explain the use of biodiversity in recreation and tourism, scientific experiments.

8.2 BIODIVERSITY AS PRODUCTS

Individual components of biodiversity provide an unbelievable wide range of products that are used to enhance the lives of people in all countries of the world. It is the diversity of the resource base, due to the existence of a range of biological resources that has enabled the present high quality of life for humans. Biodiversity underlies the wealth of raw materials for:

- direct harvesting of food from the wild and from cultivation ranging from basic subsistence farming to sophisticated agricultural systems,
- medicines to combat diseases and pests that threaten human health, agriculture and animal husbandry,
- industry that provides humans with essential and luxury items including clothing, construction, timber and wood products, etc.

You will study about these in following subsections:

8.2.1 Food

Simply stated, our food comes directly or indirectly from plants. More than 90 percent of the calories consumed by people worldwide come from 80 plant species. Fruits, nuts, mushroom, honey, spices and other foods that humans and wild life consume originate from natural ecosystems.

A recently discovered tropical species – the winged beans is a potential source of food. Every part of this plant is edible. Its leaves taste like spinach, young pods are like green beans, young seeds like peas, mature seeds like soybeans, and its underground stems are like potatoes and are rich in proteins. It is a fast growing nodule-bearing plant that enriches soil with fixed nitrogen. Such plants and others like them from the wild give hope to feed growing millions.

Plant food

Due to the modern high yielding varieties of crops and the homogenization of food habits across the world, there has been an increasing reliance on a few edible species. Consequently of the estimated 240,000 species of flowering plants worldwide, only about 3,000 are used somewhat consistently and considered edible (i.e. suitable as food). There are records to show that approximately 80,000 edible plants have been used at one time or another in human history although at present only about 150 have ever been cultivated on a large scale and a mere 10 to 20 provide 80 to 90% of the world's calories today.

Box 8.1: The history of food crops

The evolution of crop plants began between 5,000 and 10,000 years ago, and it is now generally believed that agriculture originated more or less simultaneously in various parts of the world. The "Fertile Crescent" or the area that we now know as Iraq, is well known as the source of domestication of wheat and barley together with certain pulses such as lentil. Early agricultural development involved the domestication of millets in China, and squashes, beans, peppers and maize were first domesticated in Southern Mexico. Agriculture is also thought to have developed independently in the South American Andes.

In the South Asian region the Hindustan Centre of Origin of Crops and Plant Diversity is one of eight centres of crop plant origin which has produced a considerable share of the major crops we use today worldwide including cereals, millets, legumes, vegetables, fruits, oilseeds, forages, fibres, sugar yielding plants, condiments, spices, medicinal and aromatic plants, and others. At least 166 species of crops (6.7% of total crop species in the world) and 320 species of wild relatives of cultivated crops are believed to have originated in India.

Source: WCMC, 1992 The India NBSAP (draft of 2002).

In the countries of South Asia people obtain a wide array of food items from agricultural systems, forests, mangrove areas, the sea, estuaries and lagoons for subsistence and commercial uses. These include a range of cereals and millets,

legumes, oilseeds, vegetables, mushrooms, yams, spices and condiments, fruits and berries. A considerable part of daily food intake of rural (especially tribal) communities of South Asia comes from the wild. These include edible greens and seeds, lichen species, spice and flavoring agents, seaweeds, floral species utilized primarily as famine foods, rhizomes and tubers, fruits, shoots, mushrooms and sap (e.g. kitul sap that is used to make a local sweetener).

"Wild edible seeds are also used as famine foods. Examples are *Indigofera glandulosa*, and *Indigofera cordifolia* out of whose flour bread is baked. Seeds of grasses such as *Echinochloa, Panicum, Eleusine* species were made into bread or roasted. Grains of *Bambusa* are cooked as rice. Grains of legumes – *Vigna capensis* Walp. *Phaseolus sublobatus* Roxb. are cooked as pulses. (Singh & Arora 1978). Grain amaranths are similarly used as reserve foods in the Himalayas (Joshi & Rana 1991)."

Source: Singh & Arora 1978 Joshi & Rana 1991 cited in the draft Indian NBSAP of 2002.

Pakistan is rich in indigenous crop diversity, with an estimated 3,000 taxa of cultivated plants. The principal crops are wheat, rice, maize, barley, pulses, oilseeds, cotton, sugar cane, tobacco, vegetables and fruits (both tropical and temperate).

Source: Anwar and Shank (2002) in IUCN 2002.

Animal food

Domesticated animals provide much of the world's meat products today, but wildlife still constitutes to be an important source of food of many rural communities. The International Trade in Wildlife for 'game meat' is carried out on a large scale due to high economic returns as revealed by customs reports. For instance, green turtles (*Chelonia mydas*) have been exported from the Caribbean and the Indian Ocean to Europe, and elsewhere, for a long time to satisfy the gourmet (i.e. luxury food) trade, although this is now prohibited by the Convention on International Trade in Endangered Species (CITES).

Invertebrates too are an important source of food for people throughout the world. There are many species of marine molluscs (e.g. oysters, cuttlefish, squid) and arthropods (e.g. crabs, shrimps, lobsters) that are used as food and are economically important. Terrestrial species in these groups are also popular in some regions. For instance, the Giant African Land Snail (genus *Achatina*), believed to have a protein value similar to beef, is eaten by many people in different parts of Africa. Large scale of frog legs were sent to Paris as these are considered as delicacy in Paris. But frogs play a very important role in mosquito control hence their export has been prohibited now.

A total of about 500 species of insects are consumed worldwide. The most widely used species are termites, that can be found in very large numbers in a given location or species that swarm periodically. The hymenopterans (bees, wasps and ants) are very important in terms of food, especially bee honey and the bee brood collected with the honey.

Global fish production is the largest source of protein from both wild and domestic animals in the world, as it exceeds the food obtained from cattle, sheep, poultry or eggs. Among the most common in the fish catch around the Indian subcontinent are sardines (especially oil sardine), Indian mackerel and prawns.

Genetic resources

Genetic diversity or the gene pools are important for promoting and ensuring high agricultural yield.

Genetic diversity provides crops with the flexibility needed for them to survive changes in the environment, which is especially important in view of the predicted global climate change in the foreseeable future. Crop diversification has resulted mainly due to the processes of natural selection in response to new ecological conditions, selection by farmers for particular characteristics over long periods of cultivation, and colonial expansion that resulted in the spread of crop species between countries and continents.

Wild relatives of crop species are important storehouses of crop genetic diversity. For example, farmlands in the Himalayan foothills of north-east India contain a large number of primitive rice cultivars that show resistance to major pests and diseases including bacterial blight, viruses, gall midge and the stem borer. An example is that a minimum of 50,000 varieties of rice have been grown in India until the very recent past. The high crop diversity in South Asia is not accidental but due to the result of careful selection and even cross-breeding, over centuries, by the regions farmers to contend with different environmental conditions and needs.

The predominant strain of rice grown in Asia, for instance was devastated by a virus, but one wild strain from India had genes for resistance. Through intensive breeding, a resistant hybrid was created which is now widely grown.

Biotechnology and the resultant GMOs and LMOs

Techniques that use gene modification through (a) recombinant DNA technology and (b) cellular techniques of introducing DNA into an organism has opened up new vistas to the agriculture sector, food processing industry and human health care. These modern techniques now enable the transferring of genes between species that is now possible through normal processes such as sexual reproduction. Such techniques used in biotechnology give rise to **Genetically Modified Organisms** (GMOs) and **Living Modified Organisms** (LMOs). For example a crop species such as tomato can have genes of an animal species introduced into its genetic makeup to increase its size or crop yields, or to provide it with resistance to disease causing organisms or pests.

Even so, there is increasing concern about the risks of biotechnology that produces GMOs and LMOs as they can have severe adverse effects on the natural environment and on human health, especially as some of the genes introduced are from viruses and bacteria.

Thus, adequate checks and balances, as well as specific guidelines, are required to control the technology and the handling, transfer and release of genetically modified organisms. This aspect is currently being addressed at the international level through Article 19 of the Convention on Biological Diversity (CBD) and the related legally binding International Protocol on Biosafety that was adopted in January 2000.

8.2.2 Wood

Wood has been important to human beings for many years. Over hundreds of years, people have destroyed vast areas of woodland. The great forests that once covered Europe have been cut and bare areas can be seen that were once covered by trees. Many people all over the world are saving the world's forests. New trees are planted to take the place of those cut down.

Wood is a material found as the primary content of the stems of woody plants, especially trees, and also shrubs. Wood is one of the most important building materials. It is used for beams, floors, doors, furniture, industries also use it for making furniture, boxes, toys, boats and hundreds of other products. Wood is commonly classified as either hardwood or softwood. The wood from conifers (e.g. pine) is called **softwood** and the wood from broad-leaved trees (e.g. oak) is called **hardwood**. Most paper is made from softwood trees such as fir, pine and spruce. About 70% of the world's timber needs are met by softwoods derived from the

coniferous trees. Some conifers mature in 30-50 years. Timber is the greatest resource of the rain forest. There is an increasing demand for hardwood timber and its costs are rising. Many hardwood trees need about 100 years to reach maturity. The trees are being felled faster than they can be replaced. Table 8.1 provides a list of commonly used timber species.

Table 8.1: List of timber yielding tree species

No.	Softwoods (conifers)	Hardwoods (angiosperms)
1.	Cedar (*Edrus*)	Afzelia (*Afzelia*)
2.	Cypress (*Chamaecyparis*)	Agba
3.	Douglas-fir (*Pseudotsuga*)	Albizia (*Albizia*)
4.	Fir (*Abies*)	Alder (*Alnus*)
5.	Hemlock (*Tsuga*)	Applewood or wild apple (*Malus*)
6.	Larch (*Larix*)	Ash (*Fraxinus*)
7.	Pine (*Pinus*)	Aspen (*Populus*)
8.	Redceedar (*Thuja plicate*)	Ayan (*Distemonanthus benthamianus*)
9.	Redwood (*Sequoia sempervirens*)	Balsa (*Ochroma pyramidale*)
10.	Spruce (*Picea*)	Basswood (*Tilia americana*)
11.	Sugi (*Cryptomeria japonica*)	Beech (*Fagus*)
12.	Yew	Birch (*Betula*)
		Cherry (*Prunus*)
		Coralwood (*Guilbourtia spp.*)
		Ebony (*Diospyros*)
		Elm
		Eucalyptus (*Eucalyptus*)
		Gum
		Hickory (*Carya*)
		Mahogany
		Maple (*Acer*)
		Oak (*Quercus*)
		Rosewood (*Dalbergia spp.*)
		Sandalwood (*Santalum album*)
		Teak (*Tectona grandis*)
		Willow (*Salix*)

8.2.3 Energy

In many countries of Asia biomass contributes largely as a source of primary energy. People in rural areas at the peripheries of forests, continue to collect fuel wood from adjacent forests. India consumes 15% of the world energy. The source of energy are renewable and non-renewable (commercial energy). Energy is being used for domestic and industrial purposes. Non-renewable energy sources include coal, petrol, diesel, kerosene etc. The intensity of energy extraction, production and use of these resources have resulted in the destruction of environment through pollution – The consumption rate of these resources is twice than production. Hence renewable energy

Fig.8.1: The important sources of fibres. a) Cotton - from seed coat; b-d) Flax, Hemp and Jute respectively, fibres are extracted from their stems

sources are being used extensively in India. Major renewable energy sources are solar energy, wind energy and biomass.

India is considered as world leader in renewable energy resources. It ranks first in the use of solar cookers (4.6 lakh) and biomass (mh 27).

Relatively poor societies are entirely dependent on firewood and other biomass for their energy needs particularly the forest dwellers and forest tribes. In India, biomass combustion includes fuel for domestic cooking in stoves (hence referred to as biofuel). Biofuels used in rural India include wood, crop waste and dung cake.

The only reported biofuel used in urban areas is wood. The largest contribution to biofuel consumption is from Uttar Pradesh (13%, dung cake – 7%, fuel wood – 4%) followed by Andhra Pradesh (11%, fuel wood – 5% crop waste – 4%), Bihar (10%, fuel wood – 7%, dung cake – 1%) and Madhya Pradesh (9%, fuel wood – 7%, dung cake – 1%). Forest biomass burning is found to be high in Andhra Pradesh and east Madhya Pradesh.

Dendrothermal power (energy from plant material) is now increasingly viewed as an alternative source of energy, in preference to fossil fuels that result in the release of green house gases that add to the impacts of climate change.

8.2.4 Raw Material for Industry

The industry, producing goods and services, relies and impacts on biodiversity directly. Much of the raw material that goes into industrial operations is a by-product of biodiversity. The trees, the animal organs, the microbial culture are a few examples of sources of raw materials. Plants and animals provide a wide variety of resources used in industry and commerce for both domestic and commercial markets. As many as 2000 plant species throughout the world are known for their economic importance. The building, furniture and paper making industries are dependent on more than one hundred different species of trees. Cotton, flax, hemp and jute provide fibre for manufacture of textiles, ropes and other articles (Fig. 8.1). For example, plant extracts are used in the manufacture of glues, soaps, cosmetics, dyes, paints, plastics, lubricants and polishes. Household implements such as needles and hooks are made from horns, scales and fins of animal origin. Fat from wild species (e.g. marine mammals and sharks) is used to produce a range of oils. Wildlife products such as cane and other lianas, bark, fur, hides, scales, bones and feathers are used to make a variety of clothing and utensils.

The silk industry is dependent on several species of silkworms, but the finest silk is obtained from the mulberry silk moth, which is now domesticated. The moth pupae which are left after extracting the silk during sericulture, are used to produce soap and cosmetics. Cochineal, a brilliant red colouring agent formerly widely used in the food and cloth industries, is also an insect product obtained from the semi-domesticated form of a scale insect.

You will study in next section that pharmaceutical industry is directly dependent on biodiversity. Most of the drugs used today are from plant or animal sources. A species destroyed may mean an opportunity lost to cure a serious disease. Who knows the cure of AIDS may just be down the road coming from a root of remote plant.

Rattans as raw material

Rattans provide an economically important bioresource from tropical forests. There are about 600 species of rattans worldwide, of which most are found in South and Southeast Asia. The Phillippines, China, Indonesia, India, Sri Lanka and Thailand are the main countries that engage in the rattans industry. Rattans are used to produce cane furniture for the international market while at the community level they are used to produce baskets, boxes, mats, domestic utensils, fish traps, dyes and medicines.

Overall, the industry provides full-time employment for at least half a million people around the world.

The rattans industry relies almost entirely on wild stocks, with about 90% of the world's raw material being extracted from the wild. As such, over exploitation and habitat destruction has caused a decline of the commonly used commercial rattan species. The highest diversity of rattans occurs in the Malay Peninsula, which has about 104 species of which about 38% are endemic and most are considered to be threatened. In Sri Lanka too, forests continue to provide raw material for the cottage scale rattan and bamboo handicraft industry, which has about 2200 craftsmen and 700 families dependant on it for cash income. Interestingly, different species of rattans are used to produce different domestic utensils indicating the value of species diversity.

Rattans are climbing palms that provide the raw material for the cane-furniture industry. Sometimes confused with bamboo, canes can usually be distinguished because they are solid whereas bamboos are almost always hollow. Rattans are particularly abundant in South-east Asia and the Malay Archipelago.

Unfortunately in a planet where six billion people's needs have to the fulfilled, raw materials are being used faster than they can be replenished. The pace of industrial activity cannot be slowed down because of obvious reasons but it should be kept in mind that industrial operations should be biodiversity friendly.

8.2.5 Medicines and Drugs

The World Health Organization (WHO) has listed over 21,000 plant names (including synonyms) that have recorded medical uses around the world. However, very few of these medicinal plants have as yet been subject to scientific investigation, and only about 5,000 species of higher plants have been fully investigated as potential sources of new drugs to date. At present about 90 species of higher plants have yielded a total of 119 pure chemical substances that are used in medicines throughout the world (Table 8.2). An estimated 4.5 billion people (about 80 percent of the world's population) still use plants as their primary source of medicine. The use of most of these medicines is based on ancestral knowledge. Even in today's high-tech society whose most things can be synthesized in laboratories of modern medicines prescribed in good percentage are of biotic origin. Numerous life saving drugs have been isolated from flowering plants. Close to 30 percent of all pharmaceuticals on the market to day are developed from plants and animals.

Table 8.2: Numbers and percentage of medicinal plant species recorded in different countries and regions (Hamilton, 2003)

Country or Region	Total no. of plant species	No. of species of medicinal plants	Percentage (%)
China	27,100	11,146	41.12
India	17,000	7,555	44.44
Mexico	20,000	2,237	11.18
North America	20,000	2,572	12.86
World	297,000–510,000	52,885	17.80–10.36

In most biodiversity rich developing countries the genetic resources of medicinal plants have been inadequately assessed and there is danger that the existing indigenous knowledge about the medicinal properties of plants will be lost with a shift towards western medicines. It is therefore important to document the different medicinal species and their uses for posterity.

A wider range of plant species is used for medicinal purposes at the local level in many countries of world, and about 80% of people living in developing countries continue to rely on traditional medicines that use plants or plant extracts. Most of the plants used in indigenous medicines are collected from forests. In China more than 5000 species are used in traditional medicines alone. Medicinal plant species are largely extracted from the wild even in developed countries and relatively few are cultivated as crop plants.

1. A large number of important drugs are derived from plants. For example **Tubocuranin**, derived from plant-based curare, is used as a muscle relaxant during surgery.

Fig.8.2: A part of the foxglove plant – the source of digitoxin

Fig.8.3: A shoot of *Taxus baccata,* the source of taxol

Fig.8.4: A branch of *Cinchona* tree. Qunine is extracted from its bark

2. **Curianol**, a Guyanes fish poison is used in heart operations. It has also identified that over 1,400 tropical forest plants contain substances that can fight cancer.
3. The Rosy Periwinkle *Catharanthus roseus,* has been used for generations by tribal medicinal healers in Madagascar which is its country of origin.
4. **Digitoxin**, the most widely used cardiac stimulant is obtained directly from the foxglove *Digitalis* (Fig. 8.2).
5. Antibiotics such as penicillin are extracted from fungi and from such unlikely sources as the African clawed frog's skin.

Plants yielding pharmaceutical compounds are listed in Table 8.3 and activity of selected top-selling botanical medicines is listed in Table 8.4.

Table 8.3: Examples of plants yielding pharmaceutical compounds

Catharanthus roseus	This species yielded the alkaloids vincristine and vinblastine. Traditionally used by various cultures for the treatment of diabetes, these compounds were first discovered as part of an investigation of the plant as a possible oral hypoglycemic. Originally native to Madagascar, this species is now widespread and common. The vinca alkaloids are used in the treatment of childhood leukemia and Hodgkin's disease.
***Podophyllum* spp.**	These species were long used by indigenous people in Americea and Asia, including for the treatment of skin cancers and warts. The combination of cumulative demand and loss of the habitat led to the placement of *Podophyllum hexandrum* on Appendix II of the CITES list in January 1990.
Taxus brevifolia (Fig. 8.3)	Collected in Washington State, The needles of *Taxus baccata*, in which paclitaxel is found, are used in traditional Ayurvedic medicines, with one reported use being for various types of cancer.
Camptotheca acuminata	This species is an ornamental tree in China, and has yielded the clinically active agents topotecan, irinotecan, and 9-aminocamptothecin, which are semisynthetically derived from camptothecin. Camptothecin is now marketed under the generic name 'Topotecan' and the brand name 'Navelbine' by SKB.
Chondrodendron tomentosum	This species, used by indigenous people of South America in an arrow poison known as curare is used as model for a series of neuromuscular-blocking agents.
Rauwolfia serpentine	Known as the Indian snakeroot, with a long history of traditional medical use, including for the treatment of mental disorder, snake bites, and as a tranquiliser, this species yields the antihypertensive compound reserpine. The Indian Ministry for Environment and Forests estimated sales of antihypertensives derived from the Indian snakeroot at more than US$260 million in 1994.
***Chincona* spp.** (Fig. 8.4)	The bark of this species yields quinine, a treatment for malaria. In the 1940s the principal alkaloids were isolated and synthesized for the pharmaceutical market, but its use in international markets had been established hundreds of years earlier.

Source: Cragg et al, 1997, Sheldon et al, 1997.

Table 8.4: Claimed activity of selected top-selling botanical medicines

Product	Plant part	Activity
Ginseng	root	increases energy and sex drive
Siberian ginseng	root	defuses nervous tension and fights fatigue
Kava	root	combats anxiety and stress
Green tea	leaves	a powerful anti-oxidant and cholesterol-reducer
Milk thistle	fruit	protects from toxins – e.g. alcohol, pesticides
St. John's wort	herb	anti-depressent
Psyllium	seeds	anti-constipation; helps in weight loss
Hawthorn	fruit	lowers blood pressure and fights arthritis
Saw palmetto	seeds	treats prostate problems
Valerian	root	relieves insomnia, anxiety, menstrual cramps, headaches
Liquorice	root	treats ulcers and stomach disorders
Wild yam	roots	alleviates PMS and menopausal symptoms
Aloe	leaves	treats wounds and skin problems
Camomile	flowers	alleviates moods and skin problems; calming
Feverfew	leaves	relieves migraine headaches
Bilberry	leaves	improves eyesight
Cranberry	fruit	keeps the urinary tract healthy
Garlic	bulb	boosts the immune system; lowers cholesterol
Calendula	flowers	soothes skin; fights bacterial, viral and fungal infections
Echinacea	roots, flowers	boosts immune system; prevents colds
Ginger	rhizomes	treats nausea; inflamed joints
Elderberry	flowers, fruit	remedy for head colds
Ginkgo	leaves	improves energy, mood, and brain function

Animals and biomedical uses

Animal products too are widely used in medicines by traditional societies, and in some urbanized societies that believe in traditional animal-based remedies. Examples of such products are dried lizards of several species, the genitalia of dolphins, fox fur, musk (from musk deer *Moschus* spp.), bears, gall bladders, tiger bones, rhino horn and many other parts of wild animals that are sold for medicinal purposes. Records indicate that the international trade in medicinal products derived from deer – especially, another tendons and musk is calculated to be worth around US $ 30 million a year!

The use of leeches for medical purposes can be traced back to the Greeks in the 2nd century B.C. Today, these live animals are used during micro-surgery. The sucking action and substances (e.g. anticoagulants) produced by leeches during feeding assist to ensure the survival of accidentally severed body parts, such as fingers and ears, after re-attachment.

Gorgonids yield chemicals like prostaglandins, medically useful for birth control, prevention of peptic ulcers, treatment of asthma, regulation of blood pressure, etc. Sponges are used to obtain substances with biomedical properties. Live animals, particularly primates, are used as experimental animals in the biomedical trade. Commonly used species in the past were the rhesus macaque (*Macaca mulatta*) and the crab eating macaque (*Macaca fascicularis*). Other species used in biomedical research even today are the squirrel monkeys (*Saimiri* spp.), marmosets (*Saguinus* spp.), the night monkey (*Aotus trivigatus*) and the chimpanzee (*Pan troglodytes*).

Micro-organisms in medicines

In terms of western medicines, over 3000 antibiotics – including penicillin and tetracycline – are obtained from micro-organisms. Another product of micro-organisms i.e. cyclosporin was developed from a soil fungus. It revolutionized heart and kidney transplant surgery by suppressing immense reactions. Many micro-organisms have their own antibiotics and scientists have not yet been able to fully identify their potential uses. Biotechnology can now help to isolate useful genes and transfer them to different species to produce substances such as enzymes required in large quantities for curative purposes. Unicellular bacteria also produce the antibiotics such as gramicidin, olymyxin B and bacitracin respectively. Some micro-organisms (fungi, actinomycetes and bacteria) are used to transform chemically synthesized steroid hormones to resemble natural hormones for clinical use.

Bio-insecticides, bio-pesticides and bio-fertilisers

A large number of plants are used for bio-pesticides and bio-fertilizers. Several plant species are used as insecticides against aphids and larvae of insect pests: for insects like blister beetles and termites; chilli is used for pests that affect storage and neem (*Azadirachta indica*) is used as a bio-pesticide. Storing of wheat and barley grains with cowdung ashes also prevents insect attacks, the oil cake of *Madhuca longifolia* ach. and the oil and leaves of *Pongamia pinnata* are used for insecticidal purposes. There are accounts of how jowar grains have been stored for more than 30 years by sealing them between layers of neem leaves in bins and buried in a 12 ft. deep pit. (The Statesman, 22.3.92 cited in the Indian NBSAP, draft in 2002).

8.2.6 Ornamental Uses

As with food crops, the "discovery, domestication and cultivation" of ornamental plants have a long history. There is indication that lilies were cultivated in China for both medicinal and decorative purposes for over two thousand years. Roses, lilies, violets, anemones, and lavender have been grown as garden plants in Europe since the time of the Roman Empire. At present the diversity of decorative plant species that are cultivated is greater than the diversity of food plants that are commonly grown around the world. In the UK alone an estimated 3,000 species, and a wide range of cultivars and hybrids, are cultivated for ornamental purposes. As "novelty and variety" are important in the horticultural market, plant biodiversity is the key to this industry as it permits the addition of new species or varieties periodically.

Ornamental plants are an important commodity in international trade due to the expanding market. As such, wild species of horticultural value are under threat around the world, due to both habitat destruction and direct exploitation for local and international trade. Important plants of ornamentals trade are: species with bulbs, orchids, cacti and other succulent plants, cycads and insectivorous plants. Over 5,000 species of orchids are recorded in CITES trade statistics during the period 1983-1989. *Dendrobium* is the most heavily traded genus of orchid exported from Thailand. Sri Lanka also has about 170 species of plants of ornamental value of which 74 are endemic.

Many wildlife products are valued for their ornamental, decorative or ceremonial purposes. Examples are ivory from elephants, tortoise shell (derived from the hawsbill

turtle *Eretmochelys imbricata*) and furs. Ivory was much in demand for production of a variety of jewellery and artifacts in the past. Reptile leather from crocodiles, lizards and snakes has quite a high demand for manufacture of shoes and fancy goods.

Furs from the felix (i.e. cat) family for export are obtained from many species including the leopard, lynx, ocelot, little spotted cat, margay and the leopard cat (*Felis bengalensis*). There is high demand for these skins from Europe and Japan, although the overall market demand for these items has decreased due to the reduced popularity of furs as fashion items.

Bird feathers and some primate skins (e.g. black and white colobus) are used as items of adornment in many parts of the world, sometimes to indicated status of hierarchy. The skins of the black and white monkey (*Colobus guereza*) are used to make cloaks and head dresses for native people, and they are in demand for production of rugs and coats for the international trade.

SAQ 1

List five important plants having medicinal value.

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SAQ 2

'The industry relies and impacts on biodiversity directly'. Substantiate your answer.

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SAQ 3

List two important types of wood (Soft and Hard) used in timber trade.

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8.3 BIODIVERSITY AS SERVICES

Biodiversity provides us with life-sustaining services. As discussed below, these ecosystem services have a much higher value than most people realize. At the ecosystem level, biodiversity provides the conditions and the process that sustain the global economy and an existence as a species.

Individual species within ecosystems as well as ecosystems as a whole, are vital to human society as you will study in the following subsections. Even the most obscure organisms in an ecosystem are worth conserving.

8.3.1 Pollination

Many flowering plants rely on animals such as bees, butterflies, moths, wasps, beetles, birds, and bats for pollination to produce fruit. Thirty percent of our food crops, including almonds, apples, blueberries, cherries, and chocolate, rely on the free services of pollinators. Feed crops like alfalfa and hay for domesticated animals also

depend on pollinators, and many wild plants such as fig trees that provide food and shelter for animals depend on pollinators. But pollinators, including the managed honeybee colonies used extensively in U.S. agriculture are threatened. Increasingly fragmented and degraded habitat, pesticides, and the introduction of diseases and non-native species are causing some pollinator populations to decline. Imagine farmers having to hand-pollinate their crops if we lose natural pollinators.

8.3.2 Maintenance of Soil, Air and Water Quality

Biodiversity maintains the air we breathe and the water we drink. Green plants purify our air and our water by taking in carbon dioxide, regulating water vapour, releasing oxygen, and cycling nutrients. Through photosynthesis, trees and other plants give off oxygen that helps maintain atmosphere. As a result of these processes, plants play a crucial role in maintaining the planet's water cycle. Wetlands and the vast array of bacteria and other microscopic species they house also act as water filters.

The activities of microbial and animal species – including bacteria, algae, fungi, mites, millipedes and worms – condition soils, bring organic matter, and release essential nutrients to plants. These processes play a key role in the cycling of such crucial elements e.g. nitrogen, carbon and phosphorous between the living and non-living parts of the biosphere.

Wetland ecosystems (swamps, marshes, etc.) absorb and recycle essential nutrients, treat sewage, and cleanse wastes. In estuaries molluscs remove nutrients from the water, helping to prevent over-enrichment and its attendant problems, such as eutrophication arising from fertilizer run-off. Trees and forest soils purify water that flows through forest ecosystems. In preventing soils from being washed away, soil protection by forests also prevent the harmful siltation of rivers from erosion and landslides.

8.3.3 Climate Regulation

By giving off moisture through their leaves and providing shade, plants help keep us and other animals cool. Forests are especially good climate modifiers. Forests act as insulators helping to mitigate the impacts of freezing temperatures. As trees and other plants in forests release oxygen and take up carbon dioxide (CO_2) – the most prevalent greenhouse gas – the forests store carbon and help reduce global warming. So do oceans as they interact with the atmosphere. Algae living in the ocean take up carbon dioxide, and ocean currents and winds help control the world's climate.

8.3.4 Drought and Flood Control

Forests, grasslands and wetland protect landscapes against erosion floods and landslides through the binding action of plant roots. The root systems of plants hold soils in place, preventing erosion and mudslides. Plants also hold moisture in soils and thereby help reduce the effects of drought. Lands that have been deforested and cleared, have little ability to hold water. These natural drought and flood control services are particularly important to people living along rivers and coastlines and for people in arid regions. Ecosystems bordering regularly flooding rivers (e.g. wetlands) absorb excess waters and thus reduce the damage caused. Certain coastal ecosystems (salt marshes, mangrove forests) prevent the erosion of coastlines.

8.3.5 Cycling of Nutrients

Pick up just a tiny bit of soil and you will discover a whole new world. Researchers have found that one pinch of soil may contain more than 30,000 protozoa, 50,000 algae, 400,000 fungi and billions of individual bacteria in addition to larger organisms like worms, insects and mites also live in the soil. These organisms break down dead plants and animals and recycle the nutrients into organic materials that enrich the soil. The movement of elements such as nitrogen, sulphur and phosphorus between

different forms as they pass through the food chain. The elements cycle between gas forms and compounds which are found in soil and living organisms. For example, nitrogen cycle is heavily reliant on bacteria and involves the formation of nitrates (needed for making proteins which are the functional molecules in all organisms) from atmospheric nitrogen and then the break down of nitrogen compounds to nitrogen gas. The nitrogen cycle is an important part of soil formation and soil fertility.

8.3.6 Habitat

Natural ecosystems provide habitat for the world's species. Forests, coral reefs and deep ocean bottoms house many species. Wetlands, through their mix of aquatic and terrestrial environments, nourish and shelter thousands of bird, fish and other animal species. Estuaries, where the currents and tides of salt water and fresh water meet, are the world's nurseries for many of the aquatic species we consume, including fish and shellfish such as clams and crabs. Lakes and rivers, for example, constitute only 0.01 percent of the planet's water, but they contain a quarter of all known species. Even open spaces in cities and towns support significant biodiversity.

8.3.7 Economic Value

Biodiversity serves as an income generating activity for countries around the world. Many people visit forests, beaches, mountains, grasslands, lakes, ponds, estuaries and streams for extended vacations or for shorter periods for relaxation. More than 130 million people visit U.S. national parks each year, and millions of dollars are spent annually on nature activities such as hiking, camping, fishing, hunting, whale watching and wildlife photography. Around the world the number of ecotourists, people travelling to enjoy nature and various cultures, is increasing. You have studied in detail about economic aspect of biodiversity in Unit 6 of this course.

8.3.8 Spiritual/Cultural Value

It is no mystery why people are prepared to spend so much towards the nature. Human beings instinctively desire aesthetic and spiritual satisfaction from biodiversity. Our emotional well being is enhanced in the proximity of natural beauty. The umbilical cord between humans and biodiversity is reflected in art, religion and traditions of human cultures: a spiritual heritage that will be lost for all time if nature is continued to be destroyed.

8.3.9 Scientific Use

Nature is a major source of inspiration for scientific thought and the subject of many scientific studies. Biodiversity which constitutes the whole of "living" nature has a profound "scientific value" in all cultures. The 'life-sciences' including agriculture, medicines, biotechnology and their varied applications pertaining to conservation, scientific insight and discoveries are based on the observations and study of nature/ plants, animals and their habitats.

8.3.10 Recreation and Tourism

Biodiversity has been always of enormous recreational and aesthetic value. Many people are willing to pay for the pleasure they derive from wildlife by making special excursions to view them and to watch them on film or television. For many developing countries biodiversity as a non-consumptive resource can be best justified by the money earned through tourists who are willing to pay to observe wild animals in their natural habitat, as this brings in much-needed foreign exchange to the host country. It has been estimated that each visitor pays almost US$200 to spend an hour with the wild Mountain gorillas in Rwanda, bringing in about US$1 million per year to the country as direct park revenue. The high diversity of the parade of wildlife is

the primary draw of people to some popular tourist areas such as East and Southern Africa, the Galapagos islands and the Great Barrier Reef of Australia.

The growing market for enjoyment of wildlife and wild habitats is one of the important trends in the tourist industry in recent times, and ecotourism is gaining importance in many parts of the world. This is one way by which biodiversity contributes directly to the national economy in the form of revenue as well as jobs to local communities.

SAQ 4

How does biodiversity help in ecosystem regulation?

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SAQ 5

"Recreation and tourism pave a way for economic value of biodiversity". Discuss this statement.

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In this unit, you have studied that biodiversity of ecosystems whether terrestrial or aquatic, have similar values in providing goods or services to human beings (Table 8.5).

Table 8.5: Goods and services provided by different ecosystems

Ecosystem	Goods	Services
Terrestrial	• Food crops • Fibre crops • crop as genetic resources	• Maintain limited watershed functions (infiltration, flow control, partial soil protection) • Provide habitat for birds, pollinators, soil organisms important to agriculture • Sequester atmospheric carbon • Provide employment
Coastal ecosystems	• Fish and shellfish • Fishmeal (animal feed) • Seaweeds (for food and industrial use) • Salt • Genetic resources	• Moderate storm impacts (mangroves; barrier islands) • Provide wildlife (marine and terrestrial) habitat • Maintain biodiversity • Dilute and treat wastes • Provide harbour and transportation routes • Provide human and wildlife habitat • Provide employment • Contribute aesthetic beauty and provide recreation

Forest ecosystems	• Timber • Fuelwood • Drinking and irrigation water • Fodder • Nontimber products (vines, bamboos, leaves, etc.) • Food (honey, mushrooms, fruit, and other edible plants; game) • Genetic resources	• Remove air pollutants, emit oxygen • Cycle nutrients • Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization) • Maintain biodiversity • Sequester atmospheric carbon • Moderate weather extremes and impacts • Generate soil • Provide employment • Provide human and wildlife habitat • Contribute aesthetic beauty and provide recreation
	• Drinking and irrigation water • Fish • Hydroelectricity • Genetic resources	• Buffer water flow (control timing and volume) • Dilute and carry away wastes • Cycle nutrients • Maintain biodiversity • Provide aquatic habitat • Provide transportation corridor • Provide employment • Contribute aesthetic beauty and provide recreation
	• Livestock (food, game, hides, fibre) • Drinking and irrigation water • Genetic resources	• Maintain array of watershed functions (infiltration, purification, flow control, soil stabilization) • Cycle nutrients • Remove air pollutants, emit oxygen • Maintain biodiversity • Generate soil • Sequester atmospheric carbon • Provide human and wildlife habitat • Provide employment • Contribute aesthetic beauty and provide recreation

Source: 2000 World Resources 2000 -2001:.People and ecosystem: The fraying web of UNDP, United National Environment Programme, World Bank, World Resources Institute.

8.4 SUMMARY

Let us summarize what you have learnt so far.

- Humans benefit from biodiversity in many ways. Besides the animals and plants that we use for food, shelter, raw materials, and companionship, there are thousands of species whose natural products are literally life saving.
- Biodiversity produces goods and services for our fundamental needs.
- Plants and animals are being consumed as food. Approximately 80,000 edible plants have been used in human history, although about 150 have ever been cultivated. Invertebrates e.g. insects (mainly termites), marine molluscs (oysters),

arthropods (crabs, shrimps, lobsters) and vertebrates e.g. fish, food obtained from cattle, sheep, poultry are important edible food items.

- Plants and animals are sources for medicines and drugs. Approximately 30% of pharmaceuticals in market today are developed from plants and animals. Antibiotics are extracted from microorganisms. Biodiversity is source of medicines to combat diseases and pests that threaten human health, agriculture and animal husbandry.
- Biodiversity is source of industrial raw material. Silk industry and rattans industry are important examples.
- Biodiversity provides firewood, and other biomass for energy.
- Biodiversity is an important source for wood which is very useful in timber trade.
- Biodiversity provides services mainly in terms of ecosystems regulation.
- Ecosystem provides habitat for the world's species.
- Pollination, air and water purification, climate regulation, drought and flood control and cycling of nutrients are important services provided by biodiversity.
- Spiritual and aesthetic sense of human beings pave a way for economic value of biodiversity.

8.5 TERMINAL QUESTIONS

1. Make a list of the range of biodiversity that you use on a given day.

   a) What are the main food crops such as rice, corn and wheat that you have used?

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   ……...

   b) List the components of biodiversity that you can identify.

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   c) Discuss how the menu of the meals that you have at home or in the University/workplace canteen can change if you were in another country such as Japan or Kenya. List five such items that you would use.

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   d) Discuss whether any of the food products you obtain from the canteen today could contain genetically modified organisms.

   ……..

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2. Note (and list where possible) the different types of wood that have been used for constructing and furnishing your home.

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…….....

a) Discuss why one type of wood could not be used instead of several.

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b) Discuss the other alternative (including other types of wood) that could be used for similar purposes.

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UNIT 9 LOSS OF GLOBAL BIODIVERSITY

Structure

9.1 INTRODUCTION

As many as 500 million kinds of plants, animals and microorganisms have made earth their home since life began, over 3.5 billion years ago. Presently, it is believed that there are only 5 to 10 million species alive. We, however, do not have an exact figure because there are many areas on the earth that are biologically unexplored. Tropical rain forests are examples of such areas, about which we know little. And a majority of the organisms living there remain to be identified.

A few species naturally become extinct over time and it is believed that however, during certain periods of geological time, great numbers have been lost relatively quickly – on the scale of thousands of years. Scientists have documented five mass extinctions since the emergence of life on this planet some 3.8 billion years ago. It is thought that each of these episodes, during which a large fraction of all species were lost, was caused by a catastrophic natural event. For example, the disappearance of two-thirds of all species living on land during the time of the dinosaurs was probably the result of a large asteroid crashing into Earth about 65 million years ago. Growing human population leading to overexploitation of biotic resources and habitat destruction are responsible for today's exceptionally high extinction rates. Many scientists consider this as the sixth extinction episode.

Objectives

After studying this unit, you should be able to:

- explain the factors affecting loss of global biodiversity;
- differentiate endangered, rare, depleted and indeterminate species;
- discuss natural and artificial extinction of species;
- explain habitats vulnerable to species extinction;
- describe the ways by which species extinction are estimated; and
- discuss the major impacts of biodiversity loss.

9.2 CURRENT STATUS OF BIODIVERSITY

Based on fossil records, paeontologists estimate that 1 to 10 species go extinct as part of natural processes every year. Today, extinction rate is several hundred times greater than the natural rate and higher than any other on record. Many scientists think that we are now in the midst of an unnatural mass extinction. This time, it is caused primarily by our growing population and the demands that we place on natural resources. If this high extinction rate continues, it will grow to as much as 10,000 times above the natural rate, and result in the extinction of as many as two out of every three terrestrial species by the end of the century.

A growing human population, increased human consumption, and the growth of technology are placing tremendous stress on Earth's natural systems. Over the past 50 years alone, world population grew from 2.5 billion to 6 billion people, and global energy use tripled. More than 6 billion people now inhabit the planet, and it is predicted that by the year 2050 there may be about 9 billion. More people require more land, water, food, energy and natural resource. As our consumption of Earth's resources grows, we are likely to see a corresponding loss of biodiversity around the world. If all people worldwide enjoyed the standard of living of the United States, it would require four more planet Earths to support today's human population.

Although developed countries such as the United States, Canada, Japan, Australia and most European nations have only 20 percent of the world's human population, they consume 80 percent of global energy use and 85 percent of the world's economy – a disproportionate share of natural resources. These developed countries also produce far more waste than developing nations, such as China, India and many Latin American and African nations. For this reason, the choices we make are important for the conservation of biodiversity. Table 9.1 provides you a comparative status of Indian biodiversity with the World.

Table 9.1: Status of biodiversity in India as compared with the World

Number and Status of species	India	World
Higher Plants		
Total known species (number), 1992-2002	18664	X
Number of threatened species, 2002	244	5714
Mammals		
Total known species (number), 1992-2002	390	X
Number of threatened species, 2002	88	1137
Breeding Birds		
Total known species (number), 1992-2002	458	X
Number of threatened species, 2002	72	1192
Reptiles		
Total known species (number), 1992-2002	521	X
Number of threatened species, 2002	25	293
Amphibians		
Total known species (number), 1992-2002	231	X
Number of threatened species, 2002	3	157
Fish		
Total known species (number), 1992-2002	5749	X
Number of threatened species, 2002	9	742
Total land area (000 ha)	328759	13328979

Source: http://earthtrends. wri.org.

9.3 CAUSES OF BIODIVERSITY LOSS

Asia's biodiversity is being gradually lost. While it is not possible to quantify rates of species loss very precisely. However, high rates of land, fresh water and marine habitat degradation in this region is a reflection of species loss. It is estimated that

Asia will lose more than half of its remaining land and water habitats over the next few decades.

The main causes of biodiversity loss include land-use changes, changing levels of atmospheric carbon dioxide, changing climate, invasive species and nitrogen deposition (air pollution). The causes of biodiversity loss are many and varied, and often interrelated. You will study about these factors in detail in the following subsections.

9.3.1 Habitat Destruction

Habitat refers to the area where species seek food, get shelter, and reproduce. The greatest threat to wild plant and animal species is due to destruction or alteration of their habitat. If an animal's habitat is destroyed or disrupted, it must either adapt to the new changes, move elsewhere or die. When it is forced out of its territory, and if it finds a suitable habitat there is a possibility that the habitat is already in use. Consequently, it must compete with the local population of the same species as well as other animals. The other option is that it must migrate into a marginal habitat where it may succumb to predation, starvation or disease. Some organisms such as pigeon, house sparrow, rodents (like rat and mice) and deer flourish in the modified habitats provided by human activities but many others do not.

Some habitats are more vulnerable to species extinction, these are called fragile habitats. **Coral reefs, oceanic islands and mountain tops are important fragile habitats.**

Box 9.1: Fragile habitats

Coral Reefs

Coral reefs have been found to be particularly fragile as they are susceptible to a rise in water temperature, sea levels and the introduction of pollutants and sediments that changes water quality. Coral reef development is greatest in warm, shallow sun drenched areas and it needs clean, clear water. Productivity is decreased, or even eliminated, in areas subject to dirty sediment-laden water. Coral growth is naturally very slow.

In 1992, about 10% of the earth's existing coral reefs were found to be irreparably damaged, while 30% were expected to suffer damage within the next 20 years. It is also expected that there may be a further 30% loss within the next 20-40 years if remedial action is not implemented. It is estimated that Tsumani, 2004 has completely destroyed the coral reefs of coastal areas of India, Srilanka and Thailand.

Oceanic Islands

Existing data shows that 75% of the recorded animal extinctions since 1600 have been on islands rather than in continental areas, and terrestrial species in isolated oceanic islands are more vulnerable to being wiped out than continental species. The reasons for species extinction on oceanic island are restricted ranges, threat from alien species and characteristics of island species.

Habitat Islands

Species in ecological islands or "habitat islands" (areas of habitat separated from other such areas by inhospitable environments that act as effective barriers to dispersal) are at greater risk of extinction. For instance, freshwater lakes – bodies of water surrounded by land – like real islands, suffer high rates of extinction due to habitat modification or the introduction of exotic invasive species. Among continental extinctions, at least 66% of species loss has been in aquatic habitats.

Biodiversity loss in lakes is further increased by the fact that isolated inland water bodies can also have a high species endemism, resulting in global extinctions when these species are lost.

Most species need undisturbed habitat – unpolluted living space to find food and nutrients, water, shelter and mates. But people are altering habitats all over the world through following activities. This factor is recognised today as the most significant threat to global biodiversity and bears responsibility for much of the species loss worldwide. This includes:

- felling of forests for land use (i.e. clear felling for development, agriculture, etc.), large scale logging and small scale patchwork agriculture. Shifting cultivation alone is believed to be responsible for 70% of deforestation in Africa, 50% of deforestation in Asia, and 35% of forest loss in the Americas.
- destruction of mangrove sites for aquaculture
- mining and destruction of corals
- conversion of wetlands for land uses
- over-extraction of timber and fuel wood
- human-induced firing of habitats (e.g. forest firing for shifting cultivation and firing grasslands to improve fodder for cattle)
- damming of rivers
- siltation and sedimentation of freshwater bodies
- pollution also disturbs the natural habitat considerably. Industrial wastes cause severe impact, particularly on the aquatic habitats. For example, although the impact of acid rain is far from being understood, it may be a slow, subtle agent that is driving some species in the lakes and streams to extinction. Furthermore, during the 1950s and 1960s, insecticides particularly chlorinated hydrocarbons (such as DDT), reduced the population levels of several birds such as the bald eagle, brown pelican considerably.

Habitat loss is not only important in that it results in species loss, it also represents biodiversity loss in its own right. In many countries there are very few pristine areas that have not been modified in some way by humans. For example, Bangladesh has only about 6% of its original vegetation left now. In Sri Lanka too, much of the dry zone forests are secondary as they had been cleared for cultivation many centuries ago. Of the wet zone forests, only a few like parts of the Sinharaja forest remain as virgin forests; many of the others have been selectively logged for timber in the past decades.

When habitats are not completely destroyed, they are fragmented into smaller patches, creating islands of habitat in a sea of development. Fragmentation exposes species to more light, wind and temperature effects than are natural, thus affecting the species survival as food and water sources are lost and few mates remain. In fragmented landscapes many species soon become isolated from others of their own kind resulting in inbreeding, loss of genetic diversity and local extinction.

Box 9.2: Coastal fauna destruction by Tsunami, 2004

The tsunamis which rose out of the Indian Ocean on 26th December 2004, triggered by a massive earthquake near the Indonesia island of Sumatra have caused devastation in coastal areas of India, Thailand and Srilanka. The Ocean's seagrass bed and mangrove ecosystem has been effected but it is the coral reefs that bore the brunt of the destruction. The coral reef system might be totally destroyed. It will take hundreds of years to grow back. When a tsunami passes, reef structures grind into each other causing extensive damage. In serious cases, recovery would be slow as there would be fewer larval animals to repopulate the coral. A major problem would be a loss of fish displaced by the waves from their habitat and other forms of protein which depend on the reefs. Large stretches of oyster beds and coral reefs across the southern Indian coast have been completely washed away by the killer tsunami, which caused large scale destruction of massive life and scientists believed that it would take a long time for the precious ecosystem to restore. The after effects would be equally devastating on the reefs, which are spawning, breeding and nesting grounds for thousands of marine animals, have been almost wiped off the aquatic map of the Indian Ocean.

Box 9.3: What is wild life

The term wildlife probably originated in 1913 in a book, *Our Vanishing Wildlife* by William Hornaday, Director of the New York Zoological Park. The main focus of this book was on the over-exploitation of game birds, mammals and fishes; and also the harvesting of some birds that were not game, notably the song birds that the European immigrants often hunted. By 1937, the term wildlife had been contracted into one word.

Though the word wildlife was coined and contracted as one word by the nineteen thirty seven, it was not defined in the well known dictionaries. It was, however, included in the Webster's dictionary in 1986. Webster's dictionary defines wildlife as "**living things that are neither human nor domesticated**", and the Oxford dictionary says that the wildlife is "**the native flora and fauna of a particular region**".

If we are asked to prepare a list of wildlife species, the list would be dominated by examples of animals, birds and occasionally fishes. Generally, we all think that only large animals, carnivores, game animals and birds constitute the wildlife. In the present times, the term wildlife encompasses much more than the above mentioned life forms. Now plants, micro-organisms and all other lesser known living beings too fall within the purview of wildlife. One essential characteristic feature of wildlife is that they grow and survive in a particular area, without the care of human beings. They are well adapted to the soil, light and temperature conditions of that particular area. All our garden flowers are descendants of the wild flowers. The wild flowers grow on their own in nature, complete their life cycles and grow again the next season.

The Great Indian Bustard has been exterminated because of habitat destruction and hunting. Similarly, the Bengal tiger faces extinction as its jungles are torn down to supply timber and farm land.

We shall now take up the issue of habitat destruction due to deforestation, and elaborate on it further. More than three quarters of the species that are in danger of extinction today are due to the destruction of their forest habitats. A large number of these species are from the tropics, where human population growth has been most explosive and habitats have been destroyed most rapidly. Tropical rain forests cover a mere 7 percent of the earth's surface, yet they house about three quarters of the total species. Today these forests are being destroyed at an alarming rate, and if the ecosystems are obliterated, hundreds of thousands of species will be lost forever, and some of these may be of great importance. We shall now tell you about a species of wild corn, which got accidentally saved. Several years ago, a hillside in Mexico was being ploughed when a few alert scientists discovered a previously unknown species of wild corn – *Zea diploperennis*, that only grew on that hill and was found nowhere else. These corn plants are perennial whereas the domestic varieties of corn are annuals. Moreover, the wild corn is resistant to many diseases that infest domestic varieties. The species was thus saved and it is now being used to breed and improve new domestic varieties. So it is of utmost importance to save the living species from extinction from the face of the earth.

9.3.2 Over Exploitation of Resources

People use some plant and animal species at a greater rate than the species can replace themselves, which can lead to extinction. Nine of the world's major ocean fisheries are declining because of too much fishing as well as water pollution and habitat destruction. Popular commercial species such as the southern bluefin tuna, the Atlantic halibut and the Pacific and Atlantic salmon are now threatened. Current logging rates threaten to eliminate mahogany and other tree species that take many years to grow and mature.

The $10 billion-a-year global market in wildlife – for pets, folk medicines, gourmet foods, decorative objects and other uses – threatens elephants and rhinos, sea horses and colourful corals, tropical plants and birds, and bears, pandas and tigers.

Over harvesting of resources includes:

- **Poor land use planning** including ad hoc agricultural expansion and siting of development schemes, hydro-power projects, human settlements and mining projects.
- **Selective removal of economically important organisms** or their parts, such as over-harvesting of non-timber forest resources, edible species, ornamental fish and plants, and species of medicinal/medical use.
- **Replacement of indigenous varieties of crop species with new hybrids** that are higher yielding but are less resistant to pests, local conditions and need more fertilizer.
- **Hunting** for sport or subsistence, live capture for commercial use and deliberate extermination of species as pests.

9.3.3 Hunting and Export

The hunting and export of excessive numbers of certain animal species is another important factor leading to dangerous reductions in numbers. There are three main types of hunting:

i) **Commercial hunting** – in which the animals are killed for profit from sale of their furs or other parts;
ii) **Subsistence hunting** – the killing of animals to provide enough food for survival; and
iii) **Sport hunting** – the killing of animals for recreation. Although subsistence hunting was once a major cause of extinction of some species, it has now declined sharply in most areas. Sport hunting is now closely regulated in most countries; game species are endangered only when protective regulation does not exist or are not enforced.

On a worldwide basis, commercial hunting threatens a number of large animal species. The jaguar, tiger, snow leopard, and cheetah are hunted for their skins, elephants for their ivory tusks (accounting for the slaughter of about 90,000 elephants a year) and rhinoceros for their horns. Single rhino horn – which is a mass of compact hair – is worth as much as $24,000 in the black market. It is used to make handles for ornamental knives in North Yemen, and ground into a powder and used in parts of Asia for medicinal purposes, especially reducing fever. It is also thought to be an aphrodisiac or sexual stimulant even though it consists of a substance (Keratin) that can be obtained by eating hair trimmings and finger nails. Although 60 countries have agreed not to import or export rhino horns, illegal trafficking goes on because of its high market value. The number of black rhinos in Africa dropped from 65,000 to about 5,000 between the years 1970 and 1986. And about 100 white rhinos were left by 1986. If poaching continues at present rates, all species of rhino will be extinct within a decade.

Another highly published commercial hunt is that of the whale. The whaling industry has generally concentrated its efforts on the large, profitable baleen whales, which were slaughtered for their blubber and baleen, the bony sieves they filter sea water with. From the blubber, a high grade oil was made for lamps and for lubricating machines. The baleen or "whalebone" was used to make corset stays, combs and similar products.

The history of whaling is one of over-exploitation followed by abandonment. Whales harvested a species until it approached extinction and then moved on to another profitable one, repeating the patterns many times.

The blue whale, the largest animal that has ever lived, once numbered around 2,00,000 but by the mid 1950s it has been reduced to about 1,000. Many scientists believe that the blue whale population, although now protected, may not recover.

9.3.4 Selective Destruction

The selective destruction of one species of an existing fauna can produce equally unfortunate results. The perfect demonstration of unexpected consequences of such destruction occurred in the early years of this century in the USA. In a mistaken effort to increase the deer herds on the Kaibab Plateau, President Theodore Roosevelt, himself a very keen naturalist, authorized the destruction of the natural enemies of the deer, the puma and the wolf. The result was not as expected. Deprived of their natural enemies, which had served to keep their number in check, the deers multiplied so rapidly that there was soon in sufficient grazing areas to support them. As a result what had been fertile grassland capable of supporting large herds of deer was soon reduced to unproductive desert virtually unable to support any wildlife. As their available food supplied diminished so the deers died of starvation in the thousands, and in a very short time the total deer population fell far below what it had been when they were subjected to the full effects of their natural enemies.

Extinction or near extinction can also occur because of attempts to exterminate pest and predator species that compete with people and livestock for food. The Carolina parakeet was exterminated in the United States around 1914 because it fed on fruit crops. Its disappearance was hastened by the fact that when one member of a flock was shot, the rest of the birds hovered over its body, making themselves easy targets.

Fig.9.1: Passenger pigeon a lesson learnt but too late

When we talk of selective destruction we must narrate you the story of Passenger pigeon (Fig. 9.1). The Passenger pigeon (*Ectopistes migratorius*) probably was the most numerous bird on earth as recently as the middle of the nineteenth century. Passenger pigeons certainly were the most abundant birds in pristine North America. The records include very interesting details about these birds. They were in such immense numbers that their flocks darkened the sky during migration, and one such flock alone was 400 km long and had no less than two billion birds! So huge was their numbers that the branches of trees would break under the weight of the perching birds. It took hours for the flocks to pass through a place. There used to be as many as 90 nests per tree throughout a stretch of forest of about 5 km width and 67 km length. In 1871, an estimated 136 million passenger pigeons nested in a 2,200 sq. km areas of central Wisconsin. An immense tonnage of droppings fertilised the forests where passenger pigeons roosted. One interesting feature about these organisms is that a passenger pigeon laid just a single egg. All the above information gives us a picture of immense abundance of the species. But as you will see in the following details, an immense abundance does not exclude a species from extinction. Despite their large numbers, today there is not even a single passenger pigeon on the earth. You must be wondering why this extinction occurred. We shall discuss that now. Millions of passenger pigeons were killed for food.

In a span of three months in 1878, more than 1.5 million pigeons were shipped to market from a nesting area in Michigan. It is believed that, as many as 10 million may have perished due to hunting in the above area. The birds were served in fashionable restaurants in Chicago, New York and Boston for two cents each. Not sometimes were felled to obtain large numbers of young birds. Thus the outright killing of passenger pigeons often was accompanied by the destruction of irreplaceable nesting habitats. The lack of refrigeration meant that even more birds were killed to cover losses from spoilage during transportation to market. Another interesting aspect that played a great role in their extinction was the two technological developments – rail roads and telegraph, in the nineteenth century. The extensive rail network helped the pigeon hunters in providing ready access to the major nesting colonies of passenger pigeons east of Mississipi river. One dealer in New York received 18,000 birds a day as a result of the new rail connections. Because these birds were nomadic, the telegraph kept hunters informed about the locations of nesting colonies. Because the rail roads benefited from their association with the market hunters, the train companies also provided up-to-date information concerning places where pigeons might be caught. Such relentless disturbances of colonies resulted in large-scale nesting failures year

after year, and passenger pigeons steadily diminished. The last pigeon – Martha died in Cincinnati Zoo in 1914, and its body is preserved and kept in U.S. Natural Museum in Washington. The decline and eventual extinction of such an abundant species now seems beyond imagination – but is an event marking one of the darkest hours in environmental history.

9.3.5 Pollution

The more we consume, the more we generate waste and pollution, which threatens biodiversity and our own health. Pollution comes in many forms – oil spills, acid precipitation, toxic chemicals in fertilizers and pesticides, and urban and suburban sewage runoff, to name a few. Pollution may kill organisms outright or it may weaken them by interfering with vital processes such as mobility and reproduction. Pesticides harm wild insect pollinators, including managed honeybee populations, which can in turn reduce crop yields. Runoff seeping into rivers, lakes and coastal environments can produce negative impacts on entire aquatic ecosystems.

Some 140,000 people become sick because of pesticides and pesticide runoff each year. Several pesticides banned in the United States are still exported to developing countries. Of particular concern are chemicals called endocrine disrupters such as DDT , DDE and PCBs. These substances mimic or interface with normal hormones in living organisms. Reproductive abnormalities have been found in alligators, terns, salmon and gulls exposed to high levels of chemicals from pesticides and animal hormones in their environment.

9.3.6 Pesticides

Another recently realised danger to wildlife in many parts of the world has come from the development of more effective pesticides. As agriculture became more efficient so the need to control crop pests also became more urgent, and the agricultural chemists have devoted a great deal of their time and energy to synthesise compounds to meet this need. In the early 1960s it became clear that a certain group of chlorinated hydrocarbons, notably aldrin, dieldrin and heptachlor, which are undoubtedly extremely effective in controlling pests, are proving increasingly harmful to many wild animals. Their great disadvantage, it was discovered, was that whereas most other pesticides were fairly rapidly destroyed when they fell on the ground, the above three pesticides persisted in the soil for years, and tended to accumulate (bioaccumulation) since each year's spraying reinforced the persisting residues from previous years.

The first effect of these pesticides is a gradual accumulation in the bodies of worms, insects and some small animals. These in turn are eaten by birds, which thus acquire these accumulations, and the effects of which may be reproductive failure and egg shell thinning. These effects have been seen in birds like peregrine falcon, eastern and California brown pelicans, osprey, bald eagle.

In India, the threat to wildlife through the use of these compounds had taken rather a different turn. Here the farmers have been using them directly as poisons to kill tigers, leopards and other large animals either by adding a few grams to the animal's food or by scattering poisoned bait along their known tracks. In Kerala, elephants have also been killed by poisoned bananas.

9.3.7 Global Climate Change

Substantial evidence demonstrates that people are contributing to measurable changes in the global climate, threatening life as we know it. By burning fossil fuels such as oil, natural gas and coal and by burning trees to clear forests, we have dramatically increased the amount of CO_2 in the atmosphere. While scientists do not know the exact effects of increased CO_2, they predict that it will lead to higher overall global temperatures, increasing sea levels, and changes in climate patterns.

The changed atmospheric conditions that result from global warming could create greater numbers of intense storms and prolonged droughts. The warming may lead certain species to expand their ranges, including mosquitoes that carry malaria and encephalitis among other diseases. On the other hand, the expected speed of climate changes coupled with direct loss of natural habitat may prevent some species from adapting quickly enough. They are likely to become extinct, locally or more broadly, and their roles in natural systems will be lost forever.

Many ecosystems are highly vulnerable to the projected rate and magnitude of climate change. Corals are "bleaching" (losing their necessary symbiotic algae) throughout the world because of increased water temperatures, and many are not recovering. The goods and services lost as ecosystems are fragmented or disappear, including changes to and loss of biodiversity, are likely to be very costly or impossible to replace.

9.3.8 Invasive Species

Purposely or accidentally, people often bring non-native species into new areas where the species have few or no natural predators to keep their populations in check. These invasive species – also called **alien**, **introduced** or **exotic species** – are considered the most important cause of biodiversity loss. Invasive alien species which are accidentally or intentionally introduced into new areas. They range from microbes to mammals. Invasive species also cause economic and environmental havoc. Invasive species can also alter fire cycles, nutrient cycling and the hydrology and energy budgets in native ecosystems. The problem of invasive species will rise severely through climate change. According to Dr. Mac Kinnon, alien species have been introduced to a country by people with good motives in mind, but may lead to disastrous results.

As long as human beings have travelled around the world, they have carried with them (accidentally or intentionally) many species of plants and animals, which they have introduced to new geographical areas. In some instances, an opening has existed in the new environment and the foreign or alien species has been able to establish itself without seriously affecting the population size of the native species. But in other instances, the alien has been a superior predater, parasite or competitor, and has brought about extinction or near extinction of native species. It can also cause a population explosion of the existing species by killing off their natural predators. Island species are particularly vulnerable because many have evolved in ecosystems with few if any natural herbivores, or carnivore predators.

In 1859 a farmer in southern Australia imported a dozen pairs of wild European rabbits as a game animal. Within six years these 24 rabbits had mushroomed to 22 million so that by 1907 they had reached every corner of the country. By the 1930s, their population had reached an estimated 750 million. They competed with sheep for grass and this cut the sheep population to half. They also devoured food crops, gnawed young trees, fouled water holes and accelerated soil erosion in many places. In the early 1950s, about 90% of the rabbit population was killed by the deliberate human introduction of a virus disease. There is a concern, however, that members of the remaining population may eventually develop immunity to this viral disease through natural selection and again become the scourge of Australian farmers.

Fig.9.2: Dodo, the first animal species whose extermination could be fully documented

We shall now take up another example that demonstrates the devastating effects of the introduction of alien species on islands. In islands, particularly the endemic species are often inadequately equipped to deal with invasions of humans and their domestic animals. For example, the bird dodo (Fig. 9.2) lived only in Mauritius, which is a small island. The dodo possessed two characteristics that were its eventual undoing; it had no fear of people and, therefore, could be easily clubbed to death, and it was flightless, so, it had to lay its eggs on the ground. The dodo became extinct by 1681, after the introduction of pigs to the island, who devoured its eggs. The extinction of

Dodo may also be analysed in terms of changed habitat conditions due to the introduction of a new species – pigs, to the island.

On an island, both the variety of habitats, and the area that comprises each habitat are physically limited. As a result of such constraints, the native animals' ability to adapt to new predators and competitors is often reduced. For example, the habitat may not be large enough or diverse enough for a prey species to avoid new predators. And the diversity of resources may not be adequate to allow an existing species to coexist with a new competitive species. Hence, in some instance competitive exclusion leads to extinction of the native species. For example, the habitat was not large enough or diverse for the prey species (Dodo) to avoid new predators (pigs).

Competition exclusion can be illustrated by the demise of tortoise on one of the Galapagos islands after fisherman released some goats on the island in 1957. When a research team from the Charles Darwin Station arrived in 1962 to investigate the tortoise population on the island, they found only empty tortoise shells, many of which were wedged among the rocks that covered the upland slopes. Investigations of the lowland indicated that all the vegetation that had previously been within reach of the tortoises had been consumed by the flourishing goat herd. As a result, the hungry tortoises apparently were forced to obtain food on rocky slopes, where they subsequently either became entrapped between rocks or fell over precipices and starved to death.

Island flora, too, has been devastated by the introduction of alien species. For example, in the Hawaiian islands, no large herbivorous animals existed until the 1700s, when Europeans introduced domestic livestock. Because no prior selection pressure had existed to favour them, thorns or poisons to ward off herbivores were not characteristic of native plants. Moreover, the limited size of habitats on the islands favoured overgrazing. Thus species that had not been threatened previously were devastated by grazing animals. As a result, nearly one half of the native vegetation in the Hawiian islands is thought to be in danger of extinction.

An island, in the usual sense of the word, is a land mass that is surrounded by water. Ecologically, however, a *habitat island* is defined as any restricted area of habitat that is surrounded by dissimilar habitats. Hence, a lake without outflow is considered to be an aquatic island. Also, when natural habitats are bisected by highways and converted into farms and cities, natural and semi-natural areas become increasingly smaller and more isolated (Fig. 9.3). To save what little remains, some of those isolated areas have been set aside as parks and conservancies. Forest preserves are usually widely scattered and the intervening highways, farms and cities serve as barriers that prevent the migration of many species of plants and animals into and out of them. Hence those natural and semi-natural habitats have become islands as well, and the animals and plants that live in them are subject to the same pressures as those living on islands that are surrounded by water. Furthermore, the smaller the habitat island, the greater is the pressure on its inhabitants. Thus we would consider these factors when we plan how to use land rather than indiscriminately invade and carve up natural habitats into increasingly smaller pieces.

Some other classic examples are:

- Golden apple snail is one of the most devastating invasive alien species. It was imported from Latin America to South East Asia in the 1980s.
- Water hyacinth, a water plant with a showy purple flower was a native of the Amazon Basin and is now seen as the most important nuisance aquatic plant worldwide. It affects water flow, electricity generation, transport, water quality and indigenous biodiversity.
- Prosopis (Mesquite) in the Thar desert of India has displaced other flora of the area, while the species introduced to a semi-arid area of Sri Lanka in the early

1950s, has become as invasive seriously threatening the biodiversity of the only Ransar– listed wetland of the country.

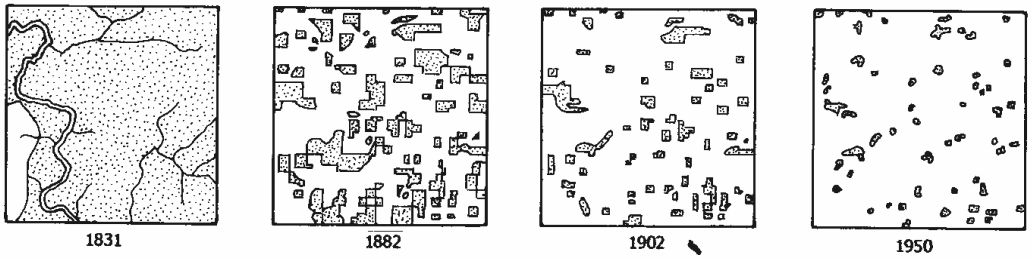

Fig.9.3: The reduction and fragmentation of woodland (shaded areas) in Cadiz township, Wisconsin between 1831 and 1950. The piecemeal destruction of habitat resulted in piecemeal extinction of many species (after J. Curtis, 1955)

Carolina parakeet –their brightly coloured leathers caused their downfall. These feathers were prized for decorating women's hats and made the birds popular as pets. Their extinction came in 1914. The heath hen was used as food. In the early 1900s people realised that the bird was becoming scarce and a bird sanctuary was set up. The flock soon grew, but a fire swept across the sanctuary, and only a few males survived. The last bird died in 1932.

The Labrador duck became extinct before anyone realised it was gone. Most of the birds were killed for their feathers, which were used to stuff pillows.

Among all the countries, India has the greatest number of mammalian species on the threatened species (endangered, rare etc.) list, and in the Red Data Book, ranks first of the world.

9.3.9 Domestication

It means that man has taken under his direct care the living beings which are useful to him. Through extensive breeding programmes, he has modified them to derive maximum benefit of their products. During the process, the species have lost certain useful characteristics so much so that these forms cannot survive on their own in nature. A very good example is corn, which is pampered so much by man that if it is left on its own, it cannot survive.

We shall now take up the other aspect of how domesticated species create hostile conditions for the survival of wildlife.

Today man has large herds of domestic animals. These animals can also play a significant part in the reduction of animal populations by overgrazing the land, thus destroying the vegetation on which both they and the wild animals depend. The native wildlife of a particular area is capable of utilising the native plant life much more efficiently than introduced domestic cattle, and is thus much less likely to convert fertile areas into deserts. So, often domestic animals have little more than prestige, value, providing little in the way of either meat or milk.

The other important parameter is that the domestic cattle are carriers of several diseases which they can transmit to wild animals. For example, the steady rehabilitation of the Great Indian Rhinoceros was seriously hampered by the rinderpest disease which they contracted from the local domestic cattle.

Box 9.4: Causes of biodiversity loss in Asia

The underlying cause of biodiversity loss is the failure of policy and budgets to recognise and reflect the fundamental relationship between economic and biodiversity well-being. There are five related causes of loss, all associated with human economic processes of production and consumption:

1. Over-harvesting of animals and plants.
2. Destruction of habitat such as forests, wetlands and coral reefs, and their replacement by high-yielding aquaculture, agricultural and forestry monocultures.
3. Fragmentation, simplification and impoverishment of remaining ecosystems leading to "islands" of habitat in a sea of disturbance (the smaller the island, the more vulnerable to extinction are its species).
4. Invasive alien species introduced into natural systems (accidentally or internationally).

5. Pollution of water, soil and air.

Source: MacKinnon (2002).

SAQ 1

Oceanic islands are particularly vulnerable to species extinction because

i) Species in them have restricted ranges
ii) Species in them are not adapted to compete with introduced alien species
iii) Many species in them have characterises that make them vulnerable to predators
iv) All of the above

SAQ 2

Habitat islands are best described as:

i) Lands surrounded by water
ii) Habitats surrounded by environments inhospitable to species that they contain
iii) Fragile habitats of high risk to species extinction
iv) All of the above

SAQ 3

It is believed that fewer species are able to persist in a fragmented habitat than they would have in the original habitat based on the:

i) Species area relationship
ii) Island biogeography theory
iii) Rate of habitat loss in tropical forests
iv) All of the above

SAQ 4

The main reason for animal species extinction at the current high rates are:

i) Habitat destruction
ii) Hunting
iii) Over harvesting from the wilds
iv) Competition from alien invasive species

SAQ 5

Habitat modification may occur due to

i) Fragmentation of original habitat
ii) Pollution
iii) Changes in species composition due to humans
iv) All of the above

SAQ 6

There is depletion of crop genetic diversity due to

i) Replacement of indigenous varieties of crop species with new hybrids
ii) Expansion of monoculture
iii) Selective breeding of some varieties of crops
iv) All of the above

9.4 EXTINCT AND THREATENED SPECIES

Some of wildlife species are considered threatened and some are extinct. What is the difference between the two? You would study in this section. Also you would learn about the various classes of threatened species.

9.4.1 Extinct Species

These no longer exist outside museums and photographs. You have read about the passenger pigeon in the previous section. It is one of the most noted examples of extinct species. Other extinct species include the Carolina parakeet, heath hen, Labrador duck, Cheetah, Pink-headed duck, and Jerdon's Courser.

The above examples indicate that the species have become extinct because of human activities. Many conservation experts warn that if deforestation, desertification and destruction of wetlands and coral reefs continue at their present rate, at least 5,00,000 and perhaps 1 million species will become extinct as a result of human activities between 1975 and 2000. Using the lower estimates, this amounts to an average extinction rate by 2000 of 20,000 species a year, or 1 species every 30 minutes. There is thus a 200-fold increase in the extinction rate in only 25 years (that is between 1975 and 2000). Most of the species will be plant and insects that are yet to be classified and not much is known about their use to people and their role in the ecosystems.

Although animal extinctions receive the most publicity, plant extinctions are more important ecologically, because most animal species depend directly or indirectly on plants for food. An estimated 10 percent of the world's plant species are already threatened with extinction and an estimated 15 to 25 percent of all plant species have faced extinction by 2000.

You will be curious to know as to why some species are more prone to extinction than others. It is because of their special characteristics which are listed in Table 9.2.

While you study these characteristics, you should keep in mind that **no single species possesses all of the following characteristics.**

It is believed that out of the 15,000 flowering plants that exist in India, at least 100 or possibly up to 200 plants are found to be threatened. Amongst the most threatened plant species in India are over-exploited medicinal plants, ornamental plants like orchids and botanical curiosities like pitcher plants. Some 1250 species or orchids occur in India, of which 300 are becoming scarce in Meghalaya, alone. Today, about 20 Meghalayan orchid species are threatened. Given below are a few examples of threatened plants in our country.

1. Atis
2. Vacha
3. Khulanjan
4. Angurshaga
5. Guggal
6. *Mishmee teeta*
7. *Picotee dendrobium*
8. Kins
9. Snow Orchid
10. Kadu
11. Lotus
12. Indian *Podophyllum*
13. Sarpagandha
14. Sukad
15. Kuth roots
16. Brahm Kamal

Table 9.2: Characteristics of Extinction-prone Species

S.No.	Characteristic	Details	Examples
1.	HABITAT	i) Island species – unable to compete with invasion from continental species	Pureto Rican parrot; Pahrump Killifish, Indiana Bat, Golden-Cheeked Warbler. Besides this, more than half of the 200 plant species of Hawaii are endangered.
		ii) Species with limited habitats – some species are found only in a few ecosystems (endemics)	Woodland Caribou, Everglades Crocodile millions of species in the tropical rain forest, Elephant,Seal,
		iii) Species with specialised niches – the niche can be destroyed even if the ecosystem remains more or less intact	Cooke's Kokio Ivory-billed Woodpecker, Whooping Crane, Orangutan
2.	FEEDING HABITS	i) Specialised feeding habits	Everglade Kite (apple snail of

		ii) Feed on high tropic levels	southern Florida); Blue Whale (Krill in polar upwelling areas); Black-footed Ferret (prairie dogs and pocket gophers); Grant Panda (bamboo) Bengal Tiger, Bald Eagle, Andean Codor, Timber Wolf
3.	REPRODUCTION	i) Species with low reproductive rates. Many species evolved low reproductive rates because predation was low, but in modern times, people have become very effective predators against some of these species	Blue Whale, California Condor, Polar Bear, Rhinoceros, Passenger Pigeon, Giant Panda, Whopping crane
		ii) Specialised nesting/breeding areas	Kirtland's Warbler (*Nests only 6 to 15 years old Jack pine trees*); Whooping Crane (*depends on marshes for nesting*); Green Sea turtle (*lays eggs on a few beaches*); Eagle (*prefers forested shoreline*); Nightingale wren (*nests and breeds only on an island in Panama*)
		iii) Species that have limited number of off-springs per breeding, long gestation/incubation periods, or require extensive parental care	Mountain Gorilla, Abbott's booby, Mississipi Sandhill Crane, California Condor
4.	PREDATORS	Often killed to reduce predation of domestic stock	Grizzly Bear, Timber Wolf, Bengal Tiger, some Crocodiles, Asiatic Lion, Gray Wolf.
5.	BEHAVIOUR	i) Intolerant of the presence of humans	Grizzly bear Passenger pigeon (*used to nest in large colonies*)
		ii) Peculiar behavioural pattern of the extinct species	Red-headed woodpecker (*files in front of cars*);
		iii) Behavioural	Carolina Parakeet

Amphibians and Reptiles

1. Agra Monitor Lizard
2. Atlantic Ridley Turtle
3. Barred, Oval or Yellow Monitor Lizard
4. Crocodiles
5. Gharial
6. Ganges soft-shelled Turtle
7. Green Sea Turtle
8. Hawksbill Turtle
9. Himalayan Newt or Salamander
10. Indian egg-eating Snake
11. Indian Soft-shelled Turtle
12. Indian Tend Turtle
13. Large Bengal Monitor Lizard
14. Leathery Turtle
15. Logger-head Turtle
16. Oliver-back Logger-head Turtle
17. Peacock-marked soft-shelled Turtle
18. Pythons
19. Three-keeled Turtle
20. Tortoise
21. Viviparous Toad
22. Water Lizard

Birds

1. Andaman Teal
2. Assam Bamboo Partridge
3. Bazas
4. Bengal Florican
5. Black-necked Crane
6. Blood Pheasants
7. Brown headed Gull
8. Cheer Pheasant
9. Eastern White Stork
10. Forest Spotted Owlet
11. Great Indian Bustard
12. Great Indian Hornbill
13. Hawks
14. Hooded Crane
15. Hornbills
16. Houbara Bustard
17. Humes bar-backed Pheasant
18. Indian Pied Hornbill
19. Jerdon's Courser
20. Lammergeier
21. Large Falcons
22. Large Whistling Teal
23. Monal Pheasants
24. Mountain Quail
25. Narcondom Hornbill
26. Nicobar Megapode
27. Nicobar Pigeon
28. Osprey of Fish – eating Eagle
29. Peacock Pheasant
30. Peafowl
31. Pinkheaded Duck
32. Scalater's Monal
33. Siberian White Crane
34. Spur Fowl
35. Tibetan Snow-Cock
36. Tragopan Pheasants

		idiosyncrasies that are non-adaptive today	(*when one bird is shot, rest of the flock hovers over the body of the dread bird*); Key Deer (*forages for cigarette butts highways – it is a "nicotine addict"*)
		iv) Migration – live largely in (or migrate across) international boundaries.	Atlantic Green Sea Turtle, Ocelot, Atlantic Salmon, Blue Whale, Kirtland's Warbler, Whooping Crane
6.	ECONOMICALLY VALUABLE FOR SPORT	Hunting pressure by humans for various commercially important products	Snow Leopard, Blue Whale, Elephant, Rhinoceros
7.	POLLUTION	Some species are more susceptible to industrial pollution, insecticides and pesticides	Bald Eagle, Great Indian Bustard

Threatened species of mammals in India (IUCN, 2003)

Critically Endangered (CR)
- Jenkin's Shrew
- Malabar Large Spotted Civet
- Namdapha Flying Squirrel
- Pygmy Hog
- Salim Ali's Fruit Bat
- Sumatran Rhinoceros
- Wroughton's Free-tailed Bat

Endangered: (EN)
- Andaman Shrew
- Andaman Spiny Shrew
- Asian Elephant
- Banteng
- Blue Whale
- Capped Leaf Monkey
- Chiru (Tibetan Antelope)
- Fin Whale
- Ganges River Dolphin
- Golden Leaf Monkey
- Hispid Hare
- Hoolock Gibbon
- Indian Rhinoceros
- Indus River Dolphin
- Kondana Soft-furred Rat
- Lion-tailed Macaque
- Markhor
- Marsh Mongoose
- Nicobar Shrew
- Nicobar Tree Shrew
- Nilgiri Tahr
- Particolored Flying Squirrel
- Peters' Tube-nosed Bat
- Red Panda (Lesser Panda)
- Sei Whale
- Servant Mouse
- Snow Leopard
- Tiger
- Wild Water Buffalo
- Woolly Flying Squirrel

Vulnerable: (VU)
- Andaman Horseshoe Bat
- Andaman Rat
- Argali
- Asiatic Black Bear
- Asiatic Wild Ass
- Assamese Macaque
- Back-striped Weasel
- Barasingha
- Bare-bellied Hedgehog
- Blackbuck
- Central Kashmir Vole
- Clouded Leopard
- Day's Shrew
- Dhole
- Dugong
- Eld's Deer
- Elvira Rat
- Eurasian Otter
- Four-horned Antelope
- Gaur
- Himalayan Tahr
- Humpback Whale
- Indian Giant Squirrel

9.4.2 Threatened Species

India ranks second in terms of the number of threatened mammals and sixth in terms of countries with the most threatened birds (IUCN, 2000).

Many plant and animal species are threatened by the possibility of extinction. However, the seriousness of the threat varies. For example, a species with fewer than 50 known survivors living in one small area is in much more critical condition than another with 5,000 individuals living in several areas.

The Survival Service Commission (now called Species Survival Commission) of International Union of Conservation of Nature (IUCN) has established four categories of threatened species. These describe the degree to which a species is threatened with extinction. These categories are:

i) Endangered
ii) Rare
iii) Depleted, and
iv) Indeterminate

i) Endangered Species: A species is considered endangered when its numbers are so few or/and its homeland is so small, that it may become extinct if not given special protection.

The lion-tailed macaque which inhabits the rain forests and "Sholas" of South India, is among the world's most endangered primates. It is believed that there are not more than 195 of this beautiful animal left in the wild, as its forest home has diminished rapidly over the last 30 years to a small fraction of its former extent. The habitat of these rain forest dwellers had dominant *Dipterocarpus* trees, which have been cleared indiscriminately for establishment of coffee and tea estates. Poaching is also responsible for reducing their number considerably. The animal is also hunted for its flesh. Their capturing for pet and zoo trade also flourishes.

ii) Rare Species: These are those species whose numbers are few or they live in such small areas or in such unusual environments (endemics), that they could quickly disappear.

The Hawaiian monk seal (*Monachus schauinslandi*) is an example of a rare species. It is found only on six small islands extending north west from the Hawaiian islands. There are probably no more than 1,500 of these seals. They were killed for their fat in the late 1800s and they almost became extinct. Since 1909 they have been protected and have slowly increased in number.

Unfortunately, even stopping the killing may not be enough to save these seals. If they are disturbed on the beaches where they give birth, the mothers rush away into the water. Many of the pups left behind die. With all the Hawaiian monk seals located on just these few islands there is a great possibility of these being wiped off, by some natural catastrophe, such as an oil slick. There are a few in captivity, but they have never bred.

The second example is of the Great Indian Bustard (*Ardeotis nigriceps*), one of the world's rare birds, belonging to India. Its earlier distribution ranged from Pakistan east to West Bengal and Southwards through the Peninsular region of southern Madras. It occurs in small groups, in large grassland tracts, cultivated fields in arid and semi-arid lands of Gujarat, Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Haryana and Uttar Pradesh. It is believed that, presently only 750 birds are left, Gujarat being the main surviving habitat for the species today. This, rare and apparently declining species has been annihilated in the recent past by poachers and its natural habitat has been destroyed. The indiscriminate use of insecticides and pesticides around its natural habitat has also affected them. They have also been slaughtered for food. In all, the situation is pretty bad, and we can say that locating a bustard at the moment is often as hard as "finding a needle in a haystack"!

- Kerala Rat
- Khajuria's Roundleaf Bat
- Kolar Leaf-nosed Bat
- Lesser Horseshoe Bat
- Mainland Serow
- Malayan Porcupine
- Mandelli's Mouse-eared Bat
- Mouflon (or Urial)
- Nicobar Flying Fox
- Nilgiri Leaf Monkey
- Nilgiri Marten
- Nonsense Rat
- Pale Grey Shrew
- Palm Rat
- Red Goral
- Sikkim Rat
- Sloth Bear
- Slow Loris
- Smooth-coated Otter
- Sperm Whale
- Sri Lankan Giant Squirrel
- Sri Lankan Highland Shrew
- Stumptail Macaque
- Takin
- Wild Goat
- Wild Yak

iii) Depleted (Vulnerable) Species: These are the species whose numbers are greatly reduced from those of the recent past, and they are continuing to decrease. It is the continued decrease, that is the main cause of concern. Animals in this category can quickly change to a rare or endangered status.

The addax (*Addax nasbmaculatus*) of northern Africa is a member of the antelope family. It originally lived in deserts from Egypt to Mauritina. This animal has been so heavily hunted that presently, fewer than 5,000 survive all across their former range. Since 1900, they are no more in Egypt, and they have also been wiped out in Tunisia. It is doubtful whether they exist in Libya and Spanish Sahara, Algeria or Sudan. Their last stronghold seems to be in Mauritania and Mali, where they are still hunted by nomadic natives, who dry the meat for food. The number of the addax antelope continues to decline. If the population continues to decrease much longer, the species will become extinct. However, if the hunting were stopped today, there would still be enough animals and a habitat extensive enough for the species to survive.

In the past few years, the fur of the clouded leopard (*Neofelis nebulosa*) was sold illegally in Kashmir markets. In Himalayas, its number has decreased so much that it is rarely seen. The deteriorating state of the evergreen forests, accounts for its depleted status. Since the range of this beautiful animal extends from Nepal, Bhutan, Sikkim to Assam, proper steps for its conservation can save it from reaching a point of extinction.

iv) Indeterminate Species: The fourth category consists of those species that seem to be in danger, but there is not enough information about them to make a reliable estimate of their true status.

Examples of species in this category are many. One is the three-banded armadillo (*Tolypeutes trincinctus*) of north eastern Brazil, which is hunted for its flesh.

Second, the short-eared rabbit (*Nesolagus netscheri*) of Sumatra which is disappearing as the forests are cleared for agriculture. Third is the Mexican prairie

dog (*Cynomys mexianus*) which is killed for food and whose habitat is taken over for agriculture.

Usually, when detailed information is collected about an indeterminate species, its changes and depending upon its status it may be placed in any of the above three categories, or may be declared a safe species. For example, the status of the Amazon manatee (*Trichecus inunguis*) a fresh water sea cow, was considered indeterminate in 1966. Within two years, its condition was determined and changed to endangered. Since it is hunted for its flesh, it is now amongst the most endangered species. The snow leopard (*Leo uncia*) was classified as indeterminate species in 1968, and was declared endangered in 1970. You probably know that the snow leopard is hunted for its thick beautiful fur.

Out of Danger Species

This includes species, that were formerly included in one of the above categories, but are now considered relatively secure because effective conservation measures have been taken or the previous threat to their survival has been removed.

The Red Data Book

Species judged as threatened are listed by various agencies as well as by some private organizations. The most cited of these lists is the Red Data Book. It is a loose-leaf volume of information on the status of many kinds of species. This volume is continually updated and is issued by the International Union for Conservation of Nature (IUCN) located in Morges, Switzerland, "Red" of course is symbolic of the danger that these species both plants and animals presently experience – throughout the globe. The Red Data Book was first issued in 1966 by the IUCN's Special Survival Commission as a guide for formulation, preservation and management of species listed. In this Book, information for endangered mammals and birds is more extensive than for other groups of animals and plants, coverage is also given to less prominent organisms facing extinction.

The pink pages in this publication include the critically endangered species. As the status of the animals changes, new pages are sent to the subscribers. Green pages are used for those species that were formerly endangered, but have now recovered to a point where they are no longer threatened. With passing time, the number of pink pages continue to increase. There are pitifully few green pages.

SAQ 7

In the line on the left of each phrase in column A write the letter of the word in column B that *best matches* the phase. Each word in column B may be used once, more than once, or not at all.

A	B
i) Species which are thought to be in danger but their exact data is not available	a. extinct species
ii) Species whose numbers are few or they occur in unusual environments	b. threatened species
iii) Species whose all individuals have perished	c. endangered species
iv) Species whose numbers have greatly reduced in the recent past and they continue to decrease	d. rare species
	e. depleted species
	f. indeterminate species
	g. out of danger species

SAQ 8

Which of the following best defines wildlife? Write your answer in the space provided.

a) all birds and animals that are not domesticated by humans
b) all micro-organisms occurring in a forest that are not useful to man
c) all forms of life that man has not been able to domesticate
d) all forms of life including micro-organisms that grow and survive without human intervention.

SAQ 9

The following are some of the basic causes that threaten the existence of wildlife:

a) elimination or disturbance of habitat
b) domestication
c) introduction of new species
d) selective destruction
e) hunting and export
f) pesticides
g) pests, medical research and zoos

For each of the following explanations, indicate which of the above cause is involved. Write the correct choice in the space on the left side. Write N if none of the above are involved.

i) being superior competitors, some alien species pose danger to the originally occurring species.
ii) disruption in reproduction and various other disorders are seen in instances of bioaccumulation.
iii) non-availability of food, proper habitat and human care to the animals.
iv) destruction or non-availability of the area where species seek food, get shelter and reproduce because of factors like deforestation, over-grazing, agriculture, urbanisation, pollution, development projects and mining.
v) picking, choosing, over-exploiting and exterminating a particular species for various uses.
vi) bringing under human care, and modifying their characters through selective breeding to suit the human requirements.
vii) chasing, capturing or killing of wild animals for sport, subsistence or profit.
viii) natural enemies; and collection of animals for exhibition, breeding and as tool for study.

Box 9.5: The categories of threatened species (IUCN, 2003)

Extinct (EX)

A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

Extinct in the Wild (EW)

A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

Critically Endangered (CR)

A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria for Critically Endangered, i.e. reduction in population (> 90% over the last 10 years), population size (number less than 50 mature individuals), quantitative analysis showing the probability in wild in at least 50% in their 10 years) and it is therefore considered to be facing an extremely high risk of extinction in the wild.

Endangered (EN)

A taxon is Endangered when the best available evidence indicates that it meets any of the criteria for Endangered, i.e. reduction in population size (70% over the last 10 years), population size estimated to number fewer than 250 mature individuals, quantitative analysis showing the probability of extinction in wild in at least 20% within 20 years and it is therefore considered to be facing a very high risk of extinction in the wild.

Vulnerable (VU)

A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria for Vulnerable i.e. reduction in population (> 50% over the last 10 years) population size estimated to number fewer than 10,000 mature individuals, probability of extinction in wild is at least 10% within 100 years, and it is therefore considered to be facing a high risk of extinction in the wild.

Near Threatened (NT)

A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

Least Concern (LC)

A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

Data Deficient (DD)

A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.

Not Evaluated (NE)

A taxon is Not Evaluated when it is has not yet been evaluated against the criteria.

SAQ 10

A species becomes extinct

i) When all individuals die out in its natural habitat without leaving any progeny
ii) When a species only exists in captivity
iii) When all individuals die out in its natural habitat or elsewhere without leaving any progeny
iv) All of the above

SAQ 11

According to the latest IUCN criteria and categories, a species is listed as threatened when:

i) It is in danger of extinction in the immediate, near or medium-term future
ii) It will become extinct if no conservation action is initiated
iii) It will become extinct if existing conservation action is reduced to terminated
iv) It will become extinct within the next 100 years

SAQ 12

Species are less vulnerable to extinction with

i) Increasing body size
ii) Greater ability to survive in modified or interface habitats
iii) Low adult survival rates
iv) Increased ecological specialisation

SAQ 13

According to the 2000 Red List of Threatened Animals and Plants released by IUCN, the most threatened group of species worldwide are:

i) Mammals
ii) Birds
iii) Fishes
iv) Plants

SAQ 14

Natural extinctions occur

i) When species are lost from their natural habitats
ii) When natural causes such as glaciation, break up of continents or extraterrestrial impact occur
iii) When species are lost due to human activities
iv) When species are lost due to global warming

9.5 CAUSES OF SPECIES EXTINCTION

Extinction is caused through various processes:

- Deterministic processes that have a cause and effect – e.g. glaciations, human interference such as deforestation.
- Stochastic processes (chance and random events) that effect the survival and reproduction of individuals – e.g. unexpected changes of weather patterns, decreased food supply, disease, increase of competitors, predators or parasites, etc. that may act independently or add to deterministic effects.

The impact of these processes will of course depend on the size and degree of genetic diversity and resilience of populations. Conservationists are now trying to see if the species which are most at risk from extinction following habitat fragmentation can be predicted from a knowledge of their biology and ecology. Several life history traits (some of which are highly linked with others) that adversely affect or increase a species' vulnerability to extinction due to habitat fragmentation have been identified. These are:

- rarity or low abundance
- poor dispersal ability
- ecological specialization
- unstable populations

- high trophic status – as animals occupying a higher trophic level (i.e. the position of a species in a food chain) usually have smaller populations than those at lower levels (e.g. carnivores are fewer in number than herbivores)
- low adult survival rates
- low intrinsic rate population increase

On the other hand,

- species that are able to tolerate conditions at the interface of habitats (e.g. forest edge species) may benefit from fragmentation, and
- long lived animals are less vulnerable to become extinct than short-lived species.

Other traits that can have a bearing on the vulnerability of species to extinction are body size, fecundity, dietary specialisation, natural abundance in continuous rain forests and abundance of species in modified habitats surrounding the original forest habitat fragments. The latter has been found to be very important in determining survival in fragmented habitats.

9.5.1 Natural Extinction

Over geological time, all species have a finite span of existence. The average life span of a species derived from the fossil record is 4 million years.

Natural extinction patterns are usually based on the study of the earth's fossil record in geological time. The available information indicates that overall extinction rates have not been constant over time, and that around 60% of the species extinctions have happened in relatively short episodes or spasms.

Natural extinctions have been caused due to several factors:

- the late Permian extinction is believed to be associated with global physical changes such as formation of the super continent Pangea, climate change, tectonic activity and increased volcanic activity.
- the late Ordovician extinction is correlated with global glaciation 439 Mya.
- there is some evidence that the late Cretaceous extinction was associated with an extra-terrestrial impact, but this fact remains controversial.

Extinction in vascular plants has been more gradual compared with the loss of animals. It is believed that extinction among this group was due more to competitive displacement by more advanced plant forms, or due to a gradual climate change, than due to any sudden catastrophic event.

9.5.2 Artificial Extinction

Even though species extinction is a natural process which can happen without the intervention of humans, extinctions caused by humans is now happening over and above the reasonable estimate of natural extinction rates.

The arrival of humans on previously isolated continents seem to coincide with large-scale extinction in certain groups of animals, although we cannot disregard the fact that climatic changes at these times may also be responsible for species loss.

However, around the time humans arrived in the Australian continent around 50,000 years ago, this land area lost nearly all species of very large mammals, giant snakes and reptiles and nearly half of its ratites (flightless birds). Similarly, North America

lost 73% and South America lost 80% of their genera of large mammals at the time of arrival of the first humans to these continents.

Species are threatened with extinction by the intervention of humans due to:

- **direct** causes – such as hunting, collection or capture and persecution
- **indirect** causes – such as habitat loss, modification and fragmentation and the introduction of invasive species.

In overall terms of global biodiversity loss, habitat modification and loss have had far more serious and far-reaching impacts on the loss of species diversity.

9.6 ESTIMATING RATES OF SPECIES EXTINCTION

Documenting definite species extinction is difficult unless a species can be readily seen and has a well defined geographic range that can be surveyed periodically. As such, global extinction rates are predicted more by extrapolation of measured or predicted rates of habitat loss. Various theories and models have been used by conservation biologists to try and predict the rate of species loss and to determine the species that are not in danger of extinction.

Estimates of current and future extinction rates are based on well documented relationship between the number of species in a region and habitat area and on reasonably well known rates of habitat loss.

In practice, most global extinction rates have been based on estimates of species richness in tropical forests, combined with estimates of actual and projected (estimated) deforestation rates. This has been justified on the basis that a vast majority of terrestrial species occur in tropical forests. Thus, Ehrlich and Wilson (1991) have estimated that on the basis of a 1.8% of loss of rain forest per year, there will be a 2-3% loss of rain forest species per decade. Estimates thus indicate that there could be about a 5-15% loss of species between 1990 and 2020 if the current rate of forest loss continue to increase. A more recent estimate by Reid, 1992 has predicted that global loss of rain forest species will be in the order of 1-5% per decade, and interpreted 2-8% percent of forest species will be "committed to future extinction" due to deforestation between 1990 and 2015.

Even on the best available present knowledge, the estimates of species loss that are proposed involve large degrees of uncertainty, so that we need to interpret predictions of current and future extinctions rates with considerable caution. What is more important is that every effort to estimate extinction rates have given rise to a very high figure.

9.7 MAJOR IMPACTS OF BIODIVERSITY LOSS

The continued loss of biodiversity will greatly impact human society as well as ecosystem and their valuable services. It is difficult to quantify these impacts. But looking at all the products and services biodiversity provides – and the difficulty of their replacement – gives us an idea of the magnitude of the consequences we face if we do not conserve the biodiversity.

There are several perceptible effects of biodiversity loss at both global and national levels. Some major effects are listed as follows:

i) **A steady increase in atmospheric CO_2 level** due to disruption of the carbon cycle in nature, is one of the most obvious of global climate changes in recent years. Clearing and destruction of tropical moist forest is expected to increase the atmospheric CO_2 and decrease the carbon-fixing potential of the biosphere.

"Rises in temperature associated with *El Nino* and global warming have caused 180 coral bleaching episodes in the past nine years: this compares to 100 events in the preceding decade and only three recorded events in the previous century. These episodes have killed 95 percent of all shallow -water corals in the Indian Ocean."

Source : MacKinnon, (2002).

ii) **Adverse effects on local climate and water flow** due to loss of tropical forests.

iii) **Decrease of overall population size of species** and loss of geographic range due to:

- splitting of previously contiguous (i.e. connected) populations into small isolated sub-populations that are more vulnerable to extinction than large populations. This occurs due to habitat fragmentation.

  A study of forest patches in the Brazilian Amazon has shown that forest fragments had lower species richness, a greater proportion of rare species, and less dense populations of species when compared with large undisturbed forest areas. The differences were greatest when the fragments were less than 1 ha.

- their original habitat being made unsuitable for continued existence due to habitat modification by activities such as clearing, pollution and landfills.

- contamination of soil and ground water by heavy metals and persistent organic compounds that make them unusable for agriculture; pollutants, pesticides and sediment added to soil and water that make habitats unusable to aquatic and soil living species, kills beneficial species and disrupts food webs.

- the filling of wetlands by considering them as waste lands. This also serves to decrease the water holding capacity of these areas and results in the increase of propensity for flooding.

- atmospheric pollution resulting in acid rain which kills trees and aquatic life, pollutes water, acidifies the soil, and damages buildings and materials: photochemical oxidants which harm crops and natural vegetation.

iv) **Extinction of species** which is the irreversible loss of biodiversity. The majority of the world's species, especially tropical invertebrates, have not been scientifically named or identified. When species are lost, we lose:

- essential components of biodiversity needed to maintain the earth's life support systems. This reduces the ability of the biosphere to support human life.

- crucial biological resources that are, or will be, economically, medically or agriculturally important to us are lost forever.

v) **Increased coastal erosion and loss of fishery productivity** as a result of the loss or degradation of coastal areas such as mangrove habitats and coral reefs.

vi) **Reduction of genetic diversity of crop species** due to replacement of traditional crop varieties and livestock by the use of high yielding, but less resistant and genetically uniform, varieties/species. This also results in the loss of traditional varieties that have evolved during centuries of domestication, and may have high resistance to adverse environmental conditions, disease and pests. This can have adverse implications on national food supply by decreasing the productivity of local agricultural systems and the sustainability of locally-adapted agricultural practices.

vii) **Loss of traditional knowledge and cultural practices** associated with the cultivation of traditional varieties that are lost.

viii) **Loss of livelihoods a** large proportion of the people in the world depends on bio-resources for subsistence use or their livelihood. This is seriously jeopardised due to loss of biodiversity.

There is no way, of course, to estimate losses of psychological, emotional and spiritual well being that will result from ruined forests, beaches, lakes and other places people rely on for rejuvenation.

SAQ 15

Which of the following do not figure as a major impact of biodiversity loss:

i) Extinction of species
ii) Reduction of crop genetic diversity
iii) Decrease in population size of species
iv) Increase in monoculture

9.8 SUMMARY

- Biodiversity is threatened by the sum of all human activities. It is useful to group threats into the categories of habitat destruction, invasion of non-native species, over-hunting, pollution and climate charge.
- Habitat loss presents the single greatest threat to world biodiversity, and the magnitude of this threat can be approximated from species-area curves and rates of habitat loss. The spread of non-native species threatens many local species with extinction, and pushes the world's biota towards a more homogeneous and widely distributed sub-set of survivors.
- Climate change threatens to force species and ecosystems to migrate toward higher latitudes, with no guarantee of suitable habitat or access routes.
- Many species have gone extinct, some naturally and others because of human activities i.e. deforestation, desertification and destruction of wet lands and coral reefs.
- Species that are prone to extinction have peculiar characteristics in context to their habitat, feeding habits, reproduction, behaviour and economic value.
- Threatened species based on their degree of extinction can be categorised as endangered, rare, depleted and indeterminate. Some species have obtained relative security because of effective conservation measures and have been declared 'out of danger'.
- Habitats that are vulnerable to greater species extinction are referred to as fragile habitats. Coral reefs, oceanic islands, mountain tops and habitat islands are considered as fragile habitats.
- Major impacts of biodiversity loss are steady increase in atmospheric CO_2 level, adverse effects on local climate and water flow, reduction of genetic diversity, extinction of species and loss of livelihoods.

9.9 TERMINAL QUESTIONS

1. Check the current IUCN Red List of threatened species and see what categories contain the most number of threatened species. How many indigenous and endemic species are in the global list?

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2. Discuss the major causes of biodiversity loss in South Asia.

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3. In the alphabet square given below, there are words which you have studied in this unit. We have outlined a word-"biomass", to show how to go about doing this game-exercise. Can you now identify the remaining 10 words? List them in the space provided below.

w	i	l	c	l	i	t	e	n	o	p	r	s	s	q	z
e	m	j	h	u	m	n	r	e	s	e	r	v	e	s	q
e	i	n	i	m	i	p	a	s	b	s	c	d	e	p	a
n	d	i	p	j	c	k	a	l	m	t	o	s	p	e	p
d	e	e	k	p	r	m	t	u	v	i	w	x	a	i	P
a	c	e	o	d	o	d	o	w	x	c	n	q	g	e	i
n	e	f	g	i	c	q	s	r	t	i	a	i	e	y	k
g	c	l	b	p	l	r	z	s	g	d	l	j	n	g	o
e	y	r	e	s	i	n	s	a	c	e	d	k	v	g	m
r	e	n	d	e	m	i	c	r	q	s	s	t	d	u	a
e	h	o	r	n	a	d	a	y	e	y	g	z	x	m	k
d	n	t	q	v	t	n	u	n	d	r	y	t	a	s	m
p	o	r	a	r	e	c	h	e	m	j	p	i	l	i	a
r	s	u	d	e	f	o	r	e	s	t	a	t	i	o	n
a	g	r	o	c	h	e	m	i	c	a	l	s	e	x	y
e	h	a	e	m	o	p	h	i	l	i	a	j	n	a	d

4. Write a significant line about each of the above words in context of this unit.

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GLOSSARY

Abiotic: Non-living, e.g. rocks or minerals.

Acid rain: Precipitation that becomes acidic due to acid-forming precursors put into the atmosphere by human activities.

Amphibian: Members of a class of cold-blooded vertebrates which are aquatic in the larval stage, and breathe air as adults. Frogs, toads, and newts are examples of amphibians.

Anthropogenic: Caused or influenced by human impact on natural systems.

Background rate of extinction: The natural rate of extinction in the absence of human influence. Estimates of the background rate of extinction range from one to ten species per year, which is 100 to 1,000 times lower than the current rate.

Biodiversity (also known as biological diversity): The variety of living organisms. Biodiversity encompasses variation at all levels, from the genetic diversity within a species to the variation between higher level evolutionary groupings such as families and classes. It also includes the variety of ecosystems, habitats and the natural interactions of species in the wild.

Biogeography: The scienetific study of the geographic distribution of organisms.

Biota: All the organisms, including animals, plants, fungi and microorganisms in a given area.

Chromosome: Body found in the nucleus of living cells, composed mainly of DNA and protein, in a linear sequence of genes. Exchange of genes during sexual reproduction is facilitated by splitting of chromosomes during fertilisation.

DNA (deoxyribonucleic acid): The genetic material of most living organisms, which is a major constituent of the chromosomes within the cell nucleus and plays a central role in the determination of hereditary characteristics by controlling protein synthesis in cells.

Ecological processes: Processes which play an essential part in maintaining ecosystem integrity. Four fundamental ecological processes are cycling of water, cycling of nutrients, flow of energy, and biodiversity (as an expression of the process of evolution).

Ecosystem: An integrated group of biological organisms located in a particular type of habitat, and the physical environment in which they live. The ecosystem includes the living organisms, habitat structure, factors (such as temperature, wind, elevation, etc.) and their interactions.

Endangered species: A species considered to be in imminent danger of extinction.

Endemic: Native to a particular, restricted geographic area.

Evolution: The change in organisms over generations that gradually results in changes in populations and species.

Exploitation: The killing, capturing or collecting of wild organisms for human use.

Extinction (Also see the introduction to Past Extinctions): The state in which all members of a group of organisms, such as a species, population, family or class, have disappeared from a given habitat, geographic area, or the entire world.

Extinction vortex: The interacting factors that serve to progressively reduce already small populations, drawing them into extinction like an inescapable whirlpool.

Extirpation: The complete removal of a particular type of organism from an area, usually a specified geographic area.

Fauna: All of the animals found in a given area.

Flora: All of the plants found in a given area.

Food chain: A sequence of steps through which food and energy move through the environment from the primary source (plants), through the animals that consume plants, up to the animals which consume other animals.

Fragmentation: The disruption of large areas of habitat into smaller, separate units. Fragmentation involves both a total loss of habitat area and the isolation of remaining habitat patches, which prevents interaction between some organisms located in the fragments, and renders them effectively separate populations.

Gene: The functional unit of heredity; the part of the DNA molecule that encodes a single enzyme or structural protein unit.

Genetic diversity: Variation at the genetic level, within and between species, including the different forms of genes for particular traits.

Genus (genera): A category used in the classification of organisms that consists of a number of closely related species.

Geographic range: The geographic area within which the specified type of organism may be found.

Habitat: The place or type of site where an organism naturally occurs.

Habitat island: A restricted area of habitat that is surrounded by dissimilar habitats.

Heterozygous: Having two different alleles or gene-forms at a given locus of a pair of chromosomes.

Homology: The condition of being homologous. Homologous refers to organs or structures deriving from the same evolutionary origins. For example, the forelimb of a quadruped, the human arm and the wing of a bird are said to be homologous.

Hydrological cycle: Water cycle, involving the exchange of water between the atmosphere, water-bodies, the Earth's crust and living organisms. Operates on a global to microcosm level.

In-situ: In its original place or environment.

Introduced species (also known as non-native, exotic, or alien species): Species that humans transport to an area that was previously outside of that species' geographic range. Introductions may be intentional, such as with domestic animals like sheep and dogs, or unintentional, such as with rats and other pests that live on ships.

Invertebrate: The group of animals lacking a bony spinal column. Examples of invertebrates are insects, worms, starfish, sponges, squid, plankton, crustaceans, and molluscs.

IUCN (International Union for the Conservation of Nature): The IUCN, also called World Conservation Union, is an independent body founded in 1948 that promotes scientifically based action for the conservation of wild living resources. A union of nations, government agencies, and non-governmental organizations, the IUCN links a global network of more than 4,000 scientists who share information and develop cooperative plans for conserving endangered plants, animals, and ecosystems.

Marsupials: The group of mammals who's young are born very undeveloped and must attach themselves after birth to the mother's milk glands, where they are usually protected by a pouch. Australia is known for its wide variety of marsupials, such as kangaroos, wombats, and bandicoots. The opossum, found in North and South America, is also a marsupial. Marsupials are known in Europe, Asia, and Africa only through ancient fossils.

Mass extinctions: Periods during which the rate of extinction is much higher than it is at other times, and a large percentage of the evolved biodiversity disappears in a geologically short amount of time.

Metamorphosis: An extreme change occurring between the stages of life, such as from a tadpole to a frog, or from a caterpillar to a butterfly.

Mutualism: An interaction between two species in which both species benefit.

Niche: The unique set of resources used by a species within an ecosystem.

Ozone depletion: The reduction in the layer of ozone gas, found at the top of Earth's atmosphere, which absorbs most of the ultraviolet radiation (UVR) coming from the sun. Ozone depletion decreases the absorption of UVR, which allows more of the harmful rays to penetrate to Earth's surface.

Phylogenetic: Pertaining to the evolutionary history of a particular group of organisms.

Phylum: In taxonomy, a high-level category just beneath the kingdom and above the class; a group of related, similar classes.

Poaching: Illegal hunting, capture, or collecting of wildlife. Poachers may target organisms that are protected from all hunting, such as elephants, or they may target animals outside of the regulated hunting season or inside the boundaries of a protected area.

Population (of a species): A subgroup of a species coexisting in the same time and area. Population may also be used in a different sense to refer to the number of individuals in a defined group.

Recombination: The rearrangement of genes that occurs when reproductive cells (gametes) are formed. Recombination results in offspring that have a combination of characteristics different from that of their parents.

Selection: Natural selection is the differential contribution of offspring to the next generation by various genetic types belonging to the same populations.

Species: A group of related organisms that are capable of breeding with each other to produce fertile offspring but are not capable of breeding with members of other species.

Subspecies: A geographically isolated or physiologically distinct group within a species that is capable of interbreeding with other members of the subspecies but that usually does not.

Taxon (pl. taxa): The named classification unit to which individuals, or sets of species, are assigned, such as species, genus, order etc.

Vertebrate: Any of the group of animals that have a backbone. These include amphibians, birds, fish, mammals, and reptiles.

Viable population or viability: A sufficient number of individuals of a species to make their continued existence possible. If the population dips below that number, the species will not be able to recover and will eventually become extinct. The number of individuals needed for a viable population will vary with the species, habitat conditions and other factors.

Wetland: A land area with high amounts of moisture in the soils and characterized by plant communities that prefer that moist environment. Examples of wetlands are tide flats and marshes.

Wildlife: Plants, animals and microbes that live independently of humans.

ABBREVIATIONS AND ACRONYMS

ASEAN	Association of South East Asian Nations
CBD	Convention on Biological Diversity
CGIAR	Consultative Group for International Agricultural Research
CITES	Convention on International Trade in Endangered Species
DDT	Dichloro-diphenyl-trichloroethane
EC	European Community
FAO	United Nations Food and Agricultural Organisation
GEF	Global Environmental Facility
IARC	International Agricultural Research Centre
IIED	International Institute for Environment and Development
IPR	Intellectual Property Rights
ITRG	Ivory Trade Review Group
IUCN	World Conservation Union (formerly the International Union for Conservation of Nature and Natural Resources)
IUPGR	International Undertaking on Plant Genetic Resources
LUA	Land Use Agency
NASA	National Aeronautics and Space Administration
NGO	Non-governmental Organisation
NPP	Net Primary Product
OECD	Organisation for Economic Co-operation and Development
R&D	Research and Development
RLUA	Restricted Land Use Agreement
RRAG	Renewable Resources Assessment Group
SACIM	Southern African Centre for Ivory Marketing
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United National Educational, Scientific and Cultural Organisation
USAID	United States Agency for International Development
WCED	World Commission of Environment and Development
WCMC	World Conservation Monitoring Centre
WWF	World Wide Fund For Nature

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UNIT 10 CONSERVING BIODIVERSITY

Structure

10.1 INTRODUCTION

Biodiversity "the library of life" encompasses all species of plants, animals and micro-organisms. To date, about 1.4 million species have been identified, and researches estimate that millions more are yet to be counted – but unfortunately, time is running out. Thousands of species may be vanishing each year as a result of, habitat degradation, over harvesting, pollution, and of the human actions. The library of life is on fire we must extinguish this fire even before more treasures yet to be discovered are lost beyond recovery. The planet's natural wealth lies not just in the species, but in the genetic coding which gives each living the organism traits which enables it to survive and evolve.

Biotic diversity – the richness of life on earth – is like a common property resource, belongs to the whole human race and therefore biodiversity conservation is a major concern world wide. Conservationists are involve in global efforts to protect biodiversity, the present rests on the past, but leads into the future, and we must strive to improve the attitudes and institutions that now exist. We should conserve the rich biodiversity of the earth for the posterity so they can enjoy the richness of earth.

It has also been estimated that more than 40 percent of the world's economy and 80 percent of the needs of the world's poor are derived from biodiversity. But despite these benefits, and the fact that most countries are clearly trying hard to conserve biodiversity, have signed international conventions for this purpose, have developed national legislative frameworks and established system of protected areas, the situation remains desperate.

Protection, conservation and proliferation are major strategies of the plan. In this unit the two mechanisms for protection of biological diversity have been given special emphasis. Conservation of natural communities and population in the wild is known as *in situ* or **on site** conservation. The other strategy, where species is maintained in artificial conditions under human supervision is known as *ex situ* or **off-site** conservation. The global effort to conserve and protect the biodiversity is a recent phenomenon.

Objectives

After studying this unit you should be able to:

- explain the need and concept of biodiversity conservation;
- identify the need to conserve biodiversity at the level of genes, species and ecosystems;
- identify the different categories of Protected Areas that may be seen at the national and international levels;
- describe the advantages and disadvantages of the different approaches to conserving biodiversity, namely through the species based approach and the ecosystem based approach;
- enumerate the needs for *in-situ* conservation of species and the various measures and mechanisms that are available in this respect at the national and global level;
- appreciate the need for *ex-situ* conservation of species and the various mechanisms and institutions nationally or internationally that are together involved in this process of conservation, and differentiate between introductions and reintroductions and their various effects on biodiversity; and
- appreciate the importance of biodiversity conservation for sustaining human life.

10.2 THE NEED OF CONSERVING BIODIVERSITY

"The more biodiversity we destroy and the more irrevocably we change the biosphere, the more we limit our choices for the future."

Source: WRI/IUCN/ UNEP/1992.

Why is biodiversity so important? Why should we care about – that is, value-biodiversity? May be the lay people don't understand the various role it play in our life but certainly they know the importance of biodiversity.

There are four kinds of benefits derived from biodiversity:

i) Direct harvesting, of plants for food, fodder, medicine, fibre, dyes, fuel, construction materials and other uses. While animals are also used for food, fibre and medicine.
ii) Environmental importance of ecosystems, such as climate regulation, flood and drought control, consistent water supply, nutrient recycling, natural pest control, pollution cleansing and soil generation.
iii) Social values, which includes aesthetic, cultural, recreational, education and research benefits.
iv) Development potential, through domestication, development and improvement of genetic resources and biotechnology.

There are many factors that underlie the need to conserve biodiversity, such as,

- the present and potential uses of the components of biological diversity – especially as we have no way now of predicting what will be of use in the future.
- biodiversity is essential to maintain the earth's life support systems that enable the biosphere to support human life, and we do not still understand the impact of removing even one component of biodiversity from this system.
- It is ethically important to maintain all of the earth's biological diversity, including all the other extant (currently existing) life forms.
- variety is always more interesting and attractive to humans.

Biological diversity has to be conserved at all levels – comprising genes, species and ecosystems. The greater the number of individuals of a species and the number of different populations of the species conserved, the greater will be the biological diversity conserved. Maintaining a high genetic diversity ensures that individual species are more adapted to their environment and changing conditions, and are thus less vulnerable to extinction. A wide ecosystem diversity will ensure that more species have living conditions vital for their survival, while a wide species diversity will ensure that ecosystems are more stable in the long term.

Box 10.1: Ten principles for conserving biodiversity

The Global Biodiversity Strategy sets out ten principles to guide planning and action:

- Every form of life is unique, and warrants respect from humanity.
- Biodiversity conservation is an investment that yields substantial local, national, and global benefits.
- The cost and benefits of biodiversity conservation should be shared more equitably among nations and among people within nations.
- As part of the larger effort to achieve sustainable development, conserving biodiversity requires fundamental changes in patterns and practices of economic development worldwide.
- Increased funding for biodiversity conservation will not, by itself, slow biodiversity loss. Policy and institutional reforms are needed to create the conditions in which increased funding can be effective.
- Priorities for biodiversity conservation differ when viewed from local, national, and global perspectives: all are legitimate, and should be taken into account.
- Biodiversity conservation can be sustained only if public awareness and concern are substantially heightened, and if policy-makers have access to reliable information upon which to base policy choices.

10.3 DIFFERENT LEVELS OF BIODIVERSITY CONSERVATION

Initiatives to conserve biodiversity can be focused at all the three levels i.e. the ecosystem level, species level, and genetic level. While these initiatives will be closely linked, but they will not be substitute for one another. For example, conservation of ecosystem diversity will lead to conservation of the species that are found within them. However, these species could also be maintained outside these ecosystems or habitats; in cultivation or captivity or as free living organisms living outside their natural range. This will not, however, conserve their natural habitats. Similarly, maintaining the genetic diversity of a species will lead to the conservation of the species; but the conservation of a single species will not necessarily mean that the full range of its genetic diversity is maintained. This is because a species can be conserved even though its genetic diversity is reduced due to the loss of a population, or even several populations.

10.4 DIFFERENT TYPES OF PROTECTED AREAS

Protected areas are geographically defined areas that are designated or regulated, and managed for purposes of conservation. As such, these areas play a valuable role in the protection of areas of high species diversity (encompassing habitat conservation), threatened species, traditional crops and wild relatives of crops and genetic diversity.

The term “Protected Area” covers areas that are legally designated at the national level or at the international level. There are many ways in which Protected Areas are classified at the national level. IUCN’s World Commission on Protected Areas has introduced a standardised means of classification by introducing eight categories of nationally designated and two internationally designated protected areas.

IUCN classification of Protected Areas at the national level:

The United Nations List of Protected Areas is compiled by the IUCN Commission on National Parks and Protected Areas (CNPPA), with the assistance of UNEP,

UNESCO and the WWF. The ten categories for conservation management identified in the 1982. List are divided into three groups as follows:

Group A – Areas of particular interest to CNPPA:

These are categories for which the CNPPA takes responsibility to monitor the status and to provide technical advice as requested. These include:

i) Scientific Reserves/Strict Nature Reserves.
ii) National Parks/Provincial Parks.
iii) Natural Monuments/Natural Landmarks
iv) Nature Conservation Reserves/Managed Nature Reserves/Wildlife Sanctuaries.
v) Protected Landscapes

Group B – Areas of interest to IUCN in general:

These categories are of particular importance to IUCN as a whole and are generally found in most nations, but would not be considered exclusively within the scope of CNPPA. However, CNPPA may wish to monitor and provide expertise on those areas which are of partic ular importance to nature conservation. These include:

vi) Resource Reserves.
vii) Anthropological Reserves/Natural Biotic Areas.
viii) Multiple Use Management Areas/Managed Resource Areas.

Group C – Internationally recognised/Affiliated designation:

These categories form part of international programmes and have specific relevance for nature conservation, yet may, in many cases, already receive protection under a previous category. CNPPA may be called upon to monitor these categories and to provide special attention in cooperation with other institutions with which IUCN has consultative status. These include:

ix) Biosphere Reserves.
x) World Heritage Sites (Natural)

According to the above categories, the existing network of **Protected Areas in India falls in Groups A and B as follows:-**

Group A		**Total Number as on 1.1.85**	**Total Area**
Category II	National Parks:	53	
Category IV	Wildlife Sanctuaries	247	App. 100,000 sq. kms.
Group B			
Category VIII	Multiple use Management Areas	Most of the forest areas in 22 States and 6 Union Territories	App. 750,000 sq. kms.

Most of the protected areas in Categories II & IV are covered under Category VIII.

Conservation areas covered by *Group C–*

Category IX and X – have yet to be established, though action has been initiated in regard to both.

SAQ 1

1) Why biodiversity is important for mankind. List various advantages of having biodiversity.

2) Why these days there is so much of talk of biodiversity crisis?

3) List five characteristics that make a species vulnerable to extinction.

4) Why and how fast biodiversity is going to be extinct? What are the consequences of these extinctions? How can human-driven extinctions be slowed or prevented?

5) Describe each of the five major threats to biodiversity. Give an example of a species affected by each of these threats.

10.5 DIFFERENT APPROACHES TO CONSERVING BIODIVERSITY

Conservation of biological diversity covers a range of actions from totally **preserving** a single component of biological diversity to **using** biological resources **within sustainable limits**. The ultimate goal would be to prevent the loss of biodiversity in the long term and to conserve biodiversity for posterity.

10.5.1 Habitat or Ecosystem Based Approaches

This approach attempts to ensure that protected areas are not isolated islands. In the context of the ecosystem approach, the area to be protected is defined in terms of bioregion or watersheds, and includes people and their activities as it links biophysical and socio-economic dimensions. Such an approach to protected area management enables the use of a holistic, multi-actor, integrated and interdisciplinary systems perspective for the planning and management of biodiversity (Fig. 10.1).

Fig.10.1: Himalayan alpine meadows – habitat conservation

Advantages of Habitat based approaches

- Species that are not sufficiently well known to assess the degree of threat, or to devise specific conservation measures, are maintained by conserving a sufficiently large area of habitat. This is particularly true of conserving rain forests that are rich in species, as conservation of these ecosystems serves to conserve millions of species, many of which are not even known to us as yet.

Drawback of habitat based approaches

- It may not be sufficient to conserve all species and the full complement of their genetic diversity. Further, some threatened species may require special

conservation measures to enhance declining populations. Many species, including threatened species, may also not be included in the network of Protected Areas set up on the basis of representative samples of major ecosystem types.

10.5.2 Species Based Approaches

This involves identification of species that are of high priority for conservation and channelling resources to ensure their conservation and maintenance. The advantage of this approach is that it enables threatened species, or species with actual or potential resources value, to be selectively conserved (Box 10.2). This may involve the preparation of action plans, recovery plans or strategies to ensure the conservation of the species in question.

Box 10.2: International action to conserve species

International trade in wild species is governed by the obligations to the International Trade on Endangered Species of Wild Fauna and Flora (CITES) in terms of countries (such as India, Sri Lanka) that are signatories to it.

International action to conserve species diversity is exemplified by the Species Conservation Approach adopted by the Species Survival Commission (SSC) of IUCN - The World Conservation Union. The preparation of IUCN's Red Lists of Threatened Species is an activity of the SSC. This involves identification of the conservation status of globally threatened species by the use of objectively designed scientific criteria.

The SSC comprises a global network of species related experts who hold membership in about 100 specialist groups organised primarily on geographical and/or taxonomic basis as well as in inter-disciplinary groups that address issues such as captive breeding. The taxon based specialist groups (e.g. Those covering primates, cretateans, etc.) review the conservation status of the species within their respective ambits and prepare action plans to assist with the long-term survival of species by recommending conservation action.

Source: WCMC, 1992.

Species based conservation programmes can be carried out through *in-situ* or *ex-situ* efforts at the national level, and often by a combination of both. These approaches can be assisted by:

i) Enacting national legislation to protect species and/or to control the collection and possession of these organisms or their body parts.
ii) International/national trade restrictions.
iii) Control of the import of exotic species that become invasive and threaten indigenous species.

- **Disadvantages of the species approach**

  A disadvantage of species approach is as follows:

  * only benefits to single flagship species,
  * habitat destruction, modification and fragmentation of the habitat,
  * affect the survival of other species present in the habitat.

10.5.3 Species and Ecosystem Based Approaches

This can be done by using the concept of conserving areas of megadiversity and high endemism by extending it to areas that are high in threatened species. On the other hand, the presence of flagship species can be used to justify large areas of land which will serve to conserve other species as well.

Protected Areas that conserve critical habitats have sometimes been declared with the prime motive of conserving a single threatened spec ies (e.g. Tiger Reserves of India). This enables combining the species and area-based approaches to conservation. Especially important in this context are **umbrella species** (e.g. elephant, leopard, etc.) which, if protected, will ensure the conservation of other species living in the same habitat. For instance, the home ranges (i.e. areas that individuals occupy in pursuit of

their daily activities) of such species will be large enough to include the habitat requirements of many other species.

Indicator species are especially important in the habitat-based approach as they are sensitive to changes in the abiotic and biotic components in an ecosystem (e.g. salinity change or pollution of the habitat) as they have narrow tolerance limits to specific environmental conditions. As these species will disappear when there are changes in the environment, they are important indicators of the status of the ecosystems. Indicator species include amphibians, some birds, molluscs, fungi, corals and certain insects.

10.5.4 Integrated Landscape Approaches

The underlying premise of an integrated landscape approach to conservation is that the focus for conservation planning and management must extend beyond the boundaries of nature reserves to encompass the whole landscape. Managing a linked system of habitats rather than single blocks can be more effective in achieving conservation goals. This is even more important as protected areas are inextricably linked to adjoining modified lands and are affected by activities in them.

In order to benefit from this approach it is necessary to find creative ways to develop networks of habitat across 'reserved' and 'off-reserve' lands that together can function as integrated systems of habitat for conservation of biodiversity. This approach does not reduce the value and significance of protected areas. An integrated approach is also not a substitute for protected areas in which nature conservation is the primary focus of management. The integrated landscape approach builds upon and extends from a reserve system to include other parts of the landscape in the biodiversity conservation initiative.

An integrated landscape approach is particularly relevant in a range of situations where conservation reserves are few, sparsely distributed or inadequate for effective long-term conservation.

The concept of an integrated landscape approach to conservation can be applied at a range of scales, from local conservation plans to regional or national conservation strategies. It will necessitate the protection of key areas of habitat, co-ordination of conservation across varied land tenures, the maintenance and restoration of landscape connectivity and the integration of conservation goals activities with surrounding land uses.

The role of flagship species in biodiversity conservation: Flagship species such as the elephant, tiger and panda provide a tangle symbol for people to associate with conservation and thereby play a vital role in raising public opinion and concern and a flow of information and fund raising activities. While the application of an ecosystem approach to biodiversity conservation is central to manage and conserve integral ecological systems in which species live and evolve, its focus necessarily is on the ecosystem rather than on a single species. However, these twin approaches can be mutually beneficial, and several protected areas managed using the ecosystems approach use flagship species as a rallying point for local or even global conservation action.

Basis for zonation: Zoning is the process of applying different management objectives and activities to different areas or zones of a Protected Area.

Buffer Zone: acts as an external buffer to the reserve by extending the influences and benefits of the conserving forest by integrating it into the surrounding area, promoting compatible land use, supporting and co-operating with local people in its management, and contributing to local development processes. This zone permits the extension of conservation practices to biological resources such. This area extends outward from the boundary of the reserve; include the immediately adjacent villages will a definitive outer limit. (IUCN, 1995 and Sawakar, 1995).

Participatory Management

The strategic approach for participatory management prescribed in the plan recognises the fact that the Dellawa PFR has been identified as a National Conservation Forest; as such local decision making and control of the overall forest resources will have to be vested in the Forest Department, at least until it is felt that the correct climate exists to allow a gradual and qualified transfer of full responsibility to communities for all the various aspects of forest management (e.g. determining harvest levels, allocation of user rights, user fee collection, revenue disbursement, monitoring of collection, etc.) The management plan sets out prescriptions for the setting up of Village Forest Participatory Management Committees (VFPMCs) and Community Trust Funds (CTFs) to facilitate the process of community participation in participatory forest management and outlines the strategies and mechanisms to do so – taking into account: the need for community empowerment, social mobilisation, and critical local issues.

The constraints that could arise in implementing the prescribed strategies and actions have been also identified (e.g. conflicts between resource users; natural reluctance initially on the part of officials to adopt the innovative approaches that are proposed as there is considerable departure from the established administration systems in adopting participatory management approaches, etc.)

The need for long term commitment from the Forest Department and donors to support and fund the participatory process is recognised: a minimum commitment of five years has been suggested, although a 10 year programme has been recommended as a more realistic time period for desired results.

Joint Forest Management

A new approach to protecting forest resources known as joint forest management has proposed very successful. Under this approach, local people living on the fringes of forests are forming Vena Samrakshna Samithi (VSS) village organizations established to protect forests and are joining forces with the state forestry department to work in partnership for a common cause: rejuvenating degraded forests. Together they now share the responsibilities and benefits of forest restoration, protection, and management. Joint forest management differs from many earlier attempts to promote forestry oriented to meeting people's needs. The essential difference is that it builds from the roles played by both local forest users and the professionals employed by the state to act as custodians. Participation of the people is absolutely necessary to keep constant vigil against all odds and to protect the forests. NGOs play a very vital role in bridging the gap between the bureaucracy and the people. VSS should not be viewed only to develop the degraded forests but as an instrument for an overall development of village resources and its people. The initial gains from this people-centered management strategy are impressive, and a huge effort is under way to promote joint forest management. It involves some form of co-operative arrangement between the state and local people which empowers them to assume a degree of control and responsibility for the natural resource.

SAQ 2

1) Briefly describe the single-species approach. List and describe four reasons for undertaking a single-species approach.

2) Why is protecting any one species is also important in conservation?

3) List the advantages and disadvantages of habitat based approach in biodiversity conservation.

4) Define flagship species. What role does flagship play in conservation?

10.6 DIFFERENT STRATEGIES FOR CONSERVING BIODIVERSITY

Conservation needs different strategies, they can be species based or habitat based or ecosystem based. Some species are given importance at national level while some need treatment at international levels. Most of the conservation is done at *in situ* and *ex situ* conditions. We are going to study in detail what these condition means, what is the difference between them, and what are the methods and techniques used. We have also described some important project such as project tiger and project elephant and how these projects have helped in increasing their populations. Some techniques such as seed bank and tissue culture are proving very helpful in conservation of plants which fulfil several of our needs.

In-situ conservation means "on-site conservation". It is the process of protecting an endangered plant or animal species in its natural habitat, either by protecting or cleaning up the habitat itself, or by defending the species from predators. The benefit to *in-situ* conservation is that it maintains recovering populations in the surrounding where they have developed their distinctive properties.

Wildlife conservation is mostly based on *in-situ* conservation. This involves the protection of wildlife habitats. Also, sufficiently large reserves are maintained to enable the target species to exist in large numbers. The population size must be sufficient to enable the necessary genetic diversity to survive within the population.

Flora and fauna ***Ex-situ*** **conservation** means literally, "off-site conservation". It is the process of protecting an endangered species of plant or animal by removing it from an unsafe or threatened habitat and placing it or part of it under the care of humans. While *ex-situ* conservation is comprised of some of the oldest and best known conservation methods known to man, it also involves newer, sometimes controversial laboratory methods.

Ex-situ conservation, while helpful in man's efforts to sustain and protect our environment, is rarely enough to save a species from extinction. It is to be used as a last resort or as a supplement to *in-situ* conservation because it cannot recreate the habitat as a whole: the entire genetic variation of a species, its symbiotic counterparts, or those elements which, over time, might help a species adapt to its changing surroundings. Instead, *ex-situ* conservation removes the species from its natural ecological contexts, conserving it under semi-isolated conditions whereby natural evolution and adaptation processes are either temporarily halted or altered by introducing the specimen to an unnatural habitat.

Furthermore, *ex-situ* conservation techniques are often costly, with cryogenic storage being economically infeasible in most cases since species stored in this manner cannot provide a profit but instead slowly drain the financial resources of the government or organization determined to operate them. In the case of cryogenic storage methods, the preserved specimen's adaptation processes are frozen altogether. The downside to this is that, when re-released, the species may lack the genetic adaptations and mutations which would allow it to thrive in its ever-changing natural habitat. Seed banks are ineffective for certain plant genera with recalcitrant seeds that do not remain fertile for long periods of time. Plants and animals living in *ex-situ* breeding grounds have no natural defense to the diseases and pests new to the species. These factors, combined with the specific environmental needs of many species, some of which are nearly impossible to recreate by man, make ex-situ conservation impossible for a great number of the world's endangered flora and fauna.

However, when the extinction of a species is eminent, *ex-situ* conservation becomes the only option left. It is simply better to preserve a species in part than to let it die out and vanish completely.

10.6.1 *In-situ* Conservation

This approach deals with maintaining species in their natural habitats, which is believed to be the best way to maintain the earth's biological diversity. It also allows natural evolutionary processes to continue and for species to keep on adapting to their surroundings. However, this needs good management practices and controlled land use to ensure the successes of conservation objectives. Thus **Protected Areas** play a very important role in *in-situ* conservation of species, particularly threatened species, by ensuring conservation of their habitat.

When a location is selected the design of the preserved area plays a important role and is characterized by three important characteristics: size, shape and connectivity. If the size of the preserved area is big it increases the number of species contained in preserved area. The rounder shape minimizes edge effects because the perimeter (edge) is smaller relative to the area inside than with other shapes. Connectivity between potential fragments allows members of the same species to immigrate and interbreed. The connections are also called corridors. Buffer zones are another important preserve characteristic (Fig.10.2)

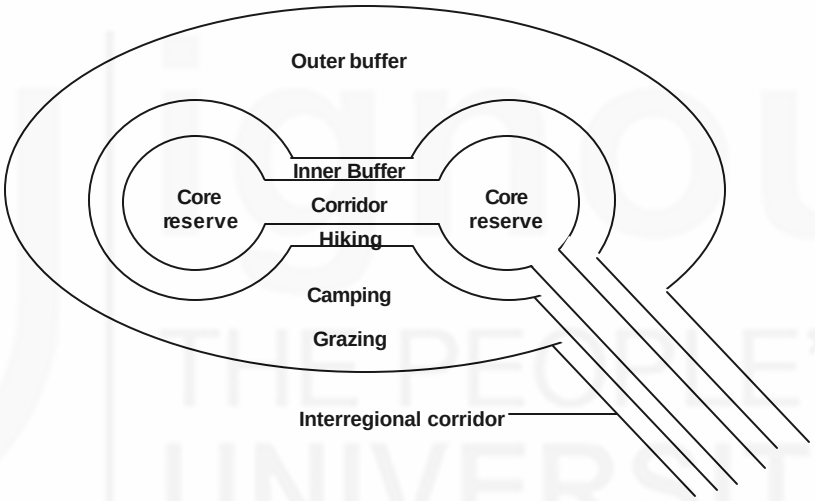

Fig.10.2: Structure of preserved areas

A buffer zone is moderately utilized land that provides a transition into the unmodified natural habitat in the core preserve where no human disturbance is allowed for example camping and grazing is allowed in outer zone while hiking in innermost buffer zone.

Buffer zones are very important for both psychological and practical reasons and from this zone inhabitants of the area can derive some benefits from the preserve. By permitting moderate recreational forestry, farming and other activities, buffer zone provides, jobs, and income with no ill effects on species in the core preserve.

Other types of areas that are important for *in-situ* conservation of species are:

- **National parks and sanctuaries**

  Most national parks are area of land that have great natural beauty (Fig. 10.3), which are set aside and protected for the conservation of scenery as well as plants and animals (Table 10.1). In national parks peoples are allowed to enjoy the scenery and wildlife, but visitor management is often required to reduce conflicts between recreational and conservation objectives.

National parks are largely natural and unchanged by human activities, but many of them already had existing human impacts before they were designated for protection and human activities often been allowed to continue (Box 10.3).

The first wildlife sanctuary was the Vedanthangal Bird Sanctuary near Madras, set up in 1878, which merely formalised the traditional protection afforded by villagers for pelicans, herons and other birds breeding at Vedanthangal. Another such sanctuary was set up at Ranganathittu near Mysore, in 1942, under British rule.

Table 10.1: Goals of parks, nature preserves and wilderness

i)	Preservation of unique geological and scenic wonder of nature.
ii)	Preservation of nature without human interference.
iii)	Wildlife conservation, including conservation of required habitat and ecosystem of the wildlife.
iv)	Conservation of specific endangered species and habitats.
v)	Conservation of the total biological diversity of a region.
vi)	Maintenance of wildlife for hunting.
vii)	Maintenance of representative natural areas for an entire country.
viii)	Maintenance of outdoor recreation and tourism.
ix)	Maintenance of a particular area for scientific research.
x)	Provision of corridors and connections between separated natural area.

Box 10.3: IUCN definition of national park

In 1975 the International Union for the Conservation of Nature (IUCN) defined a national park as a relatively large area

a) where one or several ecosystems are not materially altered by human exploitation and occupation, where plant and animal species, geomorphological sites and habitats are of special scientific, educative and recreational interest or which contain a natural landscape of great beauty, and

b) where the highest competent authority of the country has taken steps to prevent or eliminate as soon as possible exploitation or occupation in the whole area and to enforce effectively the respect of ecological, geomorphological or aesthetic features which have led to its establishment, and

c) where visitors are allowed to enter, under special conditions, for inspirational, cultural and recreative purposes.

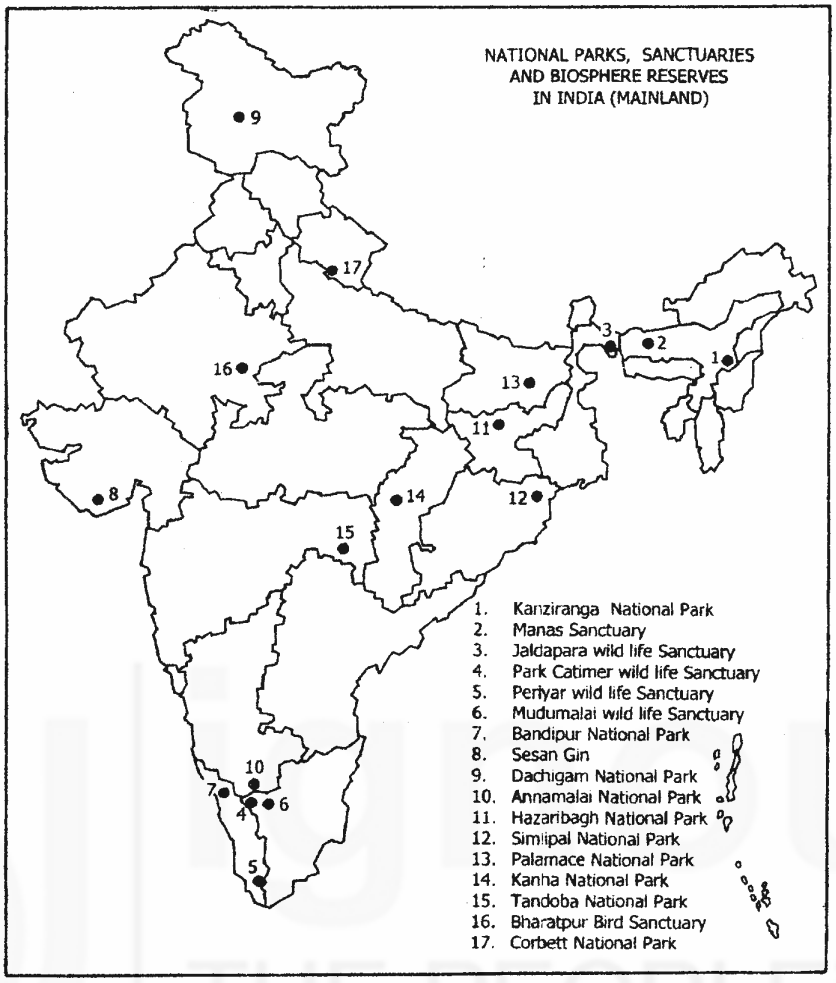

Fig.10.3: Map of India showing some of the important National Parks, Sanctuaries and biosphere reserves

- **Wetlands**

India's wetlands (Fig.10.4) are distributed in different geographical regions ranging from the cold arid zone of Ladakh to the wet humid climate of Imphal; the warm arid zone of Rajasthan to tropical monsoonal Central India, and the wet humid zone of the Southern peninsula.

It has been estimated that India has 4.1 million hectares of wetlands of which 1.5 million are natural and 2.6 million are manmade.

In the world over, a wetland is considered important if it:

* is particularly a good representative example of a natural or near natural wetland, characteristic of the appropriate biogeographic region,
* plays a substantial hydrological, biological, or ecological role in the natural functioning of a major river basin or coastal system,
* is a specific type of wetland, rare or unusual, or
* supports an appreciable assemblage of rare, minerable or endangered species or subspecies of plants or animals.

Fig.10.4: Wetlands

Importantly, wetlands are habitats for a wide variety of plant and animal life. Most important of these is the waterfowl. Since wetlands are shallow water areas, they provide an ideal habitat for water birds. Examples of such kinds of wetlands can be found all over the world.

Bulwark a defensive wall, especially of earth

Apart from harbouring birds, wetlands are also a nursery ground for several species of fish and shell fish and a wide variety of aquatic organisms. **Chilka in Orissa**, for example, has dolphins that move around in the area where the lake meets the sea. Coastal wetlands especially being an ecotone between the sea and freshwater, and/or freshwater and terrestrial habitats have high species diversity.

Ecologically, too, wetlands perform important functions. They regulate the water regime, act as natural filters and, display a marvellous nutrient dynamics. As an ecosystem, wetlands are useful for nutrient recovery and cycling, releasing excess nitrogen, deactivating phosphates, removing toxins, chemicals and heavy metals through absorption by plants and also in the treatment of waste water.

Furthermore, coastal wetlands with their unique mangroves (Fig. 10.5) are a natural bulwark against erosion by sea. The possible threat of rise in sea level is universally dreaded. One immediate preventive of this possible threat, as has been suggested by experts, would be the plan of a network of mangroves. In fact, mangrove wetlands of India and Bangladesh act as buffers against the devastating storms of the Bay of Bengal. Wetlands, thus, help in mitigating floods, recharging aquifers and reducing surface run-off and the consequent erosion.

Fig.10.5: Mangroves acting as bulwark for environment

Conservation of Biotic Resources

Some of the most important Indian wetlands are: Kolleru (Andhra Pradesh), Wullar (Jammu and Kashmir), Chilka (Orissa), Loktak (Manipur), Bhoj (Madhya Pradesh), Sambar (Rajasthan), Pichola (Rajasthan), Asthamudir (Kerala), Sasthamkotba (Kerala), Harike (Punjab), Kanjli (Punjab), Ujni (Maharashtra), Sukhma (Chandigarh), Renuka (Himachal Pradesh), Kabar (Bihar), Nalsarovar (Gujrat) and Dal (Jammu and Kashmir).

In the context of the environment, too, wetlands play a very important role. They protect and improve the quality of water and keep the local weather moderate. Using wetlands for water quality improvement has been tried in cold climates. Wetlands in urban periphery are natural receptacles for waste water and can harness effectively the nutrients available in the waste through fisheries and agriculture. Wetlands also play a major role in flood control, regulation of water quality and also help agricultural productivity in drought prone areas.

Most of the natural wetlands of India are connected with the river systems of the North and South. On the other hand, the various multi purpose projects launched to harness river systems have provided a number of wetlands, e.g., Harike Barrage at the confluence of the Beas and Sutlej in Punjab, Bhakra Nangal Dam in Punjab and the Cosi Barrage on the Bihar-Nepal border. Besides these, we also have a network of lakes – natural as well as man made, for example, Kabar lake, Chilka lake, Pichola Complex and Sukhna lake etc. In addition of these, there are 6,740 square kilometres of mangroves. The major concentrations of mangroves in the country are the Sunderbans and the Andaman and Nicobar Islands, which hold 80% of the mangroves in India. Rest of them are in Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Gujrat, and Goa.

The first International Convention on wetlands of International Importance was held in Ramsar in Iran in February 1971. This Conference made an inventory of important wetlands at the global level. The two wetlands from India which found place in the first list were Chilka and Bharatpur. Gradually, wetland conservation got incorporated in the process of planning and the Government of India constituted a National Wetland Management Committee. Long term research is needed to provide information for resource management and evaluate management effectiveness in conserving the ecosystem with all its values.

In a remarkable sense, wetlands have become central points for bird observations, the lead example being set by Bharatpur Sanctuary. It is, therefore, proposed at various forms to develop other wetlands as tourist attraction centres. After all a sanctuary is not worth its value if human beings and birds cannot communicate with each other.

It is, however, important to realise that tourist traffic needs to be strictly regulated. For this the wetland area can be divided into three distinct zones:

* Activity zones at the peripheral part of wetland
* Buffer zone
* Conservation zone forming the wetland core where no tourism intervention should be allowed.

Successful management demands much more information on how wetlands actually work so that they can be sustainably used for pisiculture, aquaculture, general environment improvement, education and scientific research. A lot of effort is being made to conserve these ecologically distinct areas including increased public consciousness. It is clear that the concept of World Conservation strategy of:

* maintenance of essential ecological process and life support system,
* preservation of genetic diversity,
* sustainable utilisation of species and ecosystem, and
* a cross sectoral approach and anticipatory environmental policies in realising the above three.

There is a need for adoption if such specific ecosystems are to be conserved. The case for protecting and managing wetlands is based not just on sentimentality or conservation of rare species. Rather it hinges on very real ecological and economic benefits of this ecosystem.

Biosphere Reserves

Biosphere reserves are internationally recognised areas established to promote and demonstrate a balanced relationship between humans and the biosphere (Fig.10.6). They highlight the value of nature conservation within a particular natural region and reconcile the conservation of biological diversity with sustainable use. Consequently they are ideally suited to meet today's conservation needs when human populations are increasing and the practicality of leaving aside large areas to protect pristine natural wild lands is decreasing, despite the fact that more people than ever before are dependant on wild species and natural ecosystems for their well-being. **(Dela, 2003)**

Fig.10.6: A view of Sundarban Biosphere Reserve

The programme of Biosphere Reserve was initially under the Man and Biosphere (MAB) programme by UNESCO in 1971.Biosphere reserves programme is intended to conserve representative ecosystems as opposed to only species or habitat conservation. It provides *in-situ* conservation under natural conditions, long-term conservation of plants, animals and micro organisms. The purpose of the formation of the biosphere reserve is to conserve *in-situ* all forms of life, along with its support system, in its totality, so that it could serve as a referral system for monitoring and evaluating changes in natural ecosystems. The first biosphere reserve of the world was established in 1979, since then the network of biosphere reserves has increased to 425 in 95 countries in the world (MAB - 2003). Presently, there are 13 existing biosphere reserves in India.

Fig.10.7: A view of Great Nicobar Biosphere Reserve

Biosphere Reserve are area of terrestrial and coastal/marine ecosystem (Fig. 10.7) where, through appropriate zoning and management, the conservation of ecosystem and their biodiversity are combined with the sustainable use of natural resources for the benefit of local communities. This includes relevant research, monitoring, education and training.

This programme is intended to enhance and strengthen efforts to establish national parks and other protected areas.

Main characteristics

The main characteristics of biosphere reserves are expected to be as given below:

- Biosphere reserves will be protected areas of land and coastal environments. Together they will constitute a part of the world-wide network linked by international understanding on purposes, standards and exchange of scientific information.
- The network of biosphere reserves will include significant examples of biomes throughout the world.
- Each biosphere reserve should include one or more of the following categories:
  - Representative examples of natural biomes.
  - Unique communities or areas with unusual natural features of exceptional interest. It is recognised that representative areas may also contain unique features e.g. one population of a globally rare species (their representativeness and uniqueness may both be characteristics of an area).
  - Examples of harmonious landscapes resulting from traditional patterns, of land use.
  - Examples of modified or degraded ecosystems capable of being restored to more natural conditions.
- Each biosphere reserve should be large enough to be an effective conservation unit, and be able to accommodate different uses without conflict (Fig.10.8).
- Biosphere reserves will provide opportunities for ecological research, education and training. They will have particular value as benchmarks or standards for measurement of long-term changes in the biosphere as a whole. The existence may be vital to other projects.
- A Biosphere reserve will have adequate long-term legal protection.
- In some cases, biosphere reserves will coincide with, or incorporate, existing or proposed protected areas, such as national parks, sanctuaries or nature reserves.

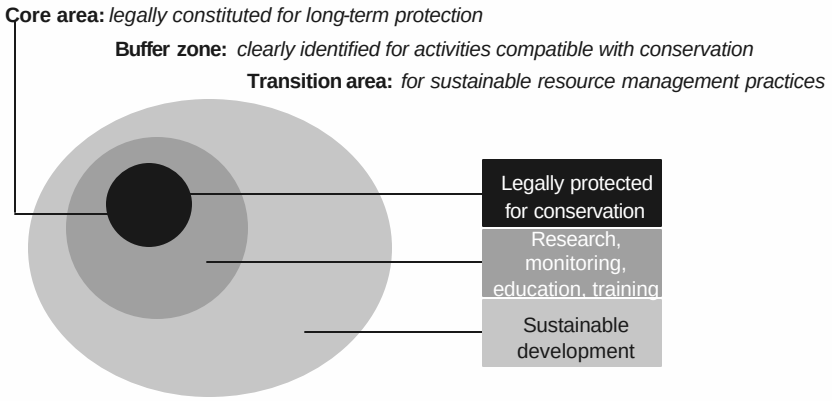

Fig.10.8: Functions and zonation of a biosphere reserve

The objectives of the Programme are:

a) Conserve representative samples of eco-systems;
b) Provide for long-term *in situ* conservation of genetic diversity;
c) Promote and facilitate basic and applied research and monitoring;
d) Promote appropriate sustainable management of the living resources in the reserve;
e) Disseminate the experience so as to promote sustainable development elsewhere; and
f) Promote international co-operation.

For the management of these biosphere reserves Central Government will have to assume direct responsibility in four main aspects:

- Full financial assistance for the approved items of the programme.
- Technical expertise and know-how, including trained personnel.
- Detailed guidelines covering all aspects of management for implementation by the State machinery.
- Close monitoring and supervision.

Legal Aspects

In biosphere adequate legal or regulatory measures will be required. The wild life (Protection) Act 1972 – which already exists in India hence biosphere reserves, should work with accordance of wild life Protection Act 1972:

Action Plan to Biosphere Reserves

There are three main thrust in the programme framework of the action plan all designed to promote and implement the concept of the biosphere reserve

a) Improving and expanding the network
b) Developing basic knowledge for conserving ecosystems and biological diversity
c) Making biosphere reserves more effective in linking conservation and development.

- **Tigers Reserves**

  "A Tiger is a large-hearted gentleman (Fig.10.9) with boundless courage and that when he is exterminated – as exterminated he will be unless public opinion rallies to his support – India will be the poorer by having lost the finest of her fauna" - **Jim Corbett .**

  Project tiger was launched on 1 April, 1973 as centrally sponsored scheme of Government of India to maintain viable population of the tiger and its natural habitat. The main objective of the scheme is to ensure a viable population of tiger in India for scientific, economic, aesthetic, cultural and ecological values and to preserve areas of biological importance as natural heritage for the benefit,

Fig.10.9: Indian tiger

education and enjoyment of the people. Main objectives under the scheme include Wildlife management and protection measure.

Initially, the Project started with nine tiger reserves, covering an area of 16,339 sq.km. with a population of 268 tigers. And at present there are 27 tiger reserves covering an area of 37, 761 sq.km. with a population of 1498 tigers. This amounts of almost 1.14% of the total geographical area of the country. Details of various Tiger Reserves alongwith their location and area are given in Table 10.2. The selection of reserves was guided by representation of ecotypical wilderness areas across the biogeographic range of tiger distribution in the country. Project Tiger is undisputedly a custodian of major gene pool in the country. It is also a repository of some of the most valuable ecosystem and habitats for wildlife (Box 10.4).

The Tiger Reserves are constituted on a 'core-buffer strategy'. The core area is kept free of biotic disturbances and forestry operations, where collection of minor forest produce, grazing, human disturbances are not allowed within. However, the buffer zone is managed as a 'multiple use area' with twin objectives of providing habitat supplement to the spill over population of wild animals from the core conservation unit, and to provide site specific ecodevelopmental inputs to surrounding villages for relieving the impact on the core. No relocation is visualized in the buffer area, and forestry operations, Non-Timber Forest Produce (NTFP) collection and other rights and concessions to the indigenous communities are permitted in a regulated manner to complement the initiatives in the core unit.

The effective protection and concerted conservation measures inside the reserves have brought about considerable intangible achievements also, viz. arresting erosion, enrichment of water regime and thereby improving the water table and overall habitat resurrection. Labour Intensive activities in tiger reserves have helped in poverty alleviation of the most backward sections and their dependence on forests has also reduced. The project has been instrumental in mustering local support for conservation programme in general.

Approach

- Elimination of all forms of human exploitation and disturbance from the core and rationalization of such activities in the buffer.
- Limitation of the habitat management to repair damage done by man.
- Researching facts about habitat and wild animals and carefully monitoring changes in flora and fauna.

The study of tiger's activities through radiometer, which is fitted in a caller of the tiger, is called **radio telemetry.**

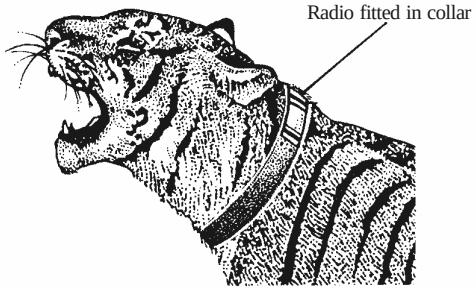

Fig.10.10: Radio telemetry

Table 10.2: Name of the tiger reserves in tiger range states with year of creation and area

Sl. No.	Year of creation	Name of tiger reserve	State	Total area in sq. km.
1.	1973-74	Bandipur	Karnataka	866
	1999-2000	Nagarhole (Extension)		643
2.	1973-74	Corbett	Uttar Pradesh	1316
3.	1973-74	Kanha	Madhya Pradesh	1945
4.	1973-74	Manas	Assam	2840
5.	1973-74	Melghat	Maharashtra	1677
6.	1973-74	Palamau	Bihar	1026
7.	1973-74	Ranthambhore	Rajasthan	1334
8.	1973-74	Similipal	Orissa	2750
9.	1978-79	Sunderbans	West Bengal	2585
10.	1978-79	Periyar	Kerala	777
11.	1978-79	Sariska	Rajasthan	866
12.	1982-83	Buxa	West Bengal	759
13.	1982-83	Indravati	Madhya Pradesh	2799
14.	1982-83	Nagarjunsagar	Andhra Pradesh	3568
15.	1982-83	Namdapha	Arunachal Pradesh	1985
16.	1987-88	Dudhwa	Uttar Pradesh	811
	1999-2000	Katerniaghat - (Extn.)		551
17.	1988-89	Kalakad - Mundanthurai	Tamil Nadu	800
18.	1989-90	Valmiki	Bihar	840
19.	1992-93	Pench	Madhya Pradesh	758
20.	1993-94	Tadoba-Andheri	Maharashtra	620
21.	1993-94	Bandhavgarh	Madhya Pradesh	1162
22.	1994-95	Panna	Madhya Pradesh	542
23.	1994-95	Dampha	Mizoram	500
24.	1998-99	Bhadra	Karnataka	492
25.	1998-99	Pench	Maharashtra	257
26.	1999-2000	Pakhui - Nameri	Arunachal Pradesh-Assam	1206
27.	1999-2000	Bori, Satpura, Panchmari	Madhya Pradesh	1486
			Total	**37,761**

The WWF also initiated the Tiger Conservation Programme in 1997 with the long-term aim of protecting this magnificent species from extinction. The programme components of the initiative include: providing infrastructure support to the government for strengthening management capacity; assessment and monitoring of tiger habitat (Fig. 10.10) strengthening political will and intensification of public awareness; sustained generation of conservation finance for support to tiger conservation; and facilitating international cooperation.

Box 10.4: Only 5000 Tigers left

The trade in tiger 'products' is a million dollar 'industry'. In Asia, a tiger skins fetches $15,000. In Vietnam, the animal skeleton costs $25,000. Reason enough for our tigers to disappear? The world's tiger population has plummeted by 95 percent from the start of the 20th century to as few as 5,000 now and is further threatened by the lucrative trade in their skins, according to an NGO estimate in 2005 only less than 2,000 tigers left. (Sunday Times of India, March 20, 2005)

In Asia, tiger skins can sell for $15,000 while in Vietnam a skeleton, the bones widely believed by Asians to be an aphrodisiac, can fetch as much as $25,000. "It is believed that about 100 years back, the global population of wild tigers was about 100,000," Dey said. "However, the population dwindled to 8,000 by 1960. Today it stands at around 5,000 to 7,000."

Three out of eight sub-species of tigers are already extinct. The South China tiger, could also soon disappear. The illegal poaching of wildlife, especially in large parts of south and south-east Asia, is to blame for the reduction in the wild tiger population. "Illegal hunting of wildlife has not been strictly controlled resulting in the severely decreased population of tigers in Vietnam," said Vietnam's Agriculture Minister Cao Duc Phat.

Elephant Reserves

Asian elephants are found in almost all vegetation types, their habitat ranges from thorn, forests to tropical rain forest, being a large animal it needs large quantities of food and water every day. Their habitat is shrinking rapidly due to human encroachment and moreover their habitats are getting fragmented by building dams, railway tracts, agriculture field or tourism, which prevent the elephants from moving around freely and safely. These are some factors which are contributing towards the significant loss in elephant populations.

For conserving the mighty animal Project Elephant was launched in February, 1992 to assist states having free ranging populations of wild elephants to ensure long term survival of identified viable populations of elephants in their natural habitats. Project Elephant is another landmark conservation initiative to protect the Asian elephant that was formally launched on the recommendations of a taskforce set up by the MoEF in 1990 to look into the conservation of the Asian elephant (Fig.10.11). The objective of Project Elephant is to assist states having ranging populations of wild elephants to ensure the long-term survival of identified viable population of elephants in their natural habitats by providing the range states with financial as well as technical and scientific assistance.

Fourteen elephant reserves have been set up during the year (till December 2002) which include Singhbhum (Jharkhand); Garo Hills (Meghalaya); Mayurbhanj, Mahanadi and Sambalpur (Orissa); Eastern Dooars and Mayurjharna (West Bengal); Wayanad, Nilambur, Anamudy and Periyar (Kerala); Kameng (Arunachal Pradesh); Mysore (Karnataka and Shiwalik (Uttaranchal).

Fig.10.11: Asian Elephant

Project Elephant is aimed at the ecological restoration of existing natural habitats and migratory routes of elephants, development of scientific and planned management for conservation of elephant habitats and viable populations, measures aimed at mitigating human-elephant conflicts, anti-poaching measures as well as enhanced research and training. Other special programmes have been launched for the in-situ conservation of mammals including the Indian rhino, lion, certain primates (such as the Indo-US Primate Project in Northeast India) and aquatic mammals including river dolphins.

The project is being implemented in 12 states, viz. Andhra Pradesh, Arunachal Pradesh, Assam, Jharkhand, Karnataka, Kerala, Meghalaya, Nagaland, Orissa, Tamilnadu, Uttaranchal and West Bengal. Financial as well as technical assistance is given to states in achieving the objectives of the Project. Other states with small populations of elephants are helped for the purpose of census, training of field staff and mitigation of human-elephant conflict.

Main Activities of Project Elephant

- Protect, restore and improve ecologically, the existing habitats and link corridors used by elephants for their free movement between forests;
- Protect wild elephant populations from poaching and unnatural deaths; and strengthening of measure for protection of wild elephants;
- Seek and encourage humane treatment in the management of captive elephants; and ecological restoration of existing natural habitats and migratory routes of elephants;
- Development of scientific and planned management for conservation of elephant habitats and viable population of wild Asiatic elephants in India;
- Promotion of measures for mitigation of man-elephant conflict in problem areas and moderating pressures of human and live stock on crucial elephant habitats;
- Eco-development;
- Veterinary care;
- Research on elephant issues relating to elephant conservation;
- Public education and awareness programme; and
- Capacity building of field staff, mahouts and veterinarians.

Setting up of Elephant Reserves

The elephant is big animal and moves over large areas to meet its large requirements of food. The movement of elephants varies from season to season. The natural habitat of elephants may often span over two or more states. That's why Project Elephant is planned at a landscape level rather than being aimed of individual Protected Areas. Elephant Reserves have been proposed to ensure the long term survival of elephants. Elephant Reserves have been conceived to:

- Ensure long term survival of identified large populations;
- Link up fragmented portions of the habitat by establishing corridors or protecting existing corridors under threat;
- Improve habitat quality through ecosystem restoration and other measures, keeping the main objective of range protection in view;
- Attend to socio-economic problems of human populations living on the fringes, including human-animal conflict.

Scientific Research done in elephant reserves

Species Management

It is very important to understand the physiology, behaviour, feeding and mating, habitat requirements, movements, family life, etc. Without such a specific understanding, it is not possible to plan for effective conservation.

Habitat Management

Scientific study to understand the elephant, its requirements and behaviour needs to be used as the basis for planning and demarcating protected areas, corridors and various management oriented problems. Scientific and research organizations like Wildlife Institute of India (WII), Bombay, Natural History Society (BNHS), Centre for Ecological Sciences (CES) and Asian Elephant Research and Conservation Centre, Bangalore are studying the elephant to scientifically manage elephant populations and their habitat (Fig.10.12).

Fig.10.12: An Asian Elephant (*Elephas maximus*) seriously threatened species

Captive Breeding Programmes

Captive breeding does play an important role in elephant conservation. Some of the most successful captive breeding programmes are those where elephants are kept under semi-natural conditions like in forest camps, etc. In the forest camps in Southern India, elephants have been seen to regularly breed in captivity and it has also been observed that the elephant population has sustained itself without the addition of any elephant from the wild.

In most forest camps, bulls and cows of all ages are kept together and are allowed to mingle with each other. They are also left in the forests at night, so that they can feed. Sometimes, the cows have been known to mate with wild bulls.

Crocodile Conservation

In situ conservation of selected species of birds and reptiles has been fortified through captive breeding programmes. The Government of India started a crocodile breeding and management project in 1976 to save the three endangered crocodilian species, the fresh water crocodile, salt water crocodile and the *gharial*. Thousands of crocodiles of these three species have been reared at 16 centres and several of these have been released into the wild. Eleven sanctuaries have been declared specially for crocodile protection including the National Chambal Sanctuary in Madhya Pradesh. The endangered white-winged wood duck was also bred in captivity and released into Protected Areas of the Northeast, in an Indo-British collaborative programme.

10.6.2 *Ex-situ* Conservation

Ex-situ conservation is comprised of some of the oldest and best known conservation methods known to man, it also involves newer, sometimes controversial laboratory methods.

Ex situ conservation has certain limitations for conservation of animals. These include adaptation problems, genetic variability, and concentration in small place, surplus animals, and continuity in funds. Research on captive population can provide insight into the basic biology of the species and suggest new conservation strategies.

However, much more needs to be done to protect global resource (flora and fauna) needed for healthy and productive animals and plants that are used for food, material, economic and aesthetic needs of the society.

- **Botanical Garden**

  Together, the world's 1500 botanic gardens, arboreta, and national plant collections maintain the largest array of plant diversity outside of nature, and they have major, if often overlooked, potential as resource centers for conservation, education, and development. If the infrastructure and technical facilities of most of these institutions can be strengthened, they could conserve *ex situ* stocks of most of the world's endangered plant species. Already, individuals of an estimated 12,000 to 15,000 threatened species are being cultivated in botanic gardens and arboreta (Box 10.5).

  A strategy for improving the conservation role of botanic gardens was developed by the Botanic Gardens Conservation Secretariat (BGCS) in 1989. The BGCS, established by IUCN in 1987 and recently renamed Botanic Gardens Conservation International (BGCI), links nearly 400 botanic gardens committed to conservation. Botanic gardens are new systems to provide local and global information on *ex-situ* holdings of wild species in botanic gardens, arboreta, and crop genebanks. Most germplasm surveys exclude the holdings of botanic gardens.

  Plants are endangered by a combination of factors such as over-collecting, unsustainable agriculture and forestry practices, urbanisation, pollution, climatic change etc. There is urgent need to conserve plants all over the world. Botanic gardens worldwide play major roles in science, horticulture and education (Fig.10.13). In the last few decades they have become important centres for biodiversity conservation.

  Protection of wildlife has a long tradition in India with the establishment of forest reserves and sanctuaries. The National Wildlife Action Plan, 1983, botanic garden are able

  * to rehabilitate indigenous and threatened species and restore them to protected portions of their former habitats;
  * to exploit commercially those species which are plentiful;
  * to promote wildlife education to a broad range of target groups such as politicians, school and college students, and communities living in and around wildlife areas.

So far, several botanic gardens and other organizations in India are members of BGCI and have active conservation programmes. These are:

There are over 1500 botanic gardens worldwide, collectively containing over three million accessions.

- National Botanical Research Institute, Lucknow, Uttar Pradesh
- Botanical Garden Guru Nanak Dev, Amritsar, Punjab
- Institute of Forest Genetics & Tree Breeding, Coimbatore, Tamil Nadu
- Narayana Gurukula Botanical Sanctuary, North Wynad, Kerala
- Botanical Garden "Dr. H.S. Gour Vishwavidyala". Sagar, Madya Pradesh
- Tropical Botanical Garden and Research Institute, Pacha-Palode, Trivandrum, Kerala
- Zoo Outreach Organisation/Captive Breeding Specialist Group (C.B.S.G.), Coimbatore, Tamil Nadu
- Magali Estates (P) Ltd., Padagiri, Kerala.

Fig.10.13: A view of Indian botanic garden, Howrah

There are 34 botanic gardens in the country including the National Botanical Garden in Noida, Uttar Pradesh (MoEE, 1998). A scheme entitled "Assistance to Botanic Gardens" provides one-time assistance to botanic gardens to strengthen and institute measures for the *ex situ* conservation of threatened and endangered species in their respective regions.

Box 10.5: Royal Botanic Garden in Calcutta

The Royal Botanic Garden in Calcutta, India founded by the East India Company in 1787, (now the Indian Botanic Garden) was one of the largest tropical gardens in the world during the nineteenth century, supporting a vast herbarium that became the core of the present day Central National Herbarium of India. Specializing in the native flora from all of the regions of India, the Garden was an important source for the cultivation of orchids, bamboos, and palms, and was an important supplier of plants to Kew and other European gardens. It remains an important center for botanical research (Fig. 10.14).

The Alphabetical Index is a classified listing of plants held in the collections of the Royal Botanic Garden at Calcutta in about 1830. Arranged by their native names in fourteen languages ranging from Arabic to Uriya, paired with their Latin binomial equivalent, the index represents a snapshot of one of the most important English colonial botanic gardens. Those species described by the former superintendent of the Garden, William Roxburgh (1751–1815), are distinctly noted.

Although lacking a date, the Index is written on a variety of watermarked papers, ranging from Whatman (1826) to Radway (1828). Eleven plant specimens have been folded between the pages.

Fig.10.14: The great banyan tree in botanical garden Calcutta

- **Zoological Garden**

The basic philosophy behind the creation of zoological parks in modern times is to create an understanding of the environment and ecological balance of life, meaning strengthening the bond between people and the living earth. These zoological parks are no more picnic spots. They are now centres for *ex-situ* wild life conservation and environmental education. For *in-situ* conservation of different animal species a number of National Parks and Sanctuaries have been established by Government of India as seen in Fig.10.3.

The history of modern zoos has started some 200 years ago with the creation of the first public zoos. Since then every part of world has developed their own zoological parks with great diversity such as aquaria, bird-parks, private zoos, and safari parks. The World Zoo Conservation Strategy refers to all these institution as "Zoos" (Box 10.6).

There have been great changes in the zoological parks since the inception of first zoo. The World Zoo Conservation Strategy concludes that the evolution of zoo should continue to help the conservation of wildlife. There are several species of wildlife which would have been extinct today except for efforts by zoos and animal reserves. The conservation work in zoos are due to cooperative management programs which were developed in the last decade with the association of zoos.

Collectively the zoos of the network are visited annually by at least 600,000,000 people (approximately 10% of the current world population).

A conservation strategy should be developed to help, set priorities and strengthen collaboration among zoos. The starting point would be identifying collective institutional strengths and weakness and evaluating national and international opportunities for further contribution to conservation.

Box 10.6: World conservation strategies

The World Conservation Strategy issued by IUCN, UNEP, and WWF in 1980, its successor *Caring for the Earth* published in 1991, and various related documents, as well as the *Convention on Biological Diversity* have provided the impetus for the formulation of the role that the zoo community will play in conservation.

The World Conservation Strategy emphasizes that there are three major initiatives to be taken by zoo community can help to achieve the goals:

- By actively supporting the conservation of endangered species populations and their natural ecosystems.
- By offering support and facilities to increase scientific knowledge that will benefit conservation.
- By promoting an increase in public and political awareness of the necessity for conservation, natural resource sustainability, and the creation of a new equilibrium between humans and nature.

These objectives will provide the basis for the mission statements of all zoos that will play a role in reaching the goals of the World Zoo Conservation Strategy.

Central Zoo Authority in India

In 1992, Central Zoo Authority (CZA) was created under section 35 of Wild life (Protection) Act 1972 in India. It is now mandatory for all zoos to seek recognition from CZA for its functioning. CZA is striving to ensure that zoo animals are provided with conditions that are congenial to their psychological and physical health and are able to successfully procreate and augment, the declining populations of some species in the wild.

Ex-Situ conservation of wild animals in zoo

Zoos can directly contribute in preventing the extinction of endangered species. This is done by propagating the population of such species *ex-situ*. The *ex-situ* zoo population is managed to support the survival of species in wild. There is increasing number of cases where *ex-situ* populations are crucial components of species survival.

Risks of genetic degeneration and domestication can be minimized by cooperatively managing *ex-situ* zoo populations according to strict guidelines. Population management guidelines are directed towards retaining as much of the original genetic variability as possible. Populations properly managed can serve as valuable genetic reservoirs for species survival in nature.

Population management practises are organized in regional breeding programmes. These have been, or are being, developed in all major regions of the world. Currently, there are regional breeding programmes for over 300 endangered species. The World Zoo Conservation Strategy calls for further increase in the number of such programmes. National and international authorities are asked to facilitate legal transfers of animals within the framework of *ex-situ* programmes aimed at supporting propagation and at minimizing loss of genetic variability and other unwanted effects.

Some important techniques used in *ex-situ* conservation are dealt here.

i) Captive breeding

Captive breeding is one of the important strategies used by both government and non-government organizations. Captive-breeding programs of endangered and threatened species have become familiar programs that strive to preserve biodiversity and species-survival plans such as cheetah.

There are 37 species in the cat family, and all except the domestic cat are considered threatened or endangered.

Careful selective breeding, re-introduction programs and the involvement of local people who once hunted them as protective wardens are important components of captive breeding. Inbreeding, the mating of closely related animals, should be avoided when possible. Individuals of some animal species may lose interest in mating in captivity. In these circumstances, artificial insemination, embryo transfer and other innovative medical biotechnological approaches may be carried out which we have discussed in this Unit.

Some species do not adapt or reproduce well in captivity. In this case medicine, cross fostering like artificial incubation Veterinary medical (cloning individual from single cells, cross species fertilization, induced hibernation, diapauses for maintaining dormant population) and biochemical and surgical sexing of animals that have no external sex differences are performed for fostering of captive breeding. (Fig. 10.15) freezing of eggs, sperms, embryos and other tissues of species on the verge of extinction is being done for future breeding programme. Maintaining captive population is expensive relative to other conservation investment. When wild population reach extremely low levels and are in danger of extinction the only way to save them is to bring them into captivity, build-up their numbers and they are re-establish in the wild population.

The International Species Inventory System now keeps genealogical information on individual animals of 2,500 species of mammals and birds kept in 326 zoos in Europe and North America. This makes it possible to arrange matings by computer in order to minimize problems caused by inbreeding.

Not all attempts at captive propagation have been successful. Only 26 of 274 species of rare mammals in captivity are self-sustaining. Giant pandas, cheetahs, elephants, penguins, humming birds, killer whales, and vicunas have been very difficult to breed. Only one species of bats (grey headed flying fox) has ever been bred in captivity. Only about10% of reptile species in zoos have reproduced. Most captive propagation programmes in zoos focus on large birds and mammals.

Fig10.15: Captive breeding

ii) Embryo Storage and transfer technology

Techniques for embryo transfer and artificial insemination, which have been developed for laboratory animals and farm animals, are potentially very useful for improving the reproductive potential of captive populations of endangered species. These kinds of techniques have been worked out mainly for mammals.

Embryo Transfer

In this technique, fertilized eggs or early embryos (usually about the 8-cell stage) are removed from the reproductive tract of a donor female and transferred into the tract of a surrogate mother, who carries the embryos to term and produces live young. This can all be done non-surgically, at least with cattle. What makes it useful is that the donor and recipient can be of two different species (although they must be of the same genus); successful transfers have been carried out from guar (endangered species) into domestic cow, Grant's zebra into horse, Przewalski's horse into domestic horse, macaque into rhesus monkey, and several others.

One technique for enhancing reproduction is super ovulation; treatment of the donor with fertility hormones such as follicle-stimulating hormone causes the release of large numbers of eggs (up to 31 in eland), all of which can potentially be fertilized, transferred and carried to term in surrogate mothers. This method works well in cattle (and humans!), but not so well in other mammals so far. Another method of increasing the reproductive rate is embryo bisection to give identical twins or triplets; this has so far been demonstrated only with laboratory and domestic animals (sheep twins).

iii) Artificial insemination

Artificial insemination is another technology that may be useful. Sperm can be frozen and used later, or transferred to another breeding facility to increase genetic diversity. Sometimes, the sperm can be added to the eggs in a dish and fertilization will occur. In other cases (for example, horses) the sperm has to be injected into the egg. A few years ago, the black-footed ferret was down to six individuals, but artificial insemination has now been used to produce 16 kittens. Elephants and cheetahs have conceived, and a cheetah cub has been born following artificial insemination. Elephants have not bred naturally in captivity, so this method may be useful simply to make captive breeding possible.

iv) Somatic cell cloning

Somatic Cell C loning (Fig. 10.16) holds some promise for propagating from one or a few survivors of an almost extinct species. This was first done with domestic sheep at the Roslin Institute in Edinburgh (see panel, from University of Virginia) but has since been done w ith other mammals. It has already been used to rescue a rare breed of cattle that had been reduced to a single old female ("Lady") and some frozen sperm. Granulosa cells (somatic cells in the ovary) from Lady were fused with enucleated eggs (lacking DNA) from a different breed, and the resulting eggs were implanted into an Angus cow (a common breed). The first calf born from these cells is genetically identical to Lady, as expected, although her markings are slightly different.

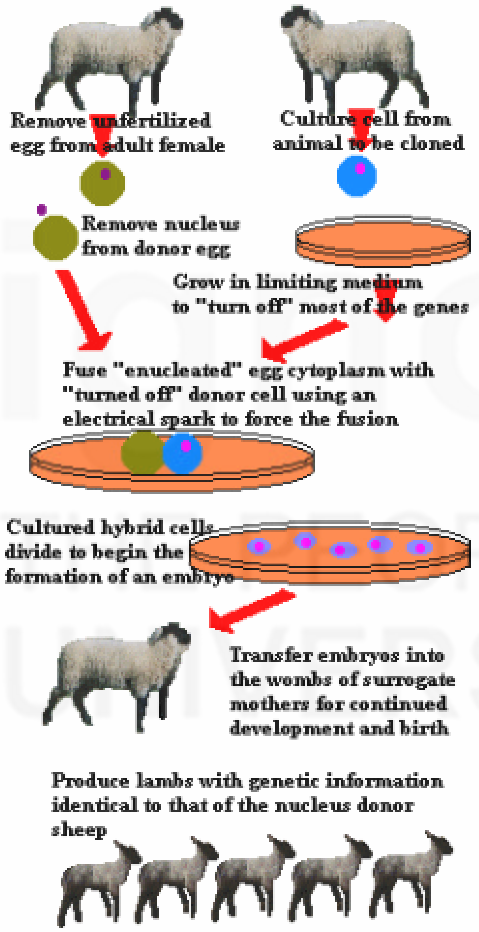

Fig.10.16: Somatic cell cloning

Some scientists are even working on using cloning techniques to bring extinct species back to life. For example, they hope to find some intact nuclei preserved in 20,000 year-old carcasses of woolly mammoths frozen in the permafrost in Siberia. The nuclei would be implanted into elephant eggs, and if development occurred the embryos would be implanted into surrogate mother elephants. If a calf was produced it would be an authentic woolly mammoth.

v) Fostering

Many egg-laying animals (i.e. birds and reptiles) are capable of producing many more eggs than they can rear. This raises the possibility of collecting the extra eggs and hatching and rearing the animals in captivity with a foster parent, then using them to supplement wild populations. It has worked extremely well with

some birds, particularly the peregrine falcon, which is now doing so well that the fostering program is being phased out. Rearing of whooping cranes has also been successful, and the species recovered from a population of 21 birds in 1941 to over 300 in 1996. But the other part of the whooping crane program, in which the young were to be reared by the much more numerous sandhill cranes, has not been successful – the fostered animals have not yet reproduced in the wild.

In at least seven cases (Pere David's deer, Arabian Oryx, American bison, Red wolf, Guam kingfisher, Guam rail, and the California condor) the species were extinct in the wild at the time of reintroduction.

A major problem with fostering programs is that the young animals learn crucial behaviours in the wild but not in captivity. Captive bred animals sometimes bond to their human keepers instead to their own species which makes reproduction even more difficult.

Ex-situ zoo populations can directly support the *in situ* survival of some species by providing the nuclei for re-establishment or reinforcement of wild populations in nature.

The World Zoo Conservation Strategy emphasizes – in accordance with the IUCN position statement on *Translocations of Living Organisms* issued in 1987 – that such reintroductions and restocking projects, when properly applied, can bring great benefits to natural biological systems. Careful consideration should, however, be given to genetic and behavioural quality of animals for reintroduction, to preventing transfer of pathogens and parasites to natural areas, and to mixing of subspecies through reintroduction. Additionally, factors threatening reintroduced animals should be eliminated from reintroduction areas, and the carrying capacity of such areas should not be exceeded. Reintroduction and restocking projects have been undertaken with more than 120 species. Fifteen of these reintroductions have resulted in the establishment of self-sufficient populations to date.

Because of limitations of space, finances, and facilities in the institutions that undertake captive breeding, species prioritization is a primary concern. An overwhelming 91% of animals kept in Indian zoos are non-threatened, yet take up much of the space and resources of zoos (Walker, 2000). Zoos in India may need to restrict their efforts to a few species that can benefit from captive breeding initiatives, such as small-bodied species of Chiroptera, Ropdentia, and Insectivora. These make up 60% of mammalian taxa in the country and are easier to reintroduce than larger mammals (Walker, 2000). Instead, mini zoos and deer parks can act as a sink for the surplus, hybrid, aged, and infirm animals while the larger zoos can focus on serious captive breeding.

Zoos are institutions that can uniquely integrate their three major conservation tasks of environmental education, research, and species and habitat conservation.

vi) Translocations

Sometimes conservation of faunal species involves or necessitates translocation of animals. This means the movement of individuals from its natural habitat, or from captivity, to another habitat. Translocations are carried out in connection with introductions or reintroductions, and should be handled with extreme caution. They are generally justified when:

- land development will definitely destroy wildlife habitat and translocation is the only way of preserving the animals in the area.
- boosting the numbers of a threatened wild population to ensure its survival by adding other individuals of the same species.
- splitting an existing population that is at risk, to prevent loosing the entire population.

The movement of animals between populations is now increasingly used as a conservation tool, and over 700 **repatriations** or **translocations** are reported each

year. These operations are carried out often with support from international captive breeding programs and receive the cooperation of zoos, aquaria, etc.

Such programmes have to be carefully planned and carried out to ensure success. The success rates of the establishment of translocated species vary. Overall, the translocation of game species (species used for hunting) appears to have been more successful than efforts connected with threatened or rare species. The success rates of establishment for translocated amphibians and reptiles are particularly low at 19% and 25% respectively.

vii) Introduction

This involves the translocation of a species (from its natural habitat or from captivity) into an area outside its historical distribution. Such species would then become an "exotic" to the area. This should be handled with extreme care and needs (•) extensive study of the habitat and the behaviour and social organization of the species to be introduced to ensure that the species has a good chance of adapting to the habitat; and (•) to prevent deleterious effects on the habitat and local species by the introduced species that may become invasive (also see subsection 11.7.3).

viii) Reintroduction

This involves the translocation of a species (from its natural habitat or from captivity) into an area within its historical distribution, either to boost existing populations, or to establish new populations when the original population had died out. This too should be handled with extreme care and needs extensive study of the habitat and the behaviour and social organization of the species to be reintroduced, especially if the individuals are being introduced to boost existing populations. If the original population had died out, it is vital to make sure that the threats underlying the original local extinction are no longer a threat to the reintroduced animals. (Box 10.7)

Box 10.7: Dudwa rhino reintroduction

The Dudwa forests were home to the one horned rhino a century and half ago (Fig. 10.17). However, due to rampant poaching for its valuable horn and for game hunting, it was wiped out from the area by the late 19th century. Rhinos were successfully reintroduced to Dudwa on 1 April, 1984 following a systematic reintroduction effort of captive bred stock. Suitable habitats were first earmarked prior to their reintroduction. About 27 km ^{2} of grasslands and open forests with perennial source of water was earmarked as the rhino-reintroduction area and two monitoring stations established. Currently there are seven rhinos breeding successfully – 4 adult females, 1 adult male, and 2 sub-adult males.

Fig.10.17: Rhino

- **Seed bank**

  The preservation of plant germplasm in seedbanks, (or genebanks), is one of the techniques of ex-suit conservation of plant species.

  Seeds have a natural dormancy feature, which allows for their suspended preservation for long periods of time with little damage, provided the conditions are favourable. Banking dormant seeds enables to keep genetically representative samples of rare and endangered plant species as a kind of "genetic insurance".

Role of seed bank in conservation

Genetic diversity among plant species has a significant impact on human life. For example, many of our medicines were first discovered from plants. It is not known which other plants could later on prove beneficial. The conservation of diversity is therefore very important to human life. Many think plants must survive in order for their benefits to be discovered.

In-situ conservation of plant species is usually thought to be the ultimate conservation strategy. However, it implementation is not always possible. For example, it can not be used to prevent extinction of endangered or rare species whose habitats are disappearing. Such situation is better dealt through (or with) *ex-situ* conservation.

Seeds storing

Storing germplasm in seedbanks is both inexpensive and space efficient. It allows preservation of large populations with little genetic erosion. Seedbanks also offer good sources of plant material for biological research, and avoid disturbance or damage of natural populations.

Two types of seeds may be considered.

- The orthodox seed those that can be dried at bw humidity and stored at low temperatures. These orthodox seeds can remain viable for many years and are rather easily stored in seedbanks.
- The recalcitrant seeds do not tolerate low humidity and temperature, and thus are not good material for seedbanking conservation.

Preparation for storage is different for each species and has to be assessed before any conservation planning. Roughly, the different processes imply first collection of the seeds, then drying to a moisture content of less than 6%. The seeds are then stored at low temperature (below −18°C). As seeds tend to lose germinative power over time monitoring of viability and regeneration processes must be done frequently.

Seed banks in the world

According to the FAO, there are about 6 millions plants stored through seed storing in about 1300 gene banks. This amount represents a small fraction of the diversity, and many important regions have not been bioprospected yet (Fig.10.18).

Fig.10.18: Seed bank

Some of the challenges facing conservation through this technique are:

- Varieties stored tend to adapt to the storage conditions, and they have to be regularly replanted to stay viable. Besides, only a limited number of specimens are stored and it is impossible to store recalcitrant seeds. Finally, most of the seeds stored are field plants. Only 15% of all seed banked plants are wild species or weed species.

- There is a need for improvement of cataloguing and data management. It should include identity of the plant stored, location of the sampling, number of seeds stored and viability state. Other information, such as farming system should also be available to future farmers. There is a need for global documentation, that could be shared between all the gene banks; research facilities, and farmers across the world.

- The human and financial cost of facilities running is sometimes too expensive for some collections.

- There is a need for storage of developing countries food seeds. Seed banks and funders are confronted to the issue of creating collections without being accused of biopiracy, through providing a free resource for seed companies in rich countries.

It is widely believed the protection of plant diversity is essential for food security in particular.

- **Tissue culture**

  Plant tissue culture is an essential component of plant biotechnology. The possibility to regenerate whole plant from protoplasts, single cells, tissues and organs, *in vitro*, has opened out entirely new approaches to plant improvement, and has considerably enhanced the efficiency of the conventional methods of plant breeding and plant propagation.

  Modern biotechnology can greatly facilitate conservation and sustainable utilization of genetic diversity. Plant tissue culture has, therefore, largely been adopted for mass production of selected elite varieties and to conserve endangered and threatened species. Research and development efforts need to be directed for commercialization of products and processes utilizing the existing rich natural resources of the country; a judicious application of biotechnology to convert biological wealth into economic wealth on a sustainable basis should be one of the major aims in the future.

  The term plant tissue culture denotes genetically all cell, tissue and organ cultures, and employs the basic dogma totipotency. The technique essentially involves separation of a cell/tissue/organ from the donor plant under aseptic conditions and growing it on a synthetic medium in a suitable container under controlled environment. Among other applications, tissue culture has been successfully dovetailed (fit readily together) to conservation and exchange of germplasm in horticulture.

  Steady and progressive genetic erosion has resulted in a marked decrease in plant diversity. A wide genetic base helps to contain biotic and abiotic stresses that destroy entire crop stands. Developing countries, such as India, Sri Lanka particularly those in the tropics, are still the repositories of vast biodiversity in their agroecosystem and act directly or indirectly as reservoirs and suppliers of germplasm. Therefore, there is an urgent need to establish genestocks which will provide recruiting grounds for gene-hunters especially for crop varieties that run the risk of elimination by intensive agriculture. An adequate genetic resource conservation programme is to genetic engineering as a library is to knowledge. In

this context, the tropical and subtropical fruit crop species stand to gain immensely from *in vitro* techniques of conservation and exchange of germplasm.

Although many gene banks exist worldwide today, only about 30 countries provide secure long-term storage because there is little provision for long-term sustainable management of gene banks. Therefore, an integrated approach is both prudent and practical. Success stories include tropical species such as cacao, coconut, *Citrus* spp., coffee, etc. Even so, *in -vitro* conservation in tropical fruit crops has a long way to go and avenues for research in this area are wide open (Fig. 10.19).

Fig.10.19: Propagating plant through tissue culture

- **Conservation at National Level in Various Institutes**

  Conservation is usually thought of as consisting of scientific research. In many countries government organisations are the only organisation taking conservation action because of great opportunities as they may be relatively well connected and securely funded. In India several Institute such as NBPGR, NBFGR, NBAGR, were established to play vital role in *in-situ* conservation of biodiversity. We will describe their contribution towards conservation of biodiversity one by one.

National Bureau of Plant Genetic Resources (NBPGR)

India is an important centre of diversity for plant genetic resources (PGR) and its management has as long history as that of domestication of crops and agriculture. However, systematic collection and evaluation started with the establishment of the then Imperial (now Indian). Agricultural Research Institute (IARI) at Pusa, Bihar, in 1905, which was shifted to New Delhi in 1935. National Bureau of Plant Genetic Resources (NBPGR) was established in January 1977 since, then institute has significant contribution in crop improvement in India through germplasm introduction from various institutes/organizations located in foreign countries and germplasm collection from within the country and abroad and conservation thereof.

Objectives of NBPGR

- To plan, organize, conduct and coordinate exploration and collection of indigenous and exotic plant genetic resources.
- To undertake introduction, exchange and quarantine of plant genetic resources.
- To characterize, evaluate, document and conserve crop genetic resources and promote their use, in collaboration with other national organizations.
- To develop information network on plant genetic resources.
- To conduct research, undertake teaching and training, develop guidelines and create public awareness on plant genetic resources.

Bureau maintains the national base collections of different crops (Table 10.3) kept under long-term storage at −20 ºc in the national gene banks. Also *in-vitro* collections are maintained in the TCCP unit. Its regional stations maintain Fields collections. It has also developed facilities for cryo-preservation of seeds, pollen and *in-vitro* cultures in liquid nitrogen, (−196°C). Besides, a chain of clonal repositories have been envisaged under its network. Computerized national database on plant genetic resources and national herbarium of cultivated and wild plants are also operative under its system. The basic research is related to conservation and utilization of germplasm from an integral part of Bureaus research programmes so as to improve quality and effectiveness of multi-faceted services for the sustainable management of plant genetic resources**.**

Table 10.3: Status of base collections in national gene bank

Crop Groups	**Accessions (no.)**
Cereals	1,14,646
Millets and Forages	41,732
Pseudocereals	3,928
Grain Legumes	42,265
Oilseeds	33,988
Fibre Crops	8,493
Vegetables	16,184
Fruits	172
Medicinal & Aromatic Plants & narcotics	2,588
Spices & Condiments	398
Agro-forestry	142
Duplicate Safety Samples	10,235
Total (also includes 1499 Released varieties and 548 Genetic Stock)	**2,74,774 (Long-Term Conservation at −20°C) (31 July, 2004)**

National Bureau of Fish Genetic Resources (NBFGR)

Conservation of fish germplasm resources is a prerequisite for increasing fish production in a sustainable manner. Preparing detailed micro-level plan for conserving the country's biodiversity is an obligation on part of India under Convention on Biological Diversity. National Bureau of Fish Genetic Resources continued its efforts in the five major programme areas related to conservation of germplasm resources.

Thrust Areas

- Database on fish biodiversity of India on GIS platform.
- Endangered fish habitat inventory for developing species specific recovery and fish habitat restoration programmes.
- Development of aquatic sanctuaries.
- DNA fingerprinting of prioritized species.
- Utilisation of genetic markers in conservation programmes.
- Gene banking of cryopreserved gametes, embryos and DNA materials.
- Database on exotics and quarantine.
- Guidelines for controlled introduction of exotics and quarantine.

The institute has worked upon the database on fish diversity of India containing information on systematics, habitat and distribution of 2118 finfishes has been prepared. Karyotype images and isozyme profile of fishes have also been incorporated. From this database specific information on fishes as per ecosystem, major rivers as well as biodiversity rich areas like North East India and Western Ghats can be queried. With respect to North East and Western Ghats, specific information on endangered, potential cultivable and ornamental fishes can be obtained. A list of threatened fishes of India comprising of 79 species under different categories of threatened status has been drawn. A digital base map of India (1:5 million scale) showing 330 Indian rivers and 20 lakes and reservoirs has been prepared. A database on these water bodies covering some parameters has been prepared on a geographic information system (GIS) platform and this will be integrated with the fish biodiversity database of India.

National Bureau of Animal Genetic Resources (NBAGR)

The diversity of climates, soil type and culture resulted in development of various breeds of livestock that are well adapted to specific sets of environmental conditions in our country. Most of these native breeds are unique in their adaptation to agro-climatic conditions of their habitat and management practices. These indigenous stocks are not only able to thrive under harsh climatic conditions and a very low input system but also produce at subsistence level. The animal genetic resources of India are represented by a broad spectrum of native breeds of cattle, buffaloes, goats, sheep, swine, equines, camels and poultry. In addition to these animals; yak, mithun, geese, ducks, quails and pet animals are also part of our genetic resources.

The Bureau has set up a fully operational data base unit on indigenous farm livestock genetic resources which is being continuously upgraded and enlarged in its scope and content and also in number of data bases. The Bureau is engaged in characterization and evaluation of vast livestock genetic resources of India with collaboration of State Agricultural Universities and ICAR institutes. Documentation of information on animal genetic resources is another major activity of the Bureau along with providing status report of various breed to the Government and other agencies working in the area of biodiversity conservation programmes. Research is going on molecular characterization and immunogenetic investigation of farm animals. Efforts are underway to develop a Gene Bank for the conservation animal.

SAQ 3

1) Name at least two distinct genetic considerations/problems involved with captive breeding programs and describe methods of avoiding them.

2) Describe the role of zoo in the conservation of faunal biodiversity.

3) Visit a local zoo or botanical garden. What activities are conducted there to promote biological conservation? List them.

4) Describe the advantages of tissue culture, how this technique will benefit our country. Try to make a list of plants which are benefited from this techniques.

5) Describe the contribution of NBPGR in the conservation of plants germplasm in the country

10.7 GOBAL EFFORTS TOWARDS BIODIVERSITY CONSERVATION

There are two international conventions and one international programme that have provision for the declaration of internationally important sites for Protection in any part of the world. Such Designations serve to channel international attention and to foster cooperation in safeguarding these valuable areas for the national as well as for the global community. These categories are:

10.7.1 World Heritage Sites (listed under Category X of IUCN's protected area classification)

A UNESCO World Heritage site is a specific site (such as a forest, mountain range, lake, desert, buildings, complex, or city that has been nominated for the intervations world heritage programme administered by UNESCO.

The programme aims to catalogue, names, and preserve sites of outstanding importance, either cultural or natural, to the common heritages of human kind. Listed sites can obtain funds from the World Heritage find under certain conditions. The program was founded with the convention concerning the protection of world cultural and natural heritage that was adopted by the general conference of UNESCO on 16 November, 1972.

World Heritage Sites (WHSs) are declared under UNESCO's World Heritage Convention and should be nominated by countries that are a party to the World Heritage Convention. The concept here is the protection of cultural and natural site and cultural landscapes that are of outstanding universal value. Their deterioration or destruction constitutes a loss to the heritage of all humanity and not just to the country where they are located. There are now 563 cultural sites, 144 natural sites and 23 mixed sites in 125 countries listed under the Convention, which seeks to identify and protect the WHSs through a system of collective assistance and cooperation that compliments (not replaces) the actions of States Parties to the Convention. The World Heritage Convention, ratified by 174 States Parties, is serviced by UNESCO's World Heritage Centre.

India ratified the World Heritage Convention in 1977, and since then five natural sites (Table 10.4) (Fig.10.20) have been inscribed as areas of outstanding universal value. These sites are:

- Kaziranga National Park
- Keoladeo Ghana National Park (Fig.10.21)
- Manas National Park
- Sunderbans National Park
- Nanda Devi National Park

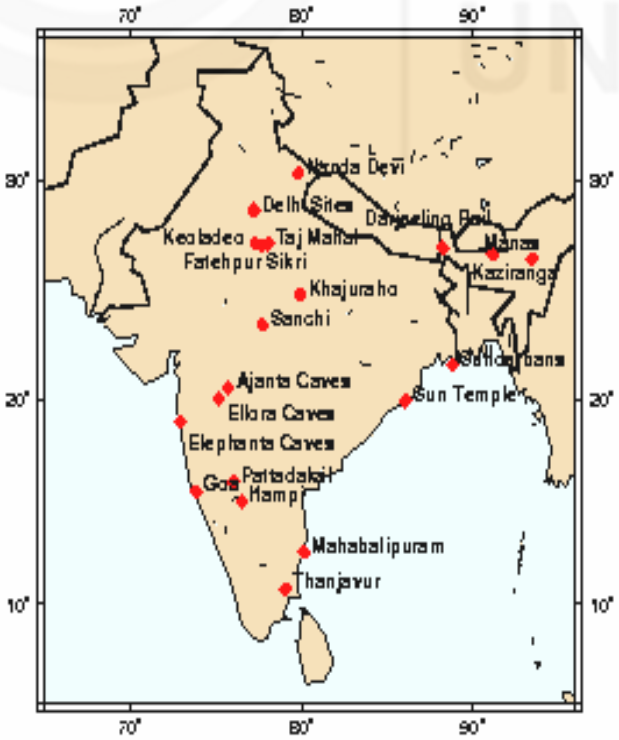

Fig.10.20: India's map showing World Heritage Sites

Fig.10.21: Keoladeo Ghana National Park

Table 10.4: Difference between World heritage sites and biosphere reserves

World Heritage Sites	Biosphere Reserves
i) WHSs are of outstanding universal value, generally cover a protected area, and mostly emphasise conservation.	i) Biosphere Reserves should be representative or typical ecosystems and they go beyond the boundaries of protected areas, thus promoting conservation, environmental and social research and sustainable development equally. They do not therefore need to be outstanding in terms of endemics or be the areas richest in biodiversity, although BR should make a significant contribution to biodiversity.
ii) All WH Natural sites are legally protected and provide the highest degree of international legal protection.	ii) Biosphere Reserves should contain a legally protected core area, but they can have varying degrees of legal protection in the different zones (i.e. transition and buffer zones).
iii) The status of WHSs are monitored on a case-by-case basis, regionally, using a six-year cycle.	iii) Biosphere Reserves are subject to a periodic review every ten years. the areas of similarity between the two concepts are many, particularly with regard to site-functioning and outreach.
iv) WHSs provide the highest degree of international protection, which can be reinforced by scientific knowledge and expertise from MAB National Committees; WHSs can benefit from the World Heritage Fund for enhanced conservation	iv) Biosphere Reserves are sites where scientists and managers meet.
v) WHSs often generate income through tourism.	v) Biosphere Reserves promote sustainable development in partnership with local people and could also promote sustainable eco-tourism.
There is increasing overlap of goals between WHS and BR with greater emphasis now on people for conserving natural areas. Many protected areas declared as a WHS and a BR are able to meet these duel demands quite successfully. **Source:** NSF, 2002	

10.7.2 Ramsar Sites

Ramsar convention is known as after the place where the convention was agreed, this treaty provides the framework for international collaboration on wetland conservation which includes mangroves and coral reefs. Contracting countries have four obligations (Davis 1994). (1) Incorporate the consideration of wetlands conservation within their national land-use planning. (2) Designate at least one wetland of international importance ('Ramsar Sites') according to specified criteria. (3) Promote wetland conservation by creating nature reserves. (4) Train staff in wetland wardening,

Wetlands are defined as areas of marsh fen, peat land or water, whether artificial or natural, permanent or temporary, with the water static or flowing, brackish or salt, including marine areas, depth of which does not exceed 6 meter for example – mangroves, corals, estuaries, weeks, bays, sea grasses and lakes etc.

research and management and consult other countries especially for species or areas in common.

The **Ramsar Convention** is an international treaty for the conservation and sustainable utilization of wetlands, i.e. to stem the progressive encroachment on and loss of wetlands now and in the future, recognizing the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value.

The official title is *The Convention on Wetlands of International Importance, especially as Waterfowl Habitat*. The convention was developed and adopted by participating nations at a meeting in Ramsar, Iran on February 2, 1971 and came into force on December 21, 1975.

The Ramsar List of Wetlands of International Importance now includes over 1,200 sites (known as Ramsar sites) covering around 1,119,000 km^2, up from 1,021 sites in 2000. The nation with the highest number of sites is the United Kingdom at 169; the nation with the greatest area of listed wetlands is Canada with over 130,000 km^2, including the Queen Maud Gulf site at 62,800 km^2.

Presently there are 145 contracting parties, up from 119 in 2000 and from 18 initial signatory nations in 1971. Signatories meet every three years as the Conference of the Contracting Parties (COP), the first held in Cagliari, Italy in 1980. Amendments to the original convention have been agreed to in Paris (in 1982) and Regina (in 1987).

There is a standing committee, a review panel and a secretariat. The headquarters is located in Gland, Switzerland shared with the IUCN.

India became a contracting party to Ramsar convention since 1 February 1982 and six wetlands in the country were designated as Ramsar sites covering 192, 973 hectares of land (Table 10.5). At present, we have nineteen Ramsar sites, covering 648,507 hectare of land (Fig. 10.22).

Table 10.5: Ramsar sites in India

Kerala	Ashtamudi Lake
Orissa	Bhitarkanika Mangroves
Madhya Pradesh	Bhoj Wetland
Orissa	Chilika Lake
Assam	Deepor Beel
West Bengal	East Calcutta Wetlands
Punjab	Harike Wetlands
Punjab	Kanjli Lake
Rajasthan	Keoladeo National Park
Andhra Pradesh	Kolleru Lake
Manipur	Loktak Lake
Tamil Nadu	Point Climere Wildlife and Bird Sanctuary
Madhya Pradesh	Pong Dam Lake
Punjab	Ropar Lake
Rajasthan	Sambhar Lake
Kerala	Sasthamkotta Lake
Jammu & Kashmir	Tsomoriri
Kerala	Vembanad - Kil Wetland
Jammu & Kashmir	Wular Lake

Fig.10.22: Ramsar sites of India at present
(**Source:** http://www.wetlands.org/RDB/asia/india_sites.html)

10.8 SUMMARY

- Biodiversity is very important for the survival of human kind as it provides several benefits such as food, medicine, shelter, environmental services to ecosystem; social values; improvement of genetically resources and biotechnology. Thus 40 percent of world economy and 80 percent of people needs are fulfilled from biodiversity.
- Biodiversity can be conserved at genetic level, species level and ecosystem level.
- Different types of protected areas are legally designated at national and international level. In India protected areas falls in Group A and Group B.
- Different approaches are used to conserve biodiversity. In Habitat based approaches habitat as a whole unit is conserved while in species based approaches only identified species are given high priority for conservation. Some species are internationally recognised as endangered species are given priority for conservation both nationally and internationally, both the approaches have some advantages and disadvantages. Ecosystem based approaches are important because they conserve the flagship species as well several other species.
- Conserving the whole landscape protect several wildlife species. Integrated landscape approach is effective for long-term conservation
- *In-situ* conservation meaning on-site conservation and *Ex-situ* conservation meaning off-site conservation are two important ways of conservation of species. Wildlife conservations are mostly based on *in-situ* conservation. *Ex-situ* conservation is man's efforts to sustain and protect the environment and *ex-situ* conservation is only used when species extinction is eminent.
- *In-situ* conservation of species is generally operated in places like, National parks and sanctuaries, wetlands, Biosphere reserves. Tiger reserves, Elephant reserves.
- *Ex-situ* conservation sites are Botanical garden, Zoological gardens (where much work is done towards conservation of animals through captive breeding, embryo

storage and transfer technology, artificial insemination, somatic cell cloning, fostering) and translocations, introductions and reintroductions of animals in the wild are some important aspects of conservation which are needed for the survival of species. Seed banks and tissue culture are important methods for plant conservation.

- World Heritage Sites, Biosphere reserves, Ramsar sites are protected areas which are internationally recognised. Nationally in India some government organisations such as NBPGR, NBFGR and NBAGR in India play important part in biodiversity conservation.

10.9 TERMINAL QUESTIONS

1. List four main reasons for national governments as well as the international community should be engaged in biodiversity conservation.
2. List the ten principles of biodiversity conservation.
3. List two important approaches to conserving biodiversity. How do they apply to conserving biodiversity in your country/state? Discuss.
4. How appropriate is the traditional knowledge for conservation of biodiversity in your country/state? Discuss.
5. Make a complete list of the different categories of Protected Areas in your country/state or province and see whether this is adequate to conserve biodiversity in that region. What categories of IUCN's PA categories do they represent?
6. Make a list of national World Heritage Sites and International MAB Reserves in your country. Which one is nearest to your home?
7. Locate (if possible) an ecological island close to where you live ,visit it, find out which species are most vulnerable to local extinction and why?
8. Name and describe two key reasons why habitat fragmentation is one of the most destructive ways of disrupting habitat.
9. Why is biodiversity important? Discuss some of its values, and indicate the ones you favour the most.
10. Differentiate between *in-situ* and *ex-situ* conservation. What is the ultimate goal of captive breeding? Why is it best used only as a last resort?

ACKNOWLEDGEMENT

For the photographs of Elephant, Chimpanze and Rhino, we acknowledge to WWF-Canon Michel GUNTHER.

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UNIT 11 SOCIAL AND ECONOMIC STRATEGIES OF BIODIVERSITY CONSERATION

Structure

11.1 INTRODUCTION

Biodiversity conservation is a complex issue which requires several strategies cooperation administration and various government agencies NGOs and local inhabitants. In order to achieve the objective of biodiversity conservation a number of social and economic strategies have been successfully applied in various combinations.

Social activities such as wild life tourism, nature tourism and Ecotourism have proved very encouraging results in protecting wild life resources and biodiversity in general.

The unit also deals with managing biodiversity in protected area and outside protected area by several methods. Traditional agro systems of our country also ensure several types of selected biodiversity. The habitat and ecosystem managements are two important aspects of biodiversity conservation which can protect a wide range of species.

Environment Impact Assessment (EIA) is one of most important tool to asses the impact of every major development projects which has profound effect on biodiversity. Management plans are also important part of biological conservation.

Communication for biodiversity conservation is an important aspect and can become very effective tool for educating and creating mass awareness about the importance of biodiversity conservation for human wellbeing. A planed and effective communication among the local communities and other stake holders can enhance the conservation of biodiversity.

Objectives

After studying this unit, you would be able to:

- differentiate between Nature Tourism and Ecotourism;
- list the negative and positive impacts of tourism;
- appreciate the possibilities of Ecotourism and its benefits in preserving biodiversity;
- to make a list of key components of a tourism management strategy for a protected area;
- describe the key aspects of implementing a tourism management strategy;
- appreciate the importance of tourism management plan for a protected area;
- enumerate the potential of ecotourism in India;
- describe the various methods to manage biodiversity in protected areas; and
- list various methods used for protecting biodiversity outside protected areas.

11.2 SOCIAL AND ECONOMIC STRATIGIES

Social and economic strategies have become increasingly prominent in biodiversity conservation. However, many of these approaches are new to conservationists and there is little experience in applying them for sustainable use and conservation of biodiversity.

Economic incentives

Economic incentives should make biodiversity an asset rather than a liability. They aim to increase returns on activities that conserve or restore valuable biological habitats.

Economic incentives tend to use market mechanisms to influence decision making. A brief description of important economic incentives is given below:

- **Positive incentives:** Any monetary (direct payments, cost sharing, tax advantages) or non monetary (such as recognition and awards for outstanding performance) inducement, which incites or motivates governments, local people, and international organizations to conserve biodiversity.

- **Disincentives:** any mechanism that internalises the cost of use and/or damage to biological resources in order to discourage activities that deplete biodiversity.

- **Indirect incentives:** any mechanism that creates or improves upon markets and price signals for biological resources encouraging the conservation and sustainable use of biodiversity.

Social strategies

The social, cultural religious norms have been woven round the practices of biodiversity conservation by various societies of this description will make it abundantly clear as how the thought of conservation have been an important element of our various believes and cultural ethos.

11.3 CULTURAL AND RELIGIOUS BELIEFS

Despite globalization and political domination of mainstream cultures, traditional resource use norms and associated cultural practices prevailing in rural societies indicate that a large number of elements of local biodiversity, regardless of their use value, are still protected by local cultural practices.

Indian scriptures mention specific one such as Kalpa Vriksha and the Chaitya Vriksha.

India has a rich ethos of biodiversity conservation and traditional knowledge systems and it is these practices that have given rise to informal and localized *in-situ* conservation.

The trees have always been associated with wisdom and immortality. Hindu scripture describes a celestial tree having its roots in heaven and its branches in the underworld that unites and connects all the living creatures (Box 11.1).

Most of us know that Enlightenment of the Buddha occurred under a tree. In fact one tradition holds that it was tree itself that inspired Buddha to spread the dharma instead of being **pratyeka buddha** eternally resting in meditative absorption.

The worship of, or at least the veneration of, the tree is a custom found all over the world. Sometimes the trees are marked sacred and sometimes they are worshiped for life and fertility of earth.

The earliest codified law on wildlife protection tracks back to the third century B.C. when King Ashoka made a law in the matter of preservation of wild life and environment where be prohibited the killing of certain species of animals such as parakeet, rhinoceros etc.

Box 11.1: Approaches towards conservation of biodiversity in India

The practice of sacred groves is the innate tradition of local communities for protecting biodiversity based on religious beliefs. This practice has led to the protection of many keystone tree species, guaranteeing the preservation of a wide array of living organisms dependent on them. Although considered as a powerful management strategy in the past, this practice has weakened today. Protected Area Management is the modern concept of linking biodiversity conservation with the improvement of human welfare. It should involve local communities and institutions in the planning and management of forests.

Source: Adapted from R. Shailaja, M. Sunil Kumar, and K.T. Srihari in IUCN, 2000.

In South India, there are a number of tree shrines. Notable ones include the mango (*ekamra*) tree at Kandhi, a black plum (*jamnu*) at Jumbukeswaram near Tiruchirappalli, the Indian plum (*panai*) at Tirupanaiyur and the "blinding" tree (*tillai*) at Chidambaram. Shrubs, too, can be considered sacred: the jasmine (*mullai*) at Tirumullaivayil and a gooseberry (relli) at Tirunellikka.

11.4 CONSERVATIVE ASPECTS OF CULTURE

Traditional ecological knowledge has been considered as for the conservation of indigenous species of plants and animals in the tropics (Johanes, 1989). There are many factors responsible:

a) First factor is that the forest management policies in the past were imposed on the culture of the indigenous communities.

b) The second factor is that decisions were taken based on existing conditions of ecology and culture of the people.

c) Then there were the factors of ancient folklores and traditions coupled with taboos.

11.4.1 Cultural Folklores

These are based on traditional ecological knowledge of a people about resource richness, utilization and preservation. They are influenced by long term settlements, farming, gathering, hunting and fishing, and development of recreational facilities. Folklores were derived through myths and legends, dreams, spiritual divinations, story telling and cultural ceremonies. Folklores influence utilization levels of biotic resources and provide a source of recreation among youths.

11.4.2 Taboos

Taboos are social norms which regulate human behaviour towards resource use. They prohibit or restrict people from either killing or eating wild animals, or from touching specific plants, and use of plants for cooking, fuel wood or other uses.

The traditional culture and its conservative aspects have faced a series of challenges with the growth of modern trends. Community rules and regulations are breaking down. To keep the culture and ecology alive, these traditions need to be revived and kept alive.

For survival of the mankind, culture must survive, and for survival of the culture, the environment per-se has to be healthy and nurturing. Traditions of the past cultures need to be amalgamated into life style of today so that the culture ecology the world over may flourish.

11.4.3 Sacred Groves

The 'Bamboo groves' of Rajbanshi community of North Bengal, 'Orans' of West Rajasthan, 'Sarnas' of Chhatisgarh and Chhota Nagpur, 'Maw-Bukhars' of Khasis of Meghalaya, 'Devrais' of Maharashtra, 'Kovil Kadu' of Tamil Nadu and 'Kuvus' of Kerala are some of the examples of Sacred groves. More than 2000 'Sacred groves' are reported to be in existence in Kerala itself.

The traditional patterns of land and water use in India did indeed create such a mosaic of patches of different levels of disturbance as might have been entirely compatible with the maintenance of high levels of biological diversity. Such a mosaic included intensively managed areas such as fields and orchards, moderately disturbed areas such as village woodlots from which some wood, leaf lopping and fruit would remove in a regulated fashion, and totally undisturbed areas protected as sacred groves or sacred ponds. This practice of setting aside refugia, or totally undisturbed sites such as sacred groves or ponds seems to have arisen in many different cultures the world over, perhaps in conjunction with the beginning of agriculture.

Sacred groves have been widely recorded from Asia and Africa. A widespread network of sacred groves apparently covered India in pre British era, though much of the forest have vanished from Indian soil but sacred groves have nevertheless continued to survive in India to this day in very remote area inhabited by tribal or peasant societies. Bambarin and Nirancarachi Rai in Satari Taluka near Goa-Karnataka border while bambarin is the abode of rare medicinal plants. Nirancarachi Rai has 19 different evergreen species whose roots protruding out. In kerala when new land is brought under cultivation 14% of the land is dedicated to cobras, these are some examples of scared groves which still are a part of our Indian culture.

11.5 NATURE TOURISM

Nature tourism or nature-based tourism includes all tourist activity that depends directly on the use of natural areas and resources that are in a relatively undeveloped state. This includes travel by tourists to view beautiful scenery, for photography, or for recreation connected with aquatic resources (e.g. water sports, boating, etc.), vegetation and wildlife – and even includes trophy hunting for adventure.

Examples of nature based-tourism are wilderness tourism, adventure tourism, green tourism and ecotourism.

11.5.1 Negative Impacts of Nature Tourism

Overcrowding, misuse of natural resources, construction of buildings and other infrastructure, and other activities associated with tourism often produce adverse impacts on the environment that are both physical and cultural. The impacts of tourism vary according to:

- The number and nature of tourists visiting a site, and
- The characteristics of the site itself.

Major management problems of protected areas, which are over visited.

- Stress on vital resources such as water, land.
- Pollution caused by indiscriminate disposal of solid waste and discarded item.
- Vandalism by souvenir hunters.
- Overcrowding and indiscriminate construction.

As with most problems, the negative impacts (Fig.11.1) of tourism can be mitigated with effective management. This can only be done if the problems are identified, assessed and evaluated. Once this is done, specific management responses will have to be developed and implemented to overcome the problems that have been created.

Fig.11.1: Negative impact of tourism

Tourism impacts **on natural areas** can be broadly classified as:

- **direct impacts** caused by the presence of the tourists, or
- **indirect impacts** caused by the presence of infrastructure for tourist activities.

Box 11.2: Examples of direct tourism impacts on natural areas

* impacts on geological exposures, minerals and fossils
* impacts on soils
* impacts on water resources
* impacts on vegetation
* impacts on animal life
* impacts on sanitation
* impacts on the landscape and aesthetic impairment
* impacts on the cultural environment (Fig. 11.2)

Source: Ceballos-Lascurain, 1996

Fig.11.2: People from some societies are used as commodities in tourism industry.

There is considerable conflict of interest between conservation and tourism, due to the desire to preserve natural sites as well as allow people to visit them. The conflict is more pronounced if tourism causes damage to the environment and the natural resources. In some countries, serious problems have already arisen due to unregulated

nature tourism. For example, about three million people visit the National Parks in Spain each year. As the total area of these parks is about 125,000 ha, over-visitation is a serious problem. In many countries of South Asia some protected areas are now experiencing a considerable increase in visitation levels which has led to various environmental problems.

Tourism and conservation can, however, co-exist if there is mutual benefit (i.e. symbiosis). This requires that both tourism and conservation are organized in such a manner that natural assets are conserved as far as possible in their original condition, or that they reach a more satisfactory condition through the tourist venture, while enabling an increasing number of people to derive more benefits from nature and natural resources.

11.5.2 Ecotourism

Ecotourism is emerging as a popular approach to protect natural areas throughout the world. In general, ecotourism can be benign and consistent with sustainable development but there are always exceptions which require careful management. Very few ecotourism sites are unique and desirable to be economically self-sufficient.

Ecotourism relies heavily on ecosystem and species diversity and it has the potential to contribute significantly to biodiversity conservation. Ecotourism also benefits greatly from biodiversity conservation, as tourists are keen to experience high biological diversity within a limited period of time in a limited geographical area.

Eco-tourism focuses on local cultures, wilderness adventures, volunteering, personal growth and learning new ways to live. It is typically defined as travel to destinations where the flora, fauna, and cultural heritage are the primary attractions. Responsible ecotourism includes programs that minimize the adverse effects of traditional tourism on the natural environment, and enhance the cultural integrity of local people. Therefore, in addition to evaluating environmental and cultural factor initiatives by hospitality providers to promote recycling, energy efficiency, water re-use, and the creation of economic opportunities for local communities are an integral part of ecotourism (Fig. 11.3).

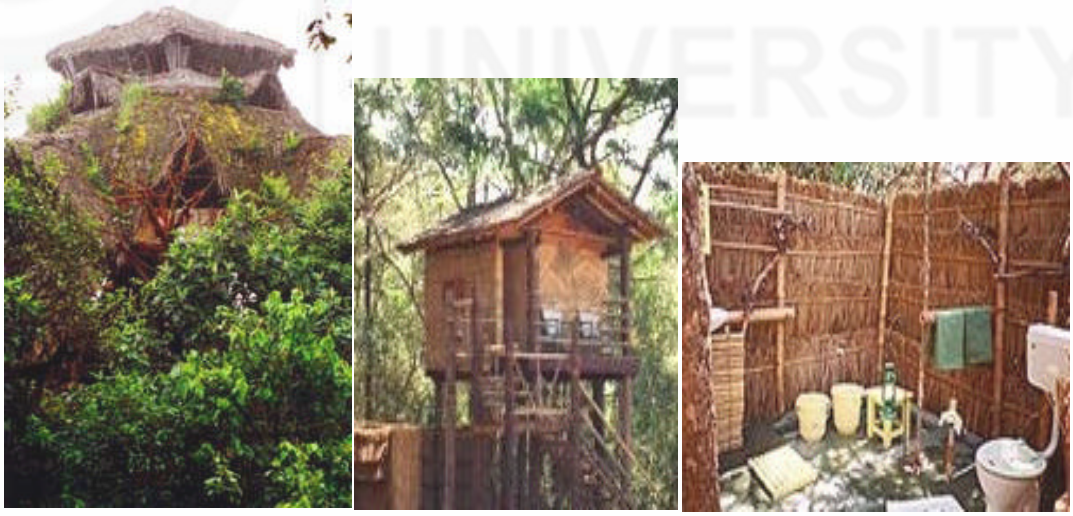

Fig.11.3: Use of local material in tourist lodges

Ecotourism: A form of tourism that focuses exclusively on wildlife, nature, or "exotic" cultures. Some argue that it is a vague term used to market anything related to nature or environmental tourism.

Ecotourism is considered the fastest growing market in the tourism industry, according to the World Tourism Organization with an annual growth rate of 5% worldwide and representing 6% of the world gross domestic product, 11.4% of all consumer spending – not a market to be taken lightly.

Ecological tourism or its shortened form '**ecotourism**' is one specific category of nature-based tourism. The word ecotourism was first invented and used by Hector

Ceballos-Lascurain in1983. '**Ecotourism'** is defined by IUCN - the World Conservation Union's Ecotourism Programme as **"environmentally responsible travel and visitation to relatively undisturbed natural areas, in order to enjoy and appreciate nature (and any accompanying cultural features – both past and present), that promotes conservation, has low visitor impact, and provides for beneficially active socio-economic involvement of the local populations."** (Ceballos-Lascurain, 1993). Another often used definition for ecotourism by the global Ecotourism Society is **"responsible travel to natural areas that conserves the environment and sustains the well-being of local people."** The underlying theme of ecotourism is that the enjoyment of a resource by today's visitors should not affect its enjoyment by future generations.

Difference between ecotourism and nature-based travel

While nature-based tourism is just travel to natural places, ecotourism provides local benefits – environmentally, culturally and economically. A nature-based tourist may just go bird watching; an ecotourist goes bird watching with a local guide, stays in a locally operated ecolodge and contributes to the local economy.

Sustainable Ecotourism:

- minimizes environmental impacts using benchmarks
- improves contribution to local sustainable development
- requires lowest possible consumption of non-renewable resources
- sustains the well-being of local people
- stresses local ownership
- supports efforts to conserve the environment
- contributes to biodiversity

11.6 ECOTOURISM AND BIODIVERSITY CONSERVATION

Ecotourism and wildlife oriented tourism have become a major economic activity and a major foreign exchange earner in many countries (Box 11.3). Ecotourism provides economic incentives for conserving biologically rich natural areas.

Box 11.3: Examples of economic potential for ecotourism

A study of Amboseli National Park in Kenya has revealed that in the early 1980s one lion was worth US$27.000 per year in tourist revenue, while today a live, fully grown named lion in the Park contributes over US$500,000 to Kenya's economy (Durrell, 1986 cited by Butler *et al*, 1992).

Another study by Thresher (1981) has shown that one manned lion for tourist viewing draws US$15,000 in foreign exchange over its lifetime, compared to only US$8,500 if the lion was used as a resource for sport hunting, and between US$960 and US$1,325 if it was used for other commercial purposes.

Yet another study (Western, 1982) estimates that the financial value of the Amboseli National Park arising principally from tourism was about US$40 per hectare in its protected state, while if the park was to be used for agriculture, its maximum predicted financial value would be less than US$0.80 per hectare. This study has also estimated that the elephant herd in Amboseli was worth US$10,000 per year. (Ceballos-Lascurain, 1996)

Ecotourism alone cannot be expected to justify the protection of large tracts of forests or other natural areas. For example, Costa Rica has the world's foremost forest-based ecotourism industry, but only a small percent of her forests are left outside reserved areas, while deforestation remains relatively high. Hence, ecotourism can only be one

aspect of the wide scene for biodiversity conservation, and can never be the answer for all problems encountered in this sphere of activity (Fig.11.4).

Fig.11.4: Ecotourism in Kerala

Managing tourism in protected areas:

The goals of tourism management in protected areas should be:

- conserving the environment,
- enhancing the quality of life of the local communities
- improving the tourism product and services

11.6.1 Assessment, Monitoring and Management

Prior to establishing a tourism project it is necessary to carry out an Environmental Impact Assessment (EIA) to ensure that there will be minimum impact on the environment, and to ensure sustainability of the project. Further, it is necessary to understand the carrying capacity of the ecosystem. This represents the threshold of human activity that it can support, which, if exceeded, will cause deterioration of the resource. Determining the carrying capacity of public-use sites in a protected area require the establishment of the following three levels of carrying capacity:

- **Physical Carrying Capacity (PCC):** defined as the maximum number of visitors that can physically fit into a defined space, over a particular time.
- **Real Carrying Capacity (RCC):** defined as the maximum permissible number of visits to a site, once the corrective (i.e. reductive) factors derived from the particular characteristics of the site have been applied to the PCC.
- **Effective or Permissible Carrying Capacity (ECC):** defined as the maximum number of visitors that a site can sustain given the management capacity (MC) that is available.

$$ECC = RCC \times MC$$

Ecotourism can make an important contribution to sustainable development throughout the world, particularly in developing tropical regions. If ecotourism is practiced carefully and managed with the interests of the local site and local people in mind, ecotourism can be a sustainable source of income that will promote the conservation of several unique habitats throughout the world. However, it has only limited potential to protect natural areas, and must be conducted in ways that minimize threats of degradation from visiting tourist activity.

Activity

Visit a nature reserve. Imagine that you are the manager of this protected area and that you wish to establish ecotourism at this site.

- What adverse aspects of the site would you want to change prior to establishing this site as a popular site for ecotourism?
- List possible partners that you would involve to make ecotourism successful at this site. How would you perceive their individual roles?
- What basic infrastructure facilities would have to be set up within the site? How would you ensure that they conform to ecotourism requirements?
- What information should be included in a brochure that would attract visitors to this site?
- List the possible negative aspects of nature tourism on the natural resources at this site, and discuss how you could eliminate these problems through ecotourism.
- Discuss as to how you hope to get the help of local people in this venture and how you can let them have access to the benefits that accrue through ecotourism.
- Make a list of people that would require to be trained in the different aspects of ecotourism to make the venture successful.
- Discuss how you can control over visitation if the site becomes very popular for tourists.
- A local businessman suggests that he can help you to promote ecotourism by building a five star hotel adjacent to the site in conformation with EIA regulations and to arrange a stream of tour buses to be brought to the site. Would you accept or reject this offer? Give reasons for your decision.

11.7 MANAGEMENT OF BIODIVERSITY IN PROTECTED AREAS

It is also increasingly felt that to survive in the long term, protected areas must do more than protect biodiversity and natural wonders. They must be managed to help integrate conservation and development and to contribute to sustain local communities. Protected area management, therefore, involves working with a large number of institutions, administrative hierarchies, organizations and individuals with varied goals and perceptions. This requires knowledge of science, management, and planning as well as sensitivity to cultural, historical and political priorities and prejudices of stakeholders. However, the nature of the management measures to be taken would ultimately depend on the specific objectives of establishing each protected area.

11.7.1 Ecosystem Manipulation

Ecosystem management is technically difficult, that's why most people are satisfied with "leaving things to nature to do its job". In most cases, however, this passive attitude is not adequate, especially when reserves are too small, too isolated, or too affected by human actions to be maintained in their original state by simply protecting the habitat. Active management is often required for conservation of unique ecosystem properties – through ecosystem manipulation as well as manipulation of species population sizes. For instance, a "sample" ecosystem that needs to be preserved may change under natural conditions due to progress in successional changes in the vegetation. In some others, total protection provided to a particular species and the resultant population build-up may induce changes in the habitat and other wildlife. Also, changes among the fauna and flora due to adverse resource uses such as unsuitable grazing and selective extraction of species (e.g. timber extraction) have to be countered through active management. Active management may also be desired to combat threats due to the spread to invasive species in protected areas and adverse human activities such as fire hazards (Box 11.4).

Box 11.4: Fire as a management tool

In many Mediterrancean ecosystems fire has positive effects on the fauna and flora, although there are negative effects in respect of soil erosion and degradation of lands already subjected to human impact. It has been found that in these areas fires that occur only every 5-6 years, accompanied by light grazing, favours good habitat conditions and preservation of early vegetation stages and maintenance of high biodiversity.

The degree to which fire should be used as a management tool would vary between ecosystems and depend on the specific management objectives of a given site. Ideally all fire patterns should be noted according to their date of burning, and extent and degree of burn, to build up a fire history that can be related to floral and faunal conditions.

The interventions required for active management would, however, depend on the conservation needs pertaining to each individual situation and should be decided after a proper assessment.

11.7.2 Management Over-abundant Population

Theoretically, wild populations should not become over abundant if the ecosystem is in equilibrium, although this is often not true due to disturbance of the system, or due to the fact that most protected areas act as "fenced islands" with no room for natural migration of animals.

Generally, the methods of control of over-abundant animal populations Box 11.5 fall into three categories:

1) Culling, through capture or killing of selected individuals – this process should be done as humanely as possible and based entirely on ecological considerations. This can, however, create considerable adverse public reaction based on ethical grounds.

2) Live trapping and removal whereby the captured animals are either introduced/reintroduced to other suitable habitats or to areas where populations are low, or be given away for domestication.

3) Biological control which, though attractive, may bring about its own problems as introduced exotic species may become invasive.

Care must, however, be taken to establish whether over-abundance is a reality, and not merely due to people's perception.

Box 11.5: Addressing the human – elephant conflict

Conflicts between humans and elephants are widespread in Africa and Tropical Asia. Expanding human populations have compressed the elephant ranges to few pocketed herds in isolated blocks of forest, with inadequate year round supply of food, water and shelter. Thus increasing conflict with local communities. Possible solutions include:

Live capture

Immobilization is the best method for capturing individual problem elephants by the help of the experienced elephant trackers, expert marksman with a dart gun, veterinarian. Groups of elephants are caught using kraals and traditional elephant capture techniques. In Asia, domestic elephants with their mahouts can be used to guide elephants freshly revived after immobilization .Sedated animals held tightly with strong jute ropes are transported.

Translocation

Translocation of adult animal is difficult thus it is however better to move a whole herd, if possible, as these are social animals. Care must be taken not to separate calves from their mothers during translocation.

Driving

A line of beaters, tame elephants or vehicles can be used to drive elephant herds to a new area. Animals should be driven to the centre of the new sanctuary. Elephant driving requires good planning and coordination to keep elephants together. Sudden noises of any kind should not be used for the drive as they tend to cause a stampede among the animals.

Creating special reserves

This is complex and costly and suitable areas of adequate size are usually scarce, especially in densely populated Asia. Further, it should be remembered that translocated elephants, with their destructive feeding habits, may even modify and degrade a 'new' sanctuary.

Elephant corridors

Reserve boundaries should ideally incorporate the entire range of the local elephant population, including the wet season dispersal areas, the areas where animals concentrate in the dry season, and the well used routes between them. Some countries have designated special elephant corridors to ensure connectivity of habitats to prevent migration into human settlements and to protect lands along elephant migration routes.

Buffer-zones

Cultivations or plantations near reserves should be well maintained as elephants are more likely to venture into poorly overgrown areas.

Extermination

Extermination of animals should be absolutely a last resort. In such an event animals should be killed as humanely. Elephant control should never be handed over to the local police or the army. (MacKinnon, Child and Thorsell, IUCN, 1986)

11.7.3 Controlling Invasive Species

First we should know what invasive species is. An invasive species is an alien species which becomes established in natural or semi-natural ecosystems or habitats, is an agent of change, and threatens native biological diversity. The invasion of protected areas by introduced species accelerates the rates of extinction of native and/or endemic species, and will commit the reserve management to large and continuing

expenditure. These effects will be made worse by climate change. In some areas such as oceanic islands, invasive species are recognized as the single greatest threat to biodiversity Table 11.1. Even so, the management of invasive species in protected areas has not been given adequate attention.

Table 11.1: Some Generalized Characteristics of Invasive Species and Invadable Communities

Characteristics of successful invaders
High reproductive rate, pioneer species, short generation time
Long-lived
High dispersal rates
Single-parent reproduction (i.e., gravid or pregnant female can colonize)
Vegetative or clonal reproduction
High genetic variability
Phenotypically plastic
Broad native range
Habitat generalist
Broad diet (polyphagous)
Human commensal
Characteristics of invadable communities
Climatically matched with original habitat of invader
Early successional
Low diversity of native species
Absence of predators on invading species
Absence of native species morpholotically or ecologically similar to invader
Absence of predators or grazers in evolutionary history ("native" prey)
Absence of fire in evolutionary history
Low-connectance food web
Anthropogenically disturbed
Characteristics of communities likely to exhibit large invasion effects
Simple communities
Anthropogenically disturbed communities

Modified from Lodge 1993.
Note: The list is not exhaustive, nor is every characteristic critical in a given situation. these are merely generalized trends, with many exceptions.

According to the definition by IUCN, The World Conservation Union, an alien species (non-native, non-indigenous, foreign or, exotic) is a species, subspecies, or lower taxon occurring outside of its natural range and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans) and includes any part, gamete or propagule of such species that might survive and subsequently reproduce.

The spread of invasive species into natural and agricultural ecosystems have been identified as one of the most serious threats to loss of global biodiversity, especially in isolated islands and protected areas. For instance, in the Galapagos archipelago of Ecuador, the native vascular flora of 500 has been added to with about 600 introduced vascular plant species. About 47% of the new species are naturalised and 37 species are identified as being potential invasives that are a threat to the local biodiversity.

The presence of exotic species in a protected area is a problem to the management objectives of conserving biodiversity at all levels, although in some cases, exotics are deliberately introduced to fulfil a management objective or have been present for so long that they are in balance with the ecosystem or are of specific interest.

The two weeds which came as invasive species in India has now established themselves in the country and causing great damage to crops. We are giving the examples of two such species. *Eichhornia crassipes* (water hyacinth was brought into India as ornamental plants; it is free floating, surface weed with large, byoyant petioles and highly attractive, mauve or lilac flowers. Each hayacinth seeding after

reaching the main water multiplies fast through its offsets into as many as 600 plants just in four months. (Box 11.6).

Box 11.6: Case study 4 - Biological control as a tool for controlling invasive species

Examples of biological control as a tool for controlling invasive species are the introduction of myxomatosis into the rabbit population in Australia, and introduction of moth *Cactoblastis catorum* to attack the prickly pear *Opuntia* and other cacti that are serious pests now in Australia and Southern Africa. It is important, however, that rigorous checking is carried out prior to the introduction of biological control agents to ensure that they do not harm other native animals or plant species. For instance, the small Indian Mongoose (*Herpestes javanicus auropunctatus*) was introduced to Mauritius and Fiji, and to the West Indies and Hawaii in the late 1800s to control rats. Unfortunately the native island species that had evolved without a threat from a fast moving mammalian predator became easy prey to the mongoose. As a result the mongoose has now caused the extinction of several endemic birds, reptiles and amphibians and is now threatening many others. The small Indian mongoose is also a vector of rabies.

Source: IUCN, 100 of the World's Worst Invasive Alien Species.

Water hayacinth is native to Brazil. In India it was introduced in 1886 in Bengal as an ornamental, pond plant. Since then it has spread throughout India as an obnoxious aquatic weed covering large area. Fish and rice crops worth millions of rupees are damaged each year at the hands of this weed.

Parthenium hysterophorus also known as congress weed was introduced in India with food grains imported from USA (Chakre 1983) is an annual weed with wide amplitude of ecological adaptability. It reproduces freely from seeds. Starting as a weed of non crop situation and neglected areas throughout the country, carrot grass is now a weed of crop lands. In dry summer month it tends to remain in rosette form, with its suspended growth. But in rainy and winter it grows in a thick strand with profuse flowering.

11.7.4 Involving Local People in Protected Area Management

It is increasingly becoming apparent that protected area management requires trust between local people and park managers, to ensure cooperation (Fig.11.5). Resource management decisions for a protected area are bound to affect different groups of people, in terms of subsistence needs, livelihoods and economies. When protected areas are perceived as a burden, the behaviour of local people can defeat the management goals and objectives. On the other hand, when protected areas show positive benefits, the local people will ally themselves with the protected area management (Box 11.7).

Fig.11.5: Participation of local people for protected area management

Box 11.7: A case study Periyar Tiger Reserve

Five year back Periyar was faced with the same conflicts that plague most other protected area in India. Every year, at least 100 cases of stealing wood and poaching were registered against the villagers. People living there felt alienated from the forest. In late 1990 using the opportunity provided by Global environmental Facility (GEF) - Ecodevelopment Project, the Government officials initiated dialogues with villagers. As the Periyar gets about 400,000 tourists a year, the resulting revenue was being taken away by private or state tourism. The ecodevelopment team identified groups of villagers dependent on the reserves for various purposes. In addition they also identified daily wage forest watchers whom government could no longer pay.

First the legal cases were dropped against participants of ecodevelopment activities. Then detailed community based tourism programme was worked out and restriction were inbuilt to avoid mass tourism. The few activities such as forest treks, simple lodging, raft rides and tribal heritage walks were handled by villagers; their salaries were paid from the income generated by them. Interestingly there has also been a noticeable increase in the wild animal populations.

Another interesting body, called the Swamy Ayyappan Poonkavana Punarudharana EDC, was created to handle two pilgrimage routes through Periyar to the heavily visited Sabarimala. This EDC provides alternative fuel source, waste management and other conservation-oriented facilities to the pilgrims.

A conservation reserve may be doomed to eventual failure, regardless of its biological soundness, if its planning does not consider and include the needs and desires of people. But if the people living in the area are included in planned and controlled way in the reserve area it will ensure greater cooperation with more positive attitudes towards, the reserves as seen in **Periyar Tiger Reserve** (Fig.11.6).

Fig.11.6: Participatory management

SAQ 1

1) List the methods used in controlling of over-abundant animal populations and which of method you find most suitable and why?

2) Make a list of the invasive species of plants which is found in your area/or you find while you are visiting any reserve area/the species you see are very dominant species in India.

3) How local people can help in the management of protected area?

11.8 PROTECTION OF BIODIVERSITY OUTSIDE PROTECTED AREAS

Conserving biodiversity by protecting areas of undisturbed ecosystems is becoming difficult due to the increasing demand for land for production. Even at present, more

than 90 percent of the terrestrial surface of the earth is not covered by any form of protected area category.

Efforts for building awareness and support to achieve biodiversity conservation is thus important, while seeking pragmatic solutions is vital, because value of natural systems provide more economically valuable goods and services – timber, non-timber products, clean water, etc. than if these systems are converted to other uses. MAB reserves are particularly suited for this purpose as they are people centered, promote an ecosystem approach, and have specific areas (buffer zones and transition zones) that are not legally protected.

11.8.1 Traditional Agro-systems

Traditional agricultural systems use a very wide range of species and land races which vary in their reaction to diseases and insect pests, and to different conditions of soil, rainfall and sunlight. They also provide sustainable yields by drawing on centuries of accumulated experience by farmers who do not depend on scientific information, external inputs, capital, credit, or markets. Thus, agricultural ecologists have learned to respect the wisdom inherent in many traditional practices.

During farming we create abnormal ecological conditions and novel ecosystems, known as agro-ecosystems. From ages, farming has affected the genetics of domesticated animals and plants, as people selected strain that were easy to grow and harvest. The act of farming makes certain species abundant where they were rare; thus farming selectively favour certain genotypes. Advances in genetic engineering now make genes and co-adapted gene complexes of almost any organism transferable to species that are useful to human.

11.8.2 Buffer Zones

During recent years, many new parks and reserves have been established in the tropics. However, protected areas now cover only about six percent of the tropical forest biome. But in many parts of the tropics the human pressure on land is so great that the options for establishing new parks and reserves are rapidly diminishing.

Conserving or protected areas may use zoning for the activities in land area around the reserves which makes it more compatible with the conservation goals of the reserves. This practice helps to avoid conflicts among various user groups and may be the only way to secure a reserve in the first place; A carefully planned zoning approach, a conservation reserve system can allow for habitat and species protection, scientific research human habitation and development, and use of natural resources.

Buffer zones were formerly defined as “areas peripheral to national parks or reserves which have restrictions place on their use to give an added layer of protection to the nature reserve itself and to compensate villagers for the loss of access to strict reserve areas” (MacKinnon, 1981). In more recent definitions the term “buffer zone” is used to cover a wide range of conservation and development activities which can be applied to the areas adjacent to parks and reserves to protect them against external pressures, and deliver benefits to local people. Thus a commonly accepted definition of a buffer zone is “a zone, peripheral to a national park or equivalent reserve, where restrictions are placed upon resource use or special development measures are undertaken to enhance the conservation value of the area” (see Fig.10.4, Unit 10) Thus, a basic objective of a buffer zone is to surround protected areas with vegetation which, if not completely natural, does at least allow some animal and plant species to extend beyond the boundaries of the totally protected core.

Buffer zones have to be actively managed. This requires readily measurable indicators (e.g. nutritional status of the people living in it) for determining the success of management interventions. It is possible to gain such information through detailed social surveys and participatory resource-base mapping.

Buffer zone development can have objectives associated with maintaining environmental quality along with achieving socio-economic development actively interface. (see Box 11.2).

11.8.3 Habitat Corridors and Linkages

Wildlife habitats are often fragmented, but continuity between habitat patches can be maintained by habitat connections that still exist. These connections enable gene flow across populations and, thereby avert the negative aspects of isolation which prevents animals from moving to and from other habitats, and help maintain population viability.

Stream and river corridors normally are the most important strips because of their numerous ecological roles, and their ecologically based minimum width varies markedly along the corridor system. Species also move along stepping-stone patches, which are equivalent to corridors with major gaps.

11.8.4 Sustainable use of Biological Resources

Wild species and ecosystems are used by people – in rural, urban and industrial environments – whose survival depends largely on them. In order to continue meeting human needs, it is required that the use of such resources be made sustainable.

Sustainability means meeting the needs of today without reducing the quality of life for future generations and without reducing the future environment. Sustainability is holistic, it realizes the necessity of addressing the social, and especially economic causes of environmental degradation.

A resource can be made sustainable by;

- Changing harvest rates
- Giving people the right to harvest the resources and conferring responsibility to conserve them
- Regulating and controlling people's access to resources, and by
- Commercialising the harvest process in the appropriate social, biological and economic situations

However, these factors can also promote unsustainable use in different social, biological and economic situations.

Activity

What are the main tools that can be used to manage a protected area based on the information given?

What are the linkages that would help conserve species in a protected area which is situated near your village/city/state?

What could you do if Tigers/Elephants in a protected area start going into nearby villages/city? Suggest action based on the various possibilities that you can think of.

SAQ 2

1) Describe how traditional agro-systems protected the biodiversity outside protected areas.

2) Explain the word “Buffer Zones”. Why the buffer zone is a necessary part of the protected area?

3) Have you ever come across a buffer zone? If yes, did you find its utility?

4) Define habitat corridors and linkages. Why they constitute important part of preserved area?

5) List common type of linkages. What is the role of linkages in preserved area?

11.9 ENVIRONMENTAL IMPACT ASSESSMENTS (EIA) – MANAGEMENT TOOL

An Environmental Impact Assessment (EIA) is a formal study process used to identify, predict and mitigate the environmental impact of a proposed development project on natural environment people and livelihoods. EAI is a management tool to improve decision making and to ensure that development options are environmentally and socially sound and sustainable. An Impact Assessment is a recognized tool for integrating environmental, economic and social concerns into the decision making process.

An EIA

- predicts the possible environmental impact of projects,
- recommends measures to minimise unacceptable impacts and makes the project more suitable to the local environment and people, and
- presents predictions and options to decision-makers.

In India Environmental Impact Assessment was made mandatory in January, 1994 for 29 categories of developmental activities including industrial project, thermal power plants, mining projects, river valley hydro-electric schemes and infrastructure projects.

11.9.1 Amendments to EIA Modification

In India a major amendment to the EIA notification was made in April 1997 for introduction of public hearing as a part of assessment procedure and also for delegation of powers to the State Government(s) for environmental clearance of certain categories of Thermal Power Plants.

The Ministry added one more activity to the existing list of 29 categories by including Meta Amino Phenol as the 30th item vide notification dated 27.01.2000. The Ministry has further amended the EIA Notification on 13.12.2000 exempting defence related road construction projects in border areas from the purview of the EIA Notification.

A draft Notification exempting from public hearing small-scale industrial units, widening and strengthening of highways, modernisation of irrigation projects and mining projects (major minerals) up to 25 ha of lease area was issued on 3.1.2001.

11.9.2 Biodiversity Impact Assessments (BIA)

A main consideration that should be considered in any EIA process are biodiversity concerns to assess threats that would lead to biodiversity loss during developmental activities. The impact assessment on biodiversity should address actual and potential effects of development activities and projects on ecosystems, species and genetic resources, as well as the effect on functional perspectives and resilience of natural habitats and ecosystems.

At the global level a framework for Biodiversity Impact Assessment (BIA) has been identified. This comprises several main steps which are given below:

Step 1: Identify impact on biological diversity – commencing with a biophysical identification of the loss of, or threat to biodiversity.

Step 2: Establish the causes of the impact: by establishing the proximate and underlying causes of the impact on biodiversity.

Step 3: Determine the winners and losers of the impact through a stakeholder analysis to determine who is being affected and how. Economic valuation of biodiversity plays a useful role in this step.

Step 4: Design an alternative package of mitigation measures to enable relevant human activities to be made compatible with conservation, sustainable use and benefit sharing. The "appropriate packages" should be customised for each situation and take into account the complexity of social, cultural, historical, political, economical, geographical and ecological factors that surround the impact on biodiversity under consideration.

Step 5: Determine the winners and losers due to mitigation, through a second round of stakeholder analysis initiatives to determine who is being affected and how through the mitigation package. Economic valuation will again play a role by helping to compare the impact scenario with the alternative mitigation scenario which will indicate the redistribution of benefits and costs, and mitigation influences on equitable sharing of benefits. It will finally lead to the selection of the most equitable mitigatory incentive measures to be negotiated.

Step 6: Implement the mitigatory measures. This requires a detailed implementation strategy as this step may involve various levels of government and economic sectors over a considerable time period.

Step 7: Monitoring and evaluation to ensure that problems are resolved through built in feedback loops in the BIAs for renegotiation of mitigatory measures where necessary.

11.9.3 Biodiversity Surveys and Assessments

Biodiversity surveys are often necessary to establish rational means of land use planning to avoid conflicts, especially during the setting up of protected areas. As such surveys should be cost effective, only relevant data should be collected.

Methods that can be used for biodiversity surveys can vary according to location and objectives of the survey. Commonly used methods for biodiversity assessments involve collection of data from different sources at the species and ecosystem levels, the community level and the user level, through technical and semi-technical field examination, and interviews with local residents and farmers.

Important Indicators for Biodiversity Assessments:

- **To gauge wild species diversity**
    - Total number of species per unit area.
    - Species threatened with extinction at the national level.
    - Species extirpated globally.
    - Endemic species.
    - Endemic species threatened with extinction.
    - Species with increasing/decreasing/stable populations.
    - Threatened species in protected areas.
    - Endemic species in protected areas.
    - Threatened species that have viable *ex-situ* populations.
    - Species used by local people.
- **To gauge ecosystem/community diversity**
    - Community structure.
    - Areas in which wild species are dominant.

- Area(s) changed from containing predominantly wild species to those with non-wild species.
- Areas that are strictly protected.
- Areas dominated by wild species occurring in patches greater than 112 km^2.

- **To gauge domesticated species and genetic diversity**
  - Number of accessions of crops/livestock in *ex-situ* collections.
  - Accession number of crops that have regenerated before 10 years.
  - Number of crops and livestock species present as a percentage of the number grown/present 10 years earlier.

(Source: IUCN, Biodiversity Assessment Method, 1998.)

SAQ 3

1) Define EIA and its importance and what are the process involved in EIA.

2) Describe the amendment made in EIA in April 1997.

3) Differentiate between BIA and EIA and describe the various steps taken during making a global level framework for Biodiversity Impact Assessment.

11.10 MANAGEMENT PLANS FOR PROTECTED AREAS TO CONSERVE BIODIVERSITY

A conservation management plan for a Protected Area is a document, prepared through a management planning process, which sets out the values, objectives and strategies for its management. It also presents strategies and operational schedules to show how "these objectives can be achieved within a time bound framework".

The basic aim of a management plan is to provide the way to reach appropriate goals and objectives, and resolve conflicts (including conflicts between conservation objectives and resource dependency) by making certain decisions to achieve the Plan's objectives. These may include compromise solutions based on acceptable trade-offs or creation of alternate resources, skills training or introducing sustainable use practices.

A proper management plan is crucial for good management of a Protected Area. A management plan acts as a guide to conserve biological diversity and controls the use of resources efficiently within a Protected Area. It also enables the development of appropriate facilities to assist management and use of resources. Management plans are prepared for a specified period of time, generally for around five years.

Management Plans are important to:

- maintain continuity of thought and action about a site,
- help minimise the adverse effects of staff changes in the implementation process,
- allow continuous evaluation of management initiatives, and
- serve as fund-raising and communication tool that can be used to obtain the cooperation of the public and decision makers.

The preparation of management plans and formulation of relevant management strategies for Protected Areas require gathering of new information, or collation and scrutiny of existing information on environmental features, including biological resources, socio-economic factors of people within or adjacent to the reserve, regional economics, visitor-use patterns, cultural/archaeological significance of the area, the past and present level of poaching or illegal extractions from the reserve, existing transportation networks, attitudes of local communities towards the reserve and the current management issues, problems and deficiencies that need to be addressed.

11.11 COMMUNICATION IN BIODIVERSITY CONSERVATION

The present loss of biodiversity on earth is often due to wasteful use of the planet's biological resources and wanton destruction of its life support systems by humans.

Environmental communication helps to gain the required behavioural change, commitment and cooperation of a diverse range of people who need to participate actively to achieve the goal. Communication has to be strategically planned and form an integral part of conservation planning and implementation.

11.11.1 What is Meant by Communication for Biodiversity Conservation?

Overall, environmental communication "is a two-way process of information sharing and reflection back, and to make bridge between different perceptions and approaches". The objectives of environmental communication is a 'specific outcome', achieved by transferring information, convincing communication partners about a given point of to achieve. The box 11.8 given below indicates some important aspects of environmental communication.

Box 11.8: Environmental communication

- is participatory and "two way" rather than "one way".
- needs planning.
- should ensure that all stakeholders and target groups are identified, reached and involved at the appropriate times and in the most appropriate manner.
- promotes ownership of the conservation process among the stakeholders.
- involves use of messages and means (i.e. channels) that suit the recipients.
- requires feedback so that the information received through dialogue can be incorporated to facilitate the communication process.
- can be used to solve existing problems, but is also very effective to prevent foreseeable problems or conflicts.
- can support other instruments such as economic incentives and legislation.
- is always a part of other instruments as they invariably send out a message, but is also an important instrument on its own.

Source: International Academy of the Environment/METAP/GTZ (1998) and ECNC, 2000.

Communication for biodiversity conservation is much more than mere information dissemination, education or awareness creation. Effective environmental communication should not only be an active transmitter at one end and a passive receiver at the other.

11.11.2 Scope of Communication in Biodiversity Conservation

Communication is only one of the mix of instruments that can change people's attitudes and behaviour towards biodiversity conservation. Communication can also raise a awareness about an issue, inform people (Fig. 11.7) about desired behaviour

Fig.11.7: Communication in Kanha National park

patterns to address the issue in question, and let them know about the implications of acting contrary to such behaviour. By influencing attitudes, communication can also make people more receptive towards required behavioural changes and enhance the effectiveness of other instruments such as regulations and laws.

11.12 TYPES OF COMMUNICATION

Communication plays an important part in any conservation programme, proper communication is needed for any project to succeed. The most important part is instruments used for communication and it should reach to the people working in the lowest level. We will discuss these two types of communications in detail.

11.12.1 Instrumental Communication

This type of communication is based to *convey a message from a sender to a receiver*. For instance, organizations are instrumental communication to obtain support for conservation plans and policies. The organization starts communicating after it has decided what to do and has yet the goals it needs to achieve. Here, communication is used as an **instrument** to influence the behaviour or opinion of other groups in order to achieve certain preset goals.

Instrumental communication often involves the use of visitor centers, brochures, posters (Fig. 11.8), films mass media and educational activities, and is widely used today to communicate about nature. The disadvantage here is that communication is often **one-way**, with little opportunity for feedback.

Fig.11.8: Various posters displayed of communication

11.12.2 Interactive Communication

This mode of communication is used when an organization wants to reach agreement between itself and relevant stakeholders before it decides on the goals to be achieved, and communication is used to jointly identify these goals though a process of consultation and negotiation. This requires communication as a two-way process, and involves the sharing of information and the development of shared understanding. However, the success of this approach depends on whether the parties involved in the communication process have a common interest in reaching a shared understanding.

11.12.3 Targeting Biodivers ity Communication – Two Major Groups

An organization that is engaged in communication for biodiversity conservation needs to target communication at two broad groups (internal and external), each requiring a specific communication approach.

Internal communication

There should be training, instruction and education so that all staff are working towards the same goal. This requires a flow of information from bottom-up (staff to the managers), top-down (managers to staff) in terms of decisions: and horizontal (between staff members). There should be emphasis on public relations, management and face-to-face communication.

External communication

External communication is used to develop relationships among partners, ensure that all groups work toward the agreed objectives, obtain funds from external sources, obtain political support, and create the necessary climate for the required action (Fig.11.9).

Fig.11.9: Communication for community consultation

SAQ 4

1) Discuss the importanc e of communication in biodiversity conservation.

2) Describe how communication helps in creating awareness, interest and give acceptance for conserving biodiversity in general public.

3) Differentiate between Instrumental and Interactive communication and give their importance.

4) List the characteristic of management plan and why management plans are important.

5) Why evaluation and monitoring are necessary component of management plan.

11.13 SUMMARY

- India has rich ethos of biodiversity conservation, combined with traditional knowledge it has informally given rise to *in-situ* conservation. According to cultural belief some trees are known as shrine trees which are considered as sacred trees and are source of single genetic resources.
- Tourism is becoming a major industry in world an environmentally responsible or sustainable tourism can led to biodiversity conservation.
- Ecotourism relies heavily on ecosystem and species diversity also provides incentives for conserving biologically rich natural area but tourist activities should be conducted in such ways that it minimizes the threat to natural preserved areas.
- Management of biodiversity in protected areas can be done through ecosystem manipulation. Active management also has to combat threat due to invasive species, fire hazards and human interaction with wildlife.
- Participatory management of protected area is increasing becoming popular. People involvement is necessary for the any successful conservation programme.
- Traditional agro-systems, Buffer zones, Habitat corridors and linkages and sustainable use of biological resources are other methods to protect biodiversity outside protected area.
- In modern days Environmental Impact Assessment (EIA) is a important tool for integrating environmental, economic and social concerns into the decision making process.
- Biodiversity Impact Assessment (BIA) constitutes important part of EIA. It looks after the actual and potential effects of any activity or projects on ecosystems, species and genetic resources.
- A good management plan is crucial for good management of a Protected Area. Each management plan should certain characteristics.
- Communication is very important for biodiversity conservation. Environmental communication is participatory and two way process rather than one way.
- Communication for biodiversity conservation is much more than mere information dissemination education or awareness creation.

11.14 TERMINAL QUESTIONS

1. How will you control the over-abundant animal populations of Elephant in the reserve area where you are posted as manager? Also discuss which of the method will be most suitable and why?
2. Give your views on “Fire as a management tool”.
3. Discuss how biological invasions can change the profile of reserve area if they become dominant species of that area.
4. There is a case study given in unit of using biological control as a tool for controlling invasive species. Give an example of such case study in India. (**Hint:** There is a biological control of *Lantana indica* in India).
5. Describe the importance of linkage between conservation areas. This preserve has no linkage with other areas. In an imaginary situation there is increase of tiger population what will be the ultimate fate tiger populations?

6. Suppose you are appointed as a manager of a reserve and you are asked to make the sustainable use of biological resources found in that preserved area. The preserved area has the dominant vegetation of Bamboo trees.
   (**Hint:** Bamboo in Assam has its use in man's life from birth to the death.)

7. List the important indicators used for Biodiversity Assessments. Before making BIAs why it is necessary to make biodiversity assessment in that particular area.

8. Describe the strategies which are to be followed if protected area is managed through participatory management of people.

9. Make a management plan to a preserved area where flagship species can be

   a) i) Birds or
      ii) Tiger or
      iii) Elephant
      and
   b) Where ecotourism has great prospect
      and
   c) Invasive species is a problem but water is abundant

10. Everyone of us is a silent observer in recent calamity of Tsunami waves. But the areas where the mangroves were not touched by civilization suffered little harm despite the fury of tsunami. How will you create awareness and interest of people to save mangroves?
    (**Hint:** You are free to use your imagination in making the slogan or preparing chats, or making any type of communication for reaching out general public living near mangroves.)

11. "Communication can become a major tool in conserving biodiversity".

12. Make a small project to conserve biodiversity in your area.

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UNIT 12 LEGAL ASPECTS OF BIODIVERSITY CONSERATION

Structure

12.1 INTRODUCTION

In order to protect wildlife (flora and fauna) from various environmental problems and prohibition of degrading the environment several legislations have been enacted at national and international levels. We will discuss some important environmental legislations which are inacted to protect biodiversity. The Indian legislations are called acts and international legislations are in form of conventions.

Objectives

After studying this unit, you will be able to:

- appreciate the importance of legislations in application of conservational plans;
- list various national legislations for biodiversity conservation;
- appreciate the need of Indian Forest Act 1927, Colonial legislation for state ownership of forest resources and to facilitate trade and timber ,Wildlife (Protection) Act 1972 , and amended in 1991;
- to protect wild animals, birds and plants including their habitat, biodiversity bill l2000, Proposed legislation to regulate access to biological resources, sustainable use and equitable benefit sharing, Environment (Protection) Act 1986, Legislation for environmental protection1986, Forest (Conservation) Act 1980, Control diversion of forest land for non-forest purposes;
- describe some important International Legislations for biodiversity conservations; and
- explain the how international registrations are necessary for conservations of wildlife.

12.2 NEED FOR LEGISLATION

India is one of 12 Mega diversity country of the world. There are innumerable species, whose potential are not known till date Biodiversity has direct consumption value in agriculture, medicine and industry.

Legislation is needed in order to prevent waste and destruction and destructive harvesting of wild life resources for commercialization and profit are the major threat to wildlife conservation. To curve destructive practice by scrupulous people and mafia group effective legislation is necessary to protect and conserve the biodiversity. Legislation also serves as a valuable tool for educating masses.

There is Constitutional provision in India for biodiversity conservation. The constitution (forty second Amendment) Act of 1976 has made it fundamental duty to protect and improve the natural environment by Clause (g) to Article 51A:

"It shall to be duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life and have compassion for living creatures."

There is a directive, given to the State as one of the Directive Principles of State Policy regarding the protection and improvement of the environment. Article 48A states "The State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country". The Department of Environment was established in India in 1980 to ensure a healthy environment for the country. This later became the Ministry of Environment and Forests in 1985. This Ministry has overall responsibility for administering and enforcing environmental legislations and policies

12.3 NATIONAL LEGISLATION

The constitution of India ensures the concept of environmental protection. It has a new section on Directive Principles of State Policy, setting out the duties for the States and all the citizens through Article 48A and Article 51A (g) and explaining that "the State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife in the country" and to protect and improve the natural environment, including forests, lakes and rivers and wildlife, and to have compassion for living creatures.

A legal and policy framework has been developed which relates specifically to biological diversity. The Forest Act of 1927, the Forest (Conservation) Act of 1980 (amended in 1988), the Wildlife (Protection) Act of 1972 (amended in 1983, 1986 and 1991) and the Environment (Protection) Act of 1986 are supported by State Laws and Statutes relating to forests and other natural resources.

The National Conservation Strategy of 1992 outlines the policy action required to give greater attention to biodiversity conservation. The National Forest Policy, as amended in 1988, stresses the sustainable use of forests, and the need for greater attention to ecologically fragile (but biologically rich) areas such as the mountain and island ecosystems. The National Wildlife Action Plan of 1973 lays down priorities in the area of wildlife conservation. One of the major considerations in Environmental Impact Assessment carried out by the Ministry of Environmental and Forests is the protection of habitats and valuable ecosystems.

12.3.1 Forest Protection Act

First Forest Act was enacted in 1927. This is one of the many surviving colonial legislations. It was enacted to consolidate the law related to forest, the transit of forest produce and the duty liveable on timber and other forest produce. Subsequently, the Forest (Conservation) Act was promulgated in 1980 to make certain reforms over the preceding Act of 1927.

The 1927 Act deals with the four categories of the forests, namely reserved forests, village forests, protected forests and private forests. A state may declare forest lands or waste lands as reserved forest and may sell the produce from these forests. Any unauthorized felling of trees quarrying, grazing and hunting in reserved forests is

punishable with a fine or imprisonment, or both. Reserved forests assigned to a village Community is called village forests. The state governments are empowered to designate protected forests and may prohibit the felling of trees, quarrying and the removal of forest produce from these forests. The preservation of protected forests is enforces through rules, licenses and criminal prosecutions. Forest officers and their staff administer the Forest Act.

Alarmed at India's rapid deforestation and resulting environmental degradation, Centre Government enacted the Forest (Conservation) Act in 1980. Under the provisions of this Act, prior approval of the Centre Government is required for diversion of forestlands for non-forest purposes. An Advisory Committee constituted under the Act advises the Centre on these approvals.

Forest acts

- The Indian Forest Act, 1927
- The Forest (Conservation) Act, 1980
- The Forest (Conservation) Rules, 1981

Wildlife protection acts

- The Wildlife (Protection) Act, 1972, as amended up to 1993
- The Wildlife (Transactions and Taxidermy) Rules, 1973
- The Wildlife (Stock Declaration) Central Rules, 1973
- The Wildlife (Protection) Licensing (Additional matters for consideration) Rules, 1983
- The Wildlife (Protection) Rules, 1995
- The Wildlife (Specified plants – conditions for possession by License) Rules, 1995

12.3.2 Wildlife Protection Act

According to the Wildlife Protection Act, 1972, "Wildlife" includes any animal, bees, butterflies, crustacea, fish and moths; and aquatic or land vegetation which forms part of any habitat.

"All beings are found of themselves, they like pleasure, they hate pain, they shun destruction, they like pleasure, they like life and want to live long. To all, life is dear, hence their life should be protected" – Mahavira.

The Wildlife Protection Act was passed by the Indian Parliament in the year 1972 to protect India's wildlife. However, in the 20 years that has passed since the Act came into force, the number of wild animals is going down alarmingly, despite of government efforts to protect them. With the increase in population, there is greater pressure on land. Forests are being destroyed as human habitations expand, thereby shrinking the habitats of our wildlife. There is also the clandestine international trade in wildlife and wildlife products which is a major cause for their wanton destruction. Meanwhile, the growing consumer society and the increasing emphasis on luxury and vanity items has also caused the exploitation of wildlife in the name of industrial progress.

The major task of protecting the wildlife cannot be handled by the Government machinery alone through its limited officials but should be the duty of every individual. This was one of the reasons why a new provision, Article 51 A (g), was inserted into our Constitution, making it the fundamental duty of every citizen to protect and improve the natural environment, including forests, lakes, rivers and wildlife, and to have compassion for living creatures.

12.3.3 Biodiversity Act 2000

India's richness in biological resources and indigenous knowledge relating to them is well recognized. One of the major challenges is in adopting an instrument which helps realize the objectives of equitable benefit sharing enshrined in the Convention. Towards this, a legislation on biodiversity was developed following an extensive consultative process. The legislation aims at regulating access to biological resources so as to ensure equitable sharing of benefits arising from their use. The Biological Diversity Bill, which was introduced in the Parliament in 15th May, 2000, was referred to the Department related Parliamentary Standing Committee for Science, Technology, Environment & Forests for examination and report.

After examination of witnesses and recording evidences, the Standing Committee approved the Bill with some amendments. The Cabinet approved the proposal for moving the official amendments based upon the recommendations of the Committee. The Biological Diversity Bill 2002 has been passed by the Lok Sabha on 2nd December, 2002 and by the Rajya Sabha on 11th December, 2002.

Salient features of the Biodiversity Legislation

The main intent of this legislation is to protect India's rich biodiversity and associated knowledge against their use by foreign individuals and organizations without sharing the benefits arising out of such use, and check biopiracy. The Act provides for setting up of a National Biodiversity Authority (NBA), State Biodiversity Boards (SBBs) and Biodiversity Management Committees (BMCs) in local bodies. NBA and SBB are required to consult BMCs in decisions relating to use of biological resources/related knowledge within their jurisdiction and BMCs are to promote conservation, sustainable use and documentation of biodiversity.

All foreign nationals/organizations require prior approval of NBA for obtaining biological resources and/or associated knowledge for any use. Indian individuals/entities require approval of NBA for transferring results of research with respect to any biological resources to foreign nationals/organizations. Collaborative research projects and exchange of knowledge and resources under these projects are exempted provided they are drawn as per the policy guidelines of the Central Government and have its approval the objectives of conservation, sustainable use and benefit sharing. However, Indian citizens/entities/local people including vaids and hakims to have free access to use biological resources within the country for their own use, medicinal purposes and research purposes.

While granting approvals, NBA will impose terms and conditions to secure equitable sharing of benefits. Before applying for any form of IPRs in or outside India for an invention based on research or information on a biological resource obtained from India, prior approval of NBA will be required. There is an enabling provision for setting up a framework for protecting traditional knowledge. The monetary benefits, fees, royalties as a result of approvals by NBA to be deposited in National Biodiversity Fund, which will be used for conservation and development of areas from where resource has been accessed, in consultation with the local self government concerned and Provision for notifying National Heritage Sites important from standpoint of biodiversity by State Governments in consultation with local self government. Provision for notifying items, areas for exemption provided such exclusion does not violate other provisions. This is to exempt normally traded commodities so as not to adversely affect trade.

12.3.4 Biosafety Act

Biosafety Framework: Rules and Institutions

Genetically modified organisms are regulated in India under the Indian Environment (Protection) Act of 1986 (henceforth the EP Act). The objective of the EP Act is the protection and improvement of the environment. To meet this objective, the act calls for regulation of "environmental pollutants" which are defined as "any solid, liquid or gaseous substance present in such concentration as may be, or tend to be, injurious to the environment" (EP Act 1986: Chapter 1, Section 2b). The ministry of environment and forests used this broad definition of 'environmental pollutant' in 1989 to issue a set of legally binding rules to govern use of genetically engineered organisms under the EP Act.

The 1989 'Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Microorganisms, Genetically Engineered Organisms or Cells' (henceforth 1989 Rules) constitute the legally binding regulatory framework for genetically modified organisms in India [Rules 1989, Ghosh and Ramanaiah 2000]. As required by the 1989 Rules, biosafety guidelines were first issued by the department of biotechnology under the ministry of science and technology in 1990. These guidelines were revised and expanded in 1994 and 1998 [DBT 1994, 1998]. I address below, first, the scope of this regulatory framework (that is, what it covers) and second, how it allocates decision-making authority for biosafety.

The Indian biosafety regulatory framework, comprising the 1989 Rules and the 1990, 1994 and 1998 DBT guidelines, covers the entire spectrum of activities relating to genetically modified organisms. This includes "research involving genetically modified organisms, as well as genetic transformations of green plants, rDNA technology in vaccine development, and large-scale production and deliberate/accidental release into the environment of organisms, plants, animals and products derived from rDNA technology"[DBT 1990:1]. Production facilities such as distilleries and tanneries that use genetically modified organisms are also covered [Rules 1989, Article 1].

The 1990 'Recombinant DNA Safety Guidelines' and 1994 'Revised Guidelines for Safety in Biotechnology' provide guidance on containment and safe laboratory practices for GMOs in the agricultural and pharmaceutical sectors [DBT 1990, 1994]. They also, however, contain an important change from the 1989 Rules in their treatment of deliberate release of GMOs. While the 1989 Rules effectively banned such releases (permitting them only under special circumstances), the 1990 guidelines permit them, with a shift to assessing and managing ecological and health risks that might result.

The 1998 'Revised Guidelines for Research in Transgenic Plants and Guidelines for Toxicity and Allergenicity Evaluation of Transgenic Seeds, Plants and Plant Parts' add to the regulatory architecture by calling for toxicity and allergenicity data for ruminants, such as goats and cows, from consumption of transgenic plants [DBT 1998]. Biosafety regulators claim that Indian risk assessment is "even stricter than the best models elsewhere" in pointing to such requirements, which are portrayed as relevant to the Indian context.

Another key addition in the 1998 guidelines is the requirement to generate data on comparative economic benefits of a modified plant [DBT 1998, Ghosh and Ramanaiah 2000]. Thus, the 1998 guidelines call for a demonstration that a transgenic crop is both "environmentally safe and economically viable" [DBT 1998: 6]. An agronomic evaluation of the transgenic crop to determine economic advantage to farmers is seen as an integral component of the transgenic crop approval process, along with the biosafety evaluation. Thus, when the government granted permission for large-scale field-testing of transgenic cotton in India in July 2000 (the first crop to receive such approval), mandatory data to be generated included "cost of transgenic seed, projected demand, and the area to be covered under transgenic cotton cultivation" [GoI 2000].

12.3.5 Environment Protection Act (EPA)

In the wake of the Bhopal tragedy, the government of India enacted the Environment (Protection) Act of 1986. The purpose of the Act is to implement the decisions of the United Nations Conference on the Human Environment of 1972, in so far as they relate to the protection and improvement of the human environment and the prevention of hazardous to human beings, other living creatures, plants and property. The Act is an "umbrella" legislations designed to provide a framework for Central Government Coordination of the activity of various central and state authorities established under previous Acts, as the Water Act and the Air Act.

In this Act, main emphasis is given to "Environment" defined to include water, air and land and the inter-relationships which exist among water, air and land and human beings and other living creatures, plants, micro-organisms and property. "Environmental pollution" is the presence of pollutant, defined as any solid, liquid, or gas substance present in such a concentration as may be or may tend to be, injurious to the environment.

Intellectual Property Rights

The *Intellectual Property Rights* (IPR's) include copyrights, trademarks, trade secrets and patents. *Patents* vest exclusive monopoly ownerships rights over the patented matter i.e. the patent holder has due right to exclude others from using, making and

selling the patented subject matter for a certain period of time. IPR's and patents have become a matter of concern because of mega mergers of multinational companies in the life science industry which involves commercial sale of seeds, pesticides, food and pharmaceuticals. Thus, multinational companies can monopolise and control the supply of these products. This essentially means an increase in their prices. In addition, the control on essential resources such as seeds, drugs and food indirectly means a control over the fundamental rights of access to food, health and nutrition.

WTO agreement on *Trade-Related Aspects of Intellectual Property Rights* (TRIPS) was negotiated during the Uruguay Round. Article 27.3(b) relates the provision of TRIPS to biodiversity. It envisages the protection of plant varieties either by patents or by effective *Sui Generis* (unique or of its own kind) system or by a combination thereof. The two main issues involved being *the patenting of life forms* and *the protection of plant varieties*. The *patenting of life forms is related to bio-piracy* i.e. the theft of biological resources and traditional knowledge from developing countries. A US patent on the use of turmeric for healing wounds is an example of bio-piracy (Box 12.1). The issue of IPR protection of the genetically engineered crops is also very important.

The protection of plant varieties is important for commercial plant breeders. The international **Union for Protection of New Varieties of Plants** (UPOV) held its first convention in 1961 which promotes the protection of breeders rights over the new plant varieties. The UPOV convention has been revised many times. Under 1991 revision, the breeders who register rights over varieties can claim full commercial control over the seed or propagating materials of their protected varieties.

Thus, the farmers can't sell the seeds from their harvest and they have to pay royalty even for the seeds that they save from their harvest for use in the next plantation.

Recently, there was another development which could be used to exercise control and ownership over the biodiversity. With the help of new genetic engineering techniques, it is possible to create sterile plants with infertile seeds that can't be replanted. Thus, the seeds are killed after one generation. This technology is known as **terminator technology**. It forces the farmers to purchase seeds for every growing season. Hence, this technology offers an inbuilt protection without the needs of patents.

Table 12.1: Rules of patent and plants

International Law	India	National Law	Domestically
WTO TRIPS	Member since 1995	Amendments in Patents Act, 1970 to make it TRIPS compliant	Introduces product patents
UPOV	India's membership application pending with the UPOV Council	Protection of Plant Varieties & Farmers' Rights Act, 2001 with elements of UPOV Act of 1978	Establishes IPR on plant varieties through grant of breeder rights
CBD	Party since 1994	Biological Diversity Act, 2002	Regulates access and screens patent applications on Indian bioresources & knowledge
ITPGR	Ratified in 2002		Binds the country to grant facilitated access to a negotiated selection of 35 food crops and 29 forages

Sources: Survey of Environment 2004, The Hindu

The schedule for implementing TRIPS obligations for various categories of countries is as follows:

Developed Countries	1st January, 1996
Developing Countries	1st January, 2000
Least Developed Countries	1st January, 2006

The issue of patents and IPRs is a matter of concern for developing countries, as the private monopolisation of life and of biological resources would adversely affect the development, food security, livelihood of farmers and the environment. Such patents are also being opposed by the people on ethical and moral grounds.

Box 12.1: A case study: Controversial patent of neem, basmati and turmeric

Another treaty of relevance in this area is the recently concluded International Treaty on Plant Genetic Resources for Food and Agriculture (PGRFA Treaty), adopted on November 3, 2001, which incorporates, to a large extent, the philosophy of the CBD.

India is a party to all the three treaties. Recent controversy in India over the controversial patents granted by the US Patent Office and the EPO on *turmeric, basmati* and *neem* (all were based on the knowledge widely shared in India, another important case of biopiracy is the patent sought on *Phyllanthus niruri* (commonly known as Bhadharti in Sanskrit and Jaramla in Hindi) for the cure of jaundice or viral hepatitis. Use of *Phyllanthus niruri* for treatment of jaundice has been an ancient and well-recorded innovation in the Indian system of medicine. The Fox Chase Cancer Centre of Philadelphia has applied to the EPO for its use in curing viral hapatitis B., has brought the issue of biopiracy to the centre-stage in all the legislative efforts undertaken by the Government of India to comply with its international obligations under these treaties. Though the of *turmeric* and *neem* patents have been revoked in the US and the EU respectively, these cases have highlighted certain gaps in the whole procedure of granting and revoking patents on bio-products, and the very issue of IPRs has become very controversial in India. On turmeric the patent was granted to the University of Mississippi Medical Centre in December 1993 on its use in normal healing, particularly in chronic and acute wounds, which was successfully challenged by the Indian Council of Scientific and Industrial Research (CSIR), on the ground that the alleged invention was part of public domain knowledge in India. On the basis of documented evidence, the patent was cancelled. Similarly, *neem* patent, granted to W.R. Grace of the U.S., was revoked by the European Patent Office (EPO) after representations made by certain NGOs (See generally, Shayana Kadidal, "Subject-Matter Imperialism? Biodiversity, Foreign Prior Art and the *Neem* Patent Controversy".

SAQ 1

1) What is Forest Protection Act and how does it helps in protecting the Forest?

2) Though India has forest protection act with several amendments but even then the forest cover is shrinking. Why it so?

3) Do you think Acts alone can not curb the illegal forest cutting or degradation? What are the other provisions which will help in conservation of forests?

4) What is Biodiversity Act 2000?

5) Describe Environmental Protection Act (EPA).

12.4 INTERNATIONAL LEGISLATIONS

Similar to national legislations, there is no international legislation body with authority to pass legislations, nor are there international agencies with power to regulate resources in a global scale. There is an international court at Hague in the Netherlands, but it has no power to enforce its decisions. Powerful nations can simply ignore the court. As a result, international legislation must depend on the agreement of the parties concerned. Certain issues of multinational concerns are addressed by

collection of policies, agreements, and treaties that are loosely called International Environmental legislations. Most of the international legislations are international agreements to which nations adhere voluntarily. These agreements are generally finalized through international conventions or treaties.

The United Nations Conference on Environment and Development, 1972, Stockholm, popularly known as the Stockholm Conference was the first step from the United Nations to address the growing problem of Environmental degradation at international level. It also gave birth to the United Nations Environment Programme (UNEP). Key international environmental conventions which have been agreed since the Stockholm Conference include the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973), the Convention for the Prevention of Marine Pollution from Land-Based Sources (1974), the Convention on Long-Range Trans boundary Air Pollution (1979), the Convention for the Protection of the Ozone Level (1985), and the Convention on the Control of Trans Boundary Movements of Hazardous Waste and their Disposal (1989).

12.4.1 Convention on Biological Diversity

The Convention on Biological Diversity (CBD) was adopted during the United Nations Conference on Environment and Development (UNCED – or the "Earth Summit") in Rio de Janeiro on 5 June 1992. CBD has been instrumental in putting the concerns for conservation of biodiversity on the international agenda and its implementation on national level. More than 150 States have signed the Convention, and it entered into force on 29 December 1993. By May 1998 a total of 174 States had ratified the Convention, making it one of the most widely adopted environmental treaties of all times. India ratified the Convention in 1994.

The CBD places emphasis on decision making at the national level. The CBD has 42 articles. Table 12.2 set out the essence of each of the main Articles. The main Articles of the CBD are given below:

Table 12.2: Summary of the key articles of the convention on biological diversity

Articles of the CBD	Objective/Purpose
Article 1	Sets out the objectives of the Convention, namely: a) conservation of biodiversity b) sustainable use of the components of biodiversity c) equitable sharing of benefits arising from such use.
Article 2	Defines terms such as biodiversity, biological resources, biotechnology, etc.
Article 3	Sets out fundamental principles by stressing the responsibility of states to express their sovereign rights to ensure development of their biological resources in a sustainable manner; but without damage to other states and their resources.
Article 4	Defines jurisdictional scope – which is essentially national in respect of resources, but national/regional/global in terms of actions/processes as required.
Article 5	Sets out measures for cooperation between Contracting Parties.
Article 6	Urges parties to develop national biodiversity plans, strategies and programmes for biodiversity conservation and sustainable use of bio-resources; and to integrate biodiversity conservation into sectoral and cross-sectoral plans and policies.

Article 7	Sets out the need for: identifying and monitoring the components of biodiversity for conservation and sustainable use, with urgent attention to threatened components; identifying and monitoring processes having adverse impacts; and maintaining data obtained through the above processes.
Article 8	Sets out major goals for *in situ* conservation: regulation and management of ecosystems and wild species in or outside Protected Areas; restoring degraded areas; promoting recovery of threatened species; controlling alien species; addressing biosafety issues; conserving indigenous knowledge; developing and maintaining required legislation; links to Article 7.
Article 9	Sets out major goals for *ex-situ* conservation to complement *in-situ* measures; preferably in country of origin; adopting measures for recovery and rehabilitation of threatened species; regulating and managing collection for *ex-situ* conservation without affecting *in-situ* measures.
Article 10	Sets out principles for: sustainable use (SU) of components of biological diversity to be integrated into national planning; measures to minimise impacts on bio-diversity; protecting and encouraging customary use of biodiversity and supporting local populations to do so; encouraging cooperation between government and private sector to develop methods for SU.
Article 11	Promotes the adoption of incentive measures for conservation and SU of biodiversity.
Article 12	Promotes research and training by establishing programmes, encourages research, and promotes use of scientific advances in biological diversity research to develop methods for SU and conservation of biodiversity.
Article 13	Deals with public education and awareness to further biodiversity conservation.
Article 14	Introducing EIAs to minimise adverse impacts on biodiversity with provision for public participation and discussion.
Article 15	Deals with conditions for access to genetic resources by other countries on "mutually agreed terms" and subject to "prior informed consent" by the providing country (governments are accorded authority to determine access to genetic resources).
Article 16	Deals with access to and transfer to technology – in terms of providing/facilitating access to and transfer of relevant technology; in favourable terms for developing countries; by respecting Intellectual Property Rights (IPR)
Article17	Facilitates the exchange of relevant information.
Article 18	Promotes technical and scientific cooperation of biodiversity, and developing methods for cooperation and capacity building in technology development, including indigenous technologies.
Article 19	Promotes taking measures to provide for effective participation in biotechnology research by the providing countries (i.e. countries of origin); developing measures for priority access to biotechnology results and benefits by providing countries; providing information on LMOs before providing them to other countries.
Article 20-21 and 39	Financial mechanisms.

Broadly the Articles 8–13 set out policies to be followed. For example, Article 8 set out the major polices for effective *in-situ* conservation of biodiversity, giving the parties a set of goals that could match their own laws and polices. Articles 9, 10 and 14 do the same for *ex-situ* conservation, sustainable use of biological resources and environment impact assessment. These goals are supported by less detailed commitments on research and training (Article 12) and on education and awareness (Article 13).

The Articles 15 and 16 are complex and leave much to the contracting parties to decide regarding their implementation. The financial Articles 20, 21 and 39 have been deliberately left vague for the Conference of Parties to clarify them later. The CBD is thus a framework Convention in two ways.

Under Article 8(g) Parties have to, at the national level, regulate the risks of Living Modified Organisms resulting from biotechnology. Under Article 19, Parties have to supply information on LMOs to other Parties to whom these organisms may be transferred. To provide some international standards to the issue on LMOs, there has been the formulation of a Biosafety Protocol. This covers the safe transfer, handling and use of LMOs resulting from biotechnology and which would have an impact on native biodiversity. Sri Lanka signed the Biosafety protocol in 2000.

Issues in Biotechnology

Biotechnology is the science of manipulating DNA. The use of *transgenic technique* – a sort of cut and paste technique has made it possible to transfer genes from one species to another. Thus, by transferring a gene with desirable traits from one species to another, one can engineer plants as well as animals which have the desired characteristics. Such a tailor made organism (plant or animal) is said to be **genetically modified** (GM). For example, a genetically modified frost-free tomato has been produced by transferring a gene from fish living in cold water.

Thus, desirable traits such as greater yield, drought tolerance, pathogen resistance, high nutritional content, herbicide tolerance etc. can be introduced into crops. Various crops such as corn, tomato (Fig.12.1), potato, soybean, cotton, melon, tobacco, sugar beet etc are under field trails.

Fig.12.1: High resistant variety of tomato

Proponents of GM plants hope to feed the World's three billion malnourished poor by using this technology. It is also expected that with GM crops, our current over-reliance upon fertilizers, pesticides and herbicides would also reduce. The enhanced crop yield would also decrease the conversion of wild habitats into arable land.

82% of the world's GM crops are grown in US and Canada whereas Argentina's share is 17%. Rest 1% GM crops are grown by 9 other countries.

In India, the first transgenic crop, Bt cotton (Fig.12.2) has been granted conditional approval by the Genetic Engineering Approval Committee (GEAC) for commercial cultivation. Bt stands for *Bacillus Thuringiensis*, a soil bacterium which synthesises a crystal (cry) protein. This protein breaks down to release a toxin in insect gut which kills the insect. The Bt gene is inserted into cotton and the plant produces its own Bt

toxin. Such cotton plants are resistant to boll worm (Earias spp) which is a major cotton pest.

Fig.12.2: Non-BT cotton and Bt cotton bolls

In India, half of the pesticides used, i.e. 35000 metric tones out a total of 70000 metric tones, are used to fight with the boll worm menace on cotton. The studies on Bt cotton have shown an increase of 41-86% in yield and an increase of 17-77% in the number of bolls. The reduction in the sprays amounted to a saving of Rs.3000-6000 hectare. The transgenic crops such as Bt cotton offer a route to increase crop production with a minimum use of chemical pesticides. The other crops such as mustard and chilli are being tested by PRO Agro and Rallis India Limited, respectively.

The three varieties of cotton namely MECH 162, Biotechnology MECH 184 and Biotechnology MECH 12 have been granted conditional approval. These varieties are suitable for central and southern cotton zones and northern zones of Punjab, Haryana and parts of Rajasthan.

The approval has been granted to Maharashtra Hybrid Seed Company (MAHYCO) which has a tie up with the multinational company Monsanto. The approval is for three years i.e. from April 2002 - March 2005. MAHYCO is developing and testing Bt cotton since 1996. The two conditions for using Bt cotton are as follows:

1. Bt cotton may be sown on 80% of the field while the remaining 20% area must be sown with non-transgenic cotton. The non-transgenic cotton should be sown on the peripheries of the field.

2. A minimum 5 rows of non-transgenic cotton should be grown on the peripheries.

- *Safety of GM foods*: Since new proteins are synthesized in GM plants, it is feared that these may cause a sharp increase in allergic reactions.

- *Patenting of GM crops*: In many developing countries, a common practice is to save seeds from the harvest and use them for planting next year. If the GM seeds are patented, then farmers would have no right to save the seeds and every time the seeds are to be purchased from the company who has patented it. Thus, some companies may monopolise the global farming economy.

- *Creation of Superweeds*: About 70% of the GM crops are herbicide-resistant crops. It is feared that these would spontaneously breed in the wild with related plants to yield *superweeds*. In addition to being a threat to the ecosystems, these superweeds would require even more potent chemicals for their destruction.

- *Threat to Organic Farming*: The bacterium *Bacillus thuringienisis* (which was mentioned above in Bt cotton) is used by farmers in organic farming to control insect pests. They apply Bt only as per their needs. It is expected that if the insects are exposed to the Bt crops, they would develop immunity and hence the organic farming would be adversely affected.

Issues towards legislation of biodiversity

Many countries of the South Asian region are in the process of, or considering, specific legislation to bring into effect international treaties to which they are a party. In the development of such legislation, and in relevant non-legal measures, several steps need to be taken to ensure conservation, sustainable use, and equitable benefit-sharing.

A. Patent legislation

1. Countries should exclude from patentability:
   - i) All life forms;
   - ii) Existing traditional/indigenous knowledge (in current or translated forms), and essentially derived products and processes from such knowledge;(Use can be made of the European Patent Convention for a precedence for this, of Article 22 of the CBD for arguments relating to adverse impact on biodiversity from other international agreements, and of relevant exemptions provided in the TRIPs agreement)
2. Patent applications should include the following:
   - i) Disclosure of all places of origin of the material/knowledge used in the application;
   - ii) Disclosure of all communities/persons of origin;
   - iii) Proof of consent having been obtained from the community/persons of origin;
   - iv) Proof of benefit-sharing arrangement having been entered into with the community/persons of origin, in accordance with relevant guidelines developed by national authorities;
   - v) Disclosure of any previous rejection of application, in the country or other jurisdictions;
   - vi) Prior public notice in all relevant languages in the places and communities of origin. (Grounds for the above can be derived from Article 8(j), Article 15 and the clauses relating to national sovereignty under the CBD).

B. Plant varieties protective legislation

1. In view of the objectives of the CBD, UPOV 1978 or UPOV 1991 do not provide adequate models for sui generis plant variety protection legislation. Alternative regimes for providing appropriate models should contain the features elaborated below;
2. Applications for plant variety protection should include the following:
   - i) Disclosure of all places of origin of the material/knowledge used in the application;
   - ii) Disclosure of all communities/persons of origin;
   - iii) Proof of consent having been obtained from the community/persons of origin;
   - iv) Proof of benefit-sharing arrangement having been entered into with the community/persons of origin, in accordance with relevant guidelines developed by national authorities;
   - v) Disclosure of any previous rejection of application, in the country or other jurisdictions;
   - vi) Prior public notice in all relevant languages in the places and communities of origin;

3. The burden of proof should be on the applicant or plant variety right holder;

4. Farmers' Rights should get full treatment under the Act, and their definition should include: the right to protect farmers' varieties and knowledge, to continue having access to biological and other material which are important inputs into the farming system, to the cultural and social conditions which make continued innovation and resource use possible, and to save, propagate, use, exchange, share or sell varieties protected under the Act; and the obligation to ensure biodiversity conservation and sustainable use;

5. Farmers' Rights should further include the right to sue breeders if the latters' claims are not realised, with the burden of proving that the product complies with the claims being on the breeder;

6. The Act should contain provision for national and local level gene funds, derived from fees and other levies on plant breeding and the seed industry (other than those covered under agreements with local communities), which can be utilised for the purpose of supporting in-situ farmers' conservation measures and incentives for continued innovation by farmers;

7. The above funds and other sources should be used to provide a range of incentives for farmers to carry on conservation, use, and innovation of agricultural biodiversity, including financial, material, social, and other incentives;

8. The coverage of the Act should expand on a gradual step-by-step basis, applying the precautionary principle, following adequate environmental impact assessments, and assessing their implications for food security.

C. Protection of folklore

Current laws for copyright protection are unsuitable for protection of folklore. Measures should be therefore taken for the development of a sui generis legislation for protection of folklore based on an understanding of 'folklore' as inclusive of the following elements: folk knowledge/ practices/expressions of art, craft, music, scientific belief, architecture, agriculture, medicine, and conservation of natural resources.

12.4.2 Convention on International Trade of Endangered Species of Fauna and Flora (CITES)

Trade in wild animals and plants crosses borders between countries, the effort to regulate it requires international cooperation to safeguard certain species from over-exploitation. CITES was conceived in the spirit of such cooperation. Today, it accords varying degrees of protection to more than 30,000 species of animals and plants, whether they are traded as live specimens, fur coats or dried herbs. Many wildlife species in trade are not endangered, but the existence of an agreement to ensure the sustainability of the trade is important in order to safeguard these resources for the future.

This is an international agreement between Governments regarding international discussion of the regulation of wildlife trade for conservation purposes. It aims to protect wildlife from over exploitation and to prevent international trade from threatening species with extinction. Exploitation of some animal and plant species, habitat loss is causing a threat to biodiversity for CITES is in a move to ensure the sustainability of the trade in order to safeguard these resources for the future urged international cooperation by the way that all import, export, re-export and introduction from the sea of species covered by the Convention has to be authorized through a licensing system. The convention now covers about 30,000 plant and animal species and has 150 member countries. India is also party to CITES, which came into force from 18/10/1976.

Year of ratification by India: 20.07.1976
Year that Convention came into force: 18.10.1976

1. Provisions of the CBD should be given complete legal recognition and implemented effectively at a national level;

2. Article 8(j) of the CBD should be implemented under national legislation by:

   i) granting ownership of biogenetic material to local communities;

   ii) recognising and protecting of the traditional knowledge of these communities, and traditional modes of resource use regulation and dispute resolution under customary law;

   iii) ensuring the consent and involvement of these communities in the wider use of their knowledge and practices;

   iv) mandating a series of equitable benefit-sharing measures;

12.4.3 Ramsar Convention

It is an intergovernmental treaty which provides the framework for international cooperation for the conservation and wise use of wetland habitats. The United Nations Educational, Scientific and Cultural Organisation (UNESCO) serves as the Depositary for the Convention, and its secretariat, the Ramsar Bureau, shares headquarters with the IUCN- the World Conservation Union in Gland, Switzerland.

The Convention aims to halt the loss of wetlands and to ensure the conservation of fauna and flora and their ecological processes. Obligations of parties include:

- Designating one or more wetlands for inclusion in the list of Wetlands of International Importance (e.g. six Ramsar wetlands in India).
- Promoting wise use of wetlands, including mangroves.
- Promoting conservation of wetlands through establishment of nature reserves. (irrespective of their listing under the Convention) and managing wetlands for the benefit of water fowl.
- Promoting training in the field of wetland research, managing and warding.
- Consulting with other Parties about implementation of the Convention, especially with regard to Tran frontier wetlands, shared water systems, shared species, and development of wetland projects.

Year that Convention came into force: 1975
Year of ratification by India: 1981

12.4.4 Bonn Convention

Migratory species of animals are, on average, more at risk of becoming endangered than non-migratory species. This is so because their requirements are greater: not only do they need good habitat for reproduction but also during their off-season and all along their migratory routes. In an ever-changing world, human pressure is high on some of those habitats, and also often on the animals themselves (hunting, incidental catch, etc). As a result, many migratory species (Fig.12.3) that were once common are becoming increasingly rare. We all share a responsibility in the conservation of this common natural heritage.

Fig.12.3: Publications of convention on migratory species

Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention) aims to conserve terrestrial, marine and avian migratory species throughout their range and because it was signed in Bonn, Germany, on 23 June 1979. Like many other international treaties (Washington, Bern, Ramsar, Barcelona, Basel, etc.) it is commonly known after the city where it was concluded. It is an **intergovernmental treaty**, concluded under the aegis of the United Nations Environment Programme, concerned with the conservation of wildlife and habitats on a global scale. Since the Convention's entry into force, its membership has grown steadily to include 89 (as of 1 February 2005) Parties from Africa, Central and South America, Asia, Europe and Oceania.

SAQ 2

1) Discuss the advantages and disadvantages of GM crops.
2) How the genetically modified organisms ar e regulated in India?
3) What is terminator technology? Is this technology helpful for farmers of our country if not why?
4) Why International registrations are necessary for biodiversity conservation?
5) Which of the article in CBD are most important for biodiversity conservation?
6) How the issues in biotechnology are addressed in CBD?
7) Is use of Bt cotton is safe for Indian farmers comment with examples?
8) What is the importance of CITES, how it works?
9) Why Ramsar convention is important for India?
10) How Bonn convention helps the migrating animals and birds of the world for which bird India has signed the memorandum of understanding?

12.5 OTHER CONVENTIONS RELATED TO CONSERVATION OF BIODIVERSITY

Convention for Protection of the World Cultural and Natural Heritage (1972)

The aim of this is to establish an effective system of collective protection of the cultural and natural heritages of outstanding universal value organized on a permanent basis and in accordance with modern scientific methods. Convention, since 1975,

recognizes the obligation of all states to protect unique natural and cultural areas and recognizes the obligation of the international community to help pay for them.

Multilateral Environmental Agreements administered by UNEP:

Biodiversity-related Conventions:

- **Cartagena Protocol on Biosafety (2000)**

  Cartagena protocol is one of the multilateral Environmental Agreements administered by United Nations Environment Programme (UNEP) seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology hazards. .

United Nations Convention to Combat Desertification (UNCCD)

Improved productivity of land, and the rehabilitation, conservation and sustainable management of land and water resources emphasized to promote sustainable development at the community level as over 250 million people are directly affected by desertification in the wake of degradation of land in arid, semi-arid, and dry sub-humid areas. United Nation conventions gives examples how to combat desertification, how far achieved improved living conditions in particular at the community level by virtue of National, sub-regional, and regional action programmes and through partnership agreements as for example how affected countries, donors, and intergovernmental and non-governmental organizations mobilized substantial funding to combat desertification. It is acknowledged in the running conventions that changes in local and international behaviour in the name of sustainable land use and food security can reverse the precarious consequences of desertification.

12.6 SUMMARY

In this unit you have studied that:

- There is a need of appropriate legal frame work for the success of biodiversity conservation.
- National legislations are very important and incorporating biodiversity conservation into national policies and planning can help countries to define and articulate their international interest.
- The various national and international legislations, which have been framed to stop environmental degradation.
- India is one of the few countries of the world that have made specific reference in the constitution to the need for environmental protection and improvement. The Central Government State Governments have utilized this provision to pass various Acts in order to protect the environment from destruction.
- There is a great contribution of UN in addressing global environmental challenges. To implement the agenda of UN, there is movement towards environment protection on a worldwide scale through special conventions, protocols and multilateral agreements.
- SACEP is an regional cooperation among South-Asian countries to help biodiversity conservation.

12.7 TERMINAL QUESTIONS

1. “For conserving biodiversity of your country you only need national legislation” comment in favour of or against this statement.

2. Survey the area where you are living and collect the data for use of plastic carry bag. Analyse the result to see that Manufacture and Usage Amendment Rules of 2002 is carried out.

3. If in your survey (Q-N-2) if you don't find the application of above given rule, what measures would you suggest for the application of rule strictly.

4. As you know "India is a country with mega diversity" but without proper rules and regulations it is robed every day. What type of rules should be framed to protect our biodiversity from biopiracy?

5. What do you think whether the GM crops are beneficial or non beneficial for our farmers?

6. "The private monopolization of biological resources will hamper the growth of our country". Give your views why you agree or disagrees with the above given statement.

7. What are the areas which you think our country should have stricter legislations?

8. Why we should be concern about the biodiversity of our country and how you can contribute towards conservation?

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