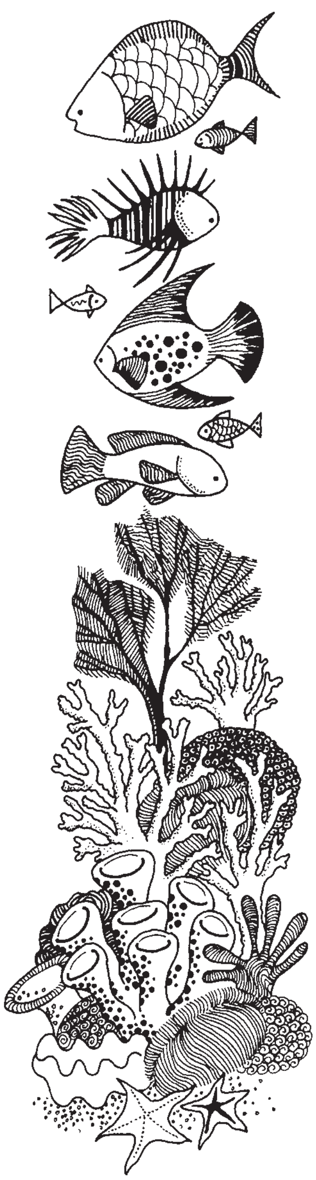
Chapter 4

Profile of Biodiversity in India

India, with 2.4% of the world's area, has over 8% of the world's total biodiversity, making it one of the 12 megadiversity countries in the world. This status is based on the species richness and levels of endemism recorded in a wide range of taxa of both plants and animals. This diversity can be attributed to the vast variety of landforms and climates, resulting in habitats ranging from tropical to temperate and from alpine to desert (see *Map 4.1*). Adding to this is a very high diversity of human-influenced ecosystems, including agricultural and pasture lands, and a diversity of domesticated plants and animals, one of the world's largest. India is also considered one of the world's eight centres of origin of cultivated plants. Being a predominantly agricultural country, India also has a mix of wild and cultivated habitats, giving rise to very specialised biodiversity, which is specific to the confluence of two or more habitats.



The first part of this chapter takes a look at India's ecosystem, its species, and its genetic diversity, both 'natural' and 'domesticated'. The second part discusses the diverse uses of this biological diversity and the values attributed to it.

4.1 Components, Range, Global Position and Current Status of Biodiversity

4.1.1 Natural Ecosystems

Biogeographic Zones of India

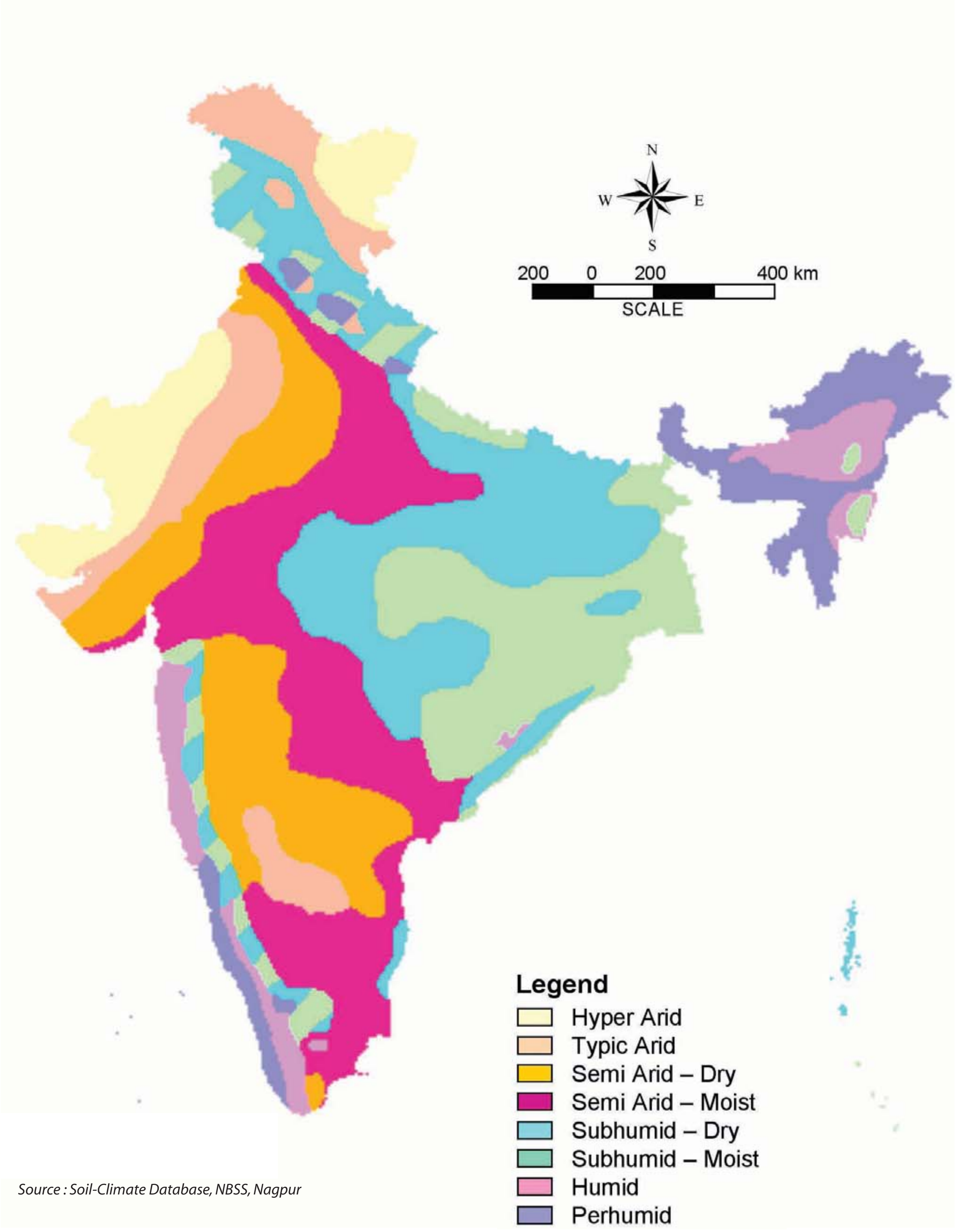
The tendency to classify ecological regions, and plant and animal groupings, according to their geographical distribution and their essential similarities and differences, is not new. Traditional human communities did this on the basis of their own understanding, though their knowledge was necessarily somewhat restricted in its geographical spread (Banwari 1992; Gurukkal 1989). Unfortunately, this aspect of traditional community knowledge is not well appreciated or studied.

In modern times, biogeographical classification started in the latter half of the 19th century, with Blandford (1870, 1901) and Elwes (1873) using the distribution of animals to classify bioregions, and Clarke (1898) followed by Hooker (1907), using plant distribution to the same end. What distinguished most of these early attempts – and indeed all except some recent efforts – was that they were either phytogeographic, i.e., based solely on plant distribution, or zoogeographic, i.e., based only on animal distribution. An attempt to synthesise the two approaches, or come up with a fresh classification based on the combination of plant and animal distribution, is very recent, and has been prompted by the need to use such zonation in fixing conservation priorities. These three kinds of approaches have been used or analysed by several authors recently, including Mani (1974), Puri *et. al.*, (1983), Meher-Homji and Mishra (1973), Menon (1990), and Rodgers and Panwar (1988).

One of the major recent approaches to classification of India's ecosystems has been based on biogeography (Rodgers and Panwar 1988). The major objective of this exercise was to develop a biogeographical classification based on known information, which will enable conservation planning both at the national and state levels. This classification uses four levels of planning:

a. The biogeographic zone, a large distinctive unit of similar ecology, biome representation, community and species;
b. The biotic province, a secondary unit within a zone, giving weight to particular communities separated by dispersal barriers or gradual change in environmental factors;

Map 4.1 Bioclimatic Regions of India



Source : Soil-Climate Database, NBSS, Nagpur

c. The sub-division or region, a tertiary set of units within a province, indicating different land forms; and finally;
d. The biome, which is an ecological unit and not a biogeographic unit. A biome can be found in several biogeographic zones or provinces.

Table 4.1 Biogeographic Zones of India and their Spatial Extent

Zone No.	Zone Name	Zone Area Sq km	Percentage of India's land area
1.	Trans-Himalaya	184823	5.62
2.	Himalaya	210662	6.41
3.	Desert	215757	6.56
4.	Semi-Arid	545850	16.60
5.	Western Ghats	132606	4.03
6.	Deccan Peninsula	1380380	41.99
7.	Gangetic Plain	354782	10.79
8.	Coasts	82813	2.52
9.	Northeast	171341	5.21
10.	Islands	8249	0.25
	Grand Total	**3287263**	**100.00**

Source: Rodgers et. al., 2002

Rodgers *et. al.* (2002) recognise ten biogeographic zones divided into twenty-six biotic provinces in India: (*see Table 4.1 and Map 4.2 and 4.3*) The zones are:

Trans-Himalaya

The Trans-Himalaya zone covers mainly the districts of Ladakh and Kargil in Jammu and Kashmir, and the Spiti valley, Lingti plains (Lahaul valley), and Pooh tehsil (district Kinnaur) in Himachal Pradesh. Small areas in the rain shadows of Nanda Devi range (Uttaranchal) and Kangchendzonga range (Sikkim) are also part of this zone (Mehta and Julka 2001). The area is a distinct biogeographic unit with harsh climatic conditions and is usually referred to as cold desert (Rodgers and Panwar 1998). The region is the most elevated zone on the earth and varies from 2800 m in the Indus to over 7000 m in the Himalayan and Karakoram ranges (Mehta and Julka 2001).

Himalaya

The Himalaya zone consists of an area of 21,0662 sq km, approximately 6.41% of the country's total land surface. It includes northwest Himalaya (Kashmir to the Sutlej river in Himachal Pradesh), west Himalaya (Sutlej river to the Gandak river in Nepal), central Himalaya (Gandak river in Nepal through West Bengal and Sikkim to central Bhutan) and east Himalaya (central Bhutan and Arunachal Pradesh).

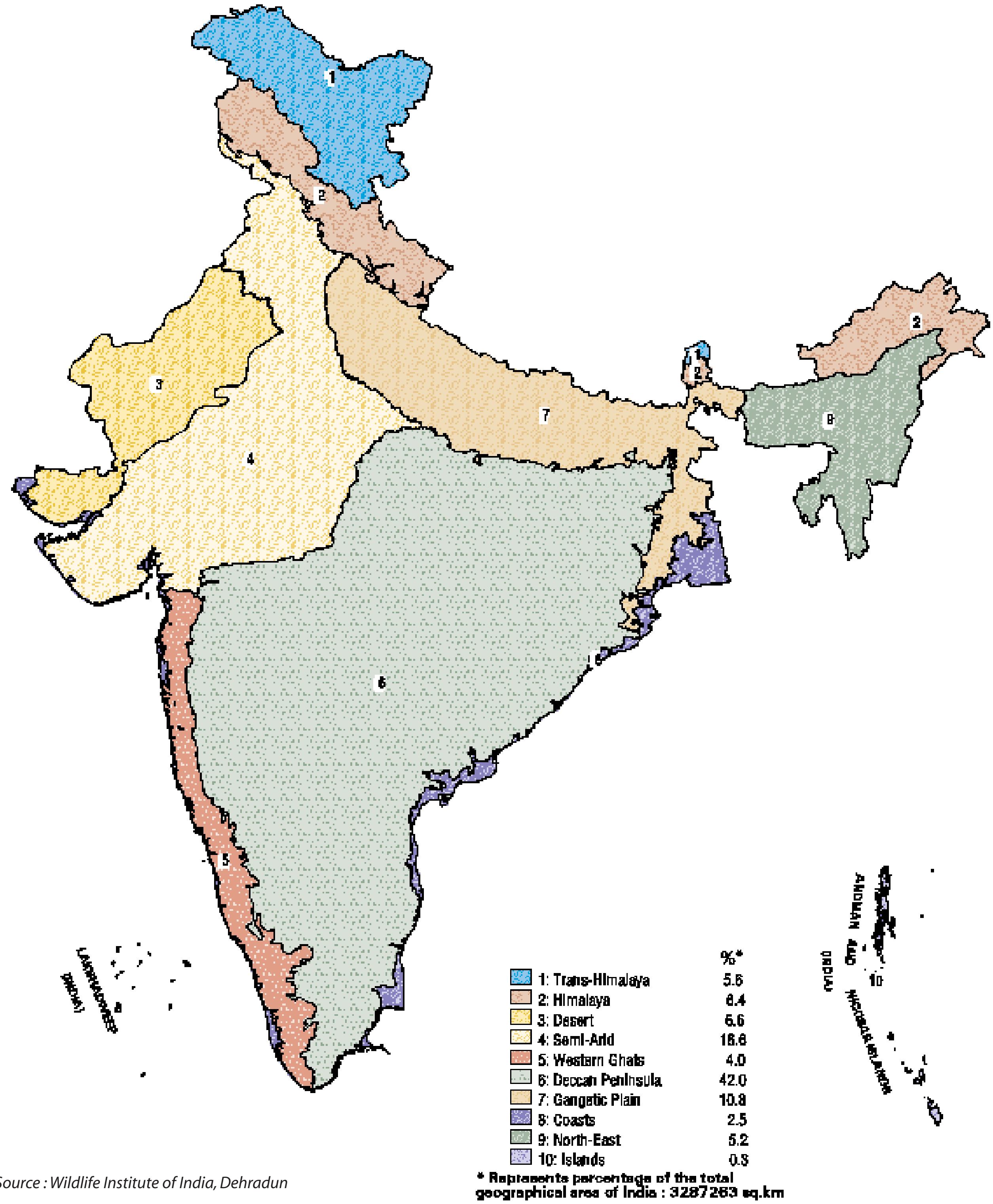
Desert

The Indian desert is the northwestern boundary of India and covers mainly the western and northwestern region of Rajasthan and part of Kachchh region of Gujarat in the southwest. It has an elevation of about 350-450 m above sea level at the Aravalli range in the east, about 100 m in the south and west and about 20 m in the Rann of Kachchh (Baqri and Kankane 2001).

Semi-Arid

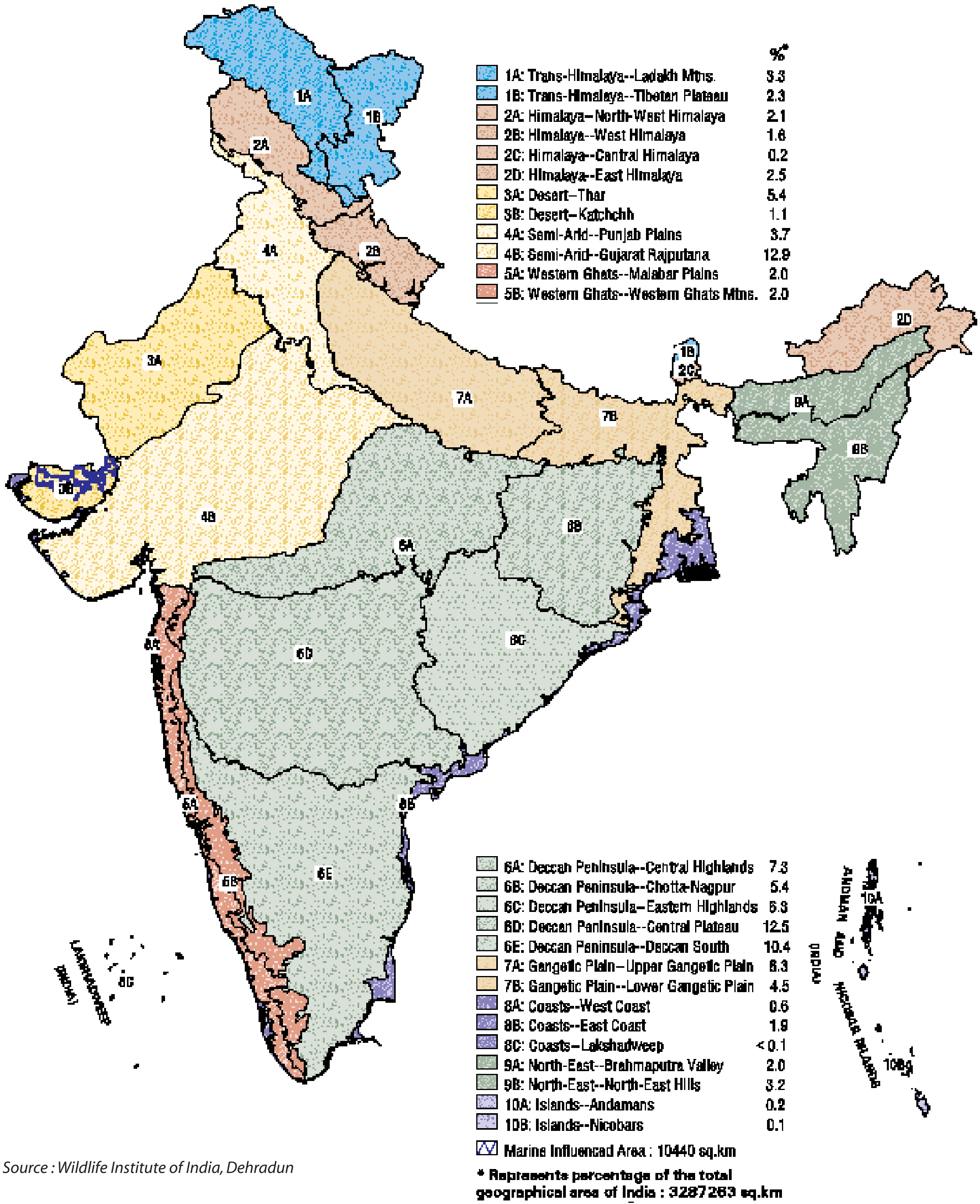
This region is a zone of transition between the true desert in the west to the extensive communities of the Deccan Peninsular India, to the south and east. This zone includes the Punjab plains, Delhi, Haryana, fringes of Jammu and Kashmir, Himachal Pradesh, western edges of Uttar Pradesh, eastern Rajasthan, eastern Gujarat and northwest Madhya Pradesh. The Semi-arid zone represents a characteristic savannah woodland and dry deciduous and tropical thorn forest zone in Western India. The Aravalli System constitutes the heart of this zone, which primarily supports two types of vegetation: Tropical Dry Deciduous Forest and Tropical Thorn Forest.

Map 4.2 Biogeographic Classification of India: Zones



Source : Wildlife Institute of India, Dehradun

Map 4.3 Biogeographic Classification of India: Provinces



Source : Wildlife Institute of India, Dehradun

Western Ghats

The Western Ghats stretch from the Tapti river in the north to Kanyakumari in the south, along the west coast of peninsular India through the states of Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala (Lakshminarayana *et. al.*, 2001). The Western Ghats zone is one of the 25 biodiversity 'hotspots' in the world (Myers *et. al.*, 2000) and is one of the major tropical evergreen forested regions in India, exhibiting enormous plant diversity. About 4000 species of flowering plants occur in the region, which harbours nearly 27% of the total flora in India (Nayar 1996). Among these, 1500 species are endemic (Mackinnon and Mackinnon 1986). The Western Ghats region is a major genetic estate with an rich biodiversity of ancient lineage.

Deccan Peninsula

The Deccan Peninsula biogeographic zone includes a major portion of the states of Maharashtra, Madhya Pradesh, Uttar Pradesh, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa and Bihar. The zone is relatively homogenous and ranges from semi-arid to moist-deciduous/semi-evergreen type of climate. The central highlands comprise the Vindhya and Satpura hill ranges, Chhota Nagpur Plateau, Eastern Ghats, Tamil Nadu Plains and Karnataka Plateau (Cherian 2001). The Vindhya and Satpura hill range are known for a rich diversity of flora.

Gangetic Plains

This zone includes the Gangetic divide, the Upper Gangetic plain, the Middle Gangetic plain and the Lower Gangetic plain (Hooker 1907). This zone is mostly under agriculture and supports dense human population stretching from eastern Rajasthan through Uttar Pradesh to Bihar and West Bengal. The Gangetic plain includes the area adjacent to Terai-Bhabar tracts in Uttar Pradesh, Bihar and West Bengal.

Coasts

The coastline of India stretches from Gujarat to Cape Comorin (Kanyakumari) in the west, and onwards from Cape Comorin to the Sundarbans in the east. The long stretch of coastline in the mainland has a very diverse set of biotic communities.

North-East Region

The north-east Indian biogeographic zone is most significant as it represents the transition zone between the Indian, Indo-Malay and Indo-Chinese biogeographic regions, as well as a meeting-place of Himalayan mountains with those of Peninsular India. It comprises eight states – Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The region acts as a biogeographic gateway for plant migration. In India, apart from the Western Ghats, Northeast India is one of the 25 biodiversity 'hotspots' in the world (Myers *et. al.*, 2000).

Islands

Islands are essentially in two major groups – the Lakshadweep islands and the Andaman group of islands. The Lakshadweep Islands are an archipelago of 27 small islands stretching from 8˚ to 12˚ N latitude and 71˚ to 74˚ E longitude in the Arabian Sea. They are 320 kms away from the Kerala coast. The Andaman and Nicobar Islands are an elongated north-south oriented group of 348 islands in the Bay of Bengal stretching for 590 km from 6˚ to 13˚ N latitude and 92˚ to 93˚ E longitude. The Andaman Islands are about 190 km from Cape Negrais in Burma, the nearest point on the mainland. Five islands close together constitute the Great Andaman (300 km long), and the Little Andaman lies to the south. The Nicobar groups of Islands are separated from the Andamans as well as internally from each other by 800 m deep channels.

4.1.1.1 Natural Terrestrial Ecosystems

India, due to its varied physical features and its geographical location, experiences almost all kinds of climate, from tropical to alpine and from desert to humid. On the basis of temperature, the landmass of India can be broadly classified into four zones:

a. Tropical zone, which is very hot round the year and does not have a winter,
b. Sub-tropical zone, which is hot for most of the year but with a cool winter,
c. Temperate zone, which has a warm summer and a pronounced winter, and,

d. Arctic or Alpine zone, which has a short summer and a long and severe winter. (*Natural Terrestrial Ecosystems Thematic BSAP 2002*)

Natural terrestrial ecosystems are of the following broad kinds: forests, grasslands, deserts and permanently snow-bound areas. Within each of these, there is an immense diversity, which is briefly described below.

Forests

Diversity

According to FSI (2002), forest cover has been assessed to be 20.55% of the country's geographical area. Of this, dense forest areas cover 4,16,809 sq km (12.68 %) and open forests cover 2,58,729 sq km (7.87%). Forest cover information of 589 of the 593 districts has been presented in the report, with statistics showing that Madhya Pradesh has the maximum forest area of 77,265 sq km, followed by Arunachal Pradesh (68,045 sq km) and Chhattisgarh (56,448 sq km) (*see Map 4.4*). Defined simply as tree-or bush-dominated ecosystems, forests are what most people think of when talking about a natural ecosystem. They are believed to contain most of the earth's terrestrial species biodiversity. Yet, though classified as one category for the sake of convenience, they display an internal diversity that is so large that often one forest type has almost no resemblance to another forest type. Indeed the term 'forests' may even cover grassland and desert areas with sparse tree cover, resulting in some confusion over ecological categorization of India's terrestrial ecosystem.

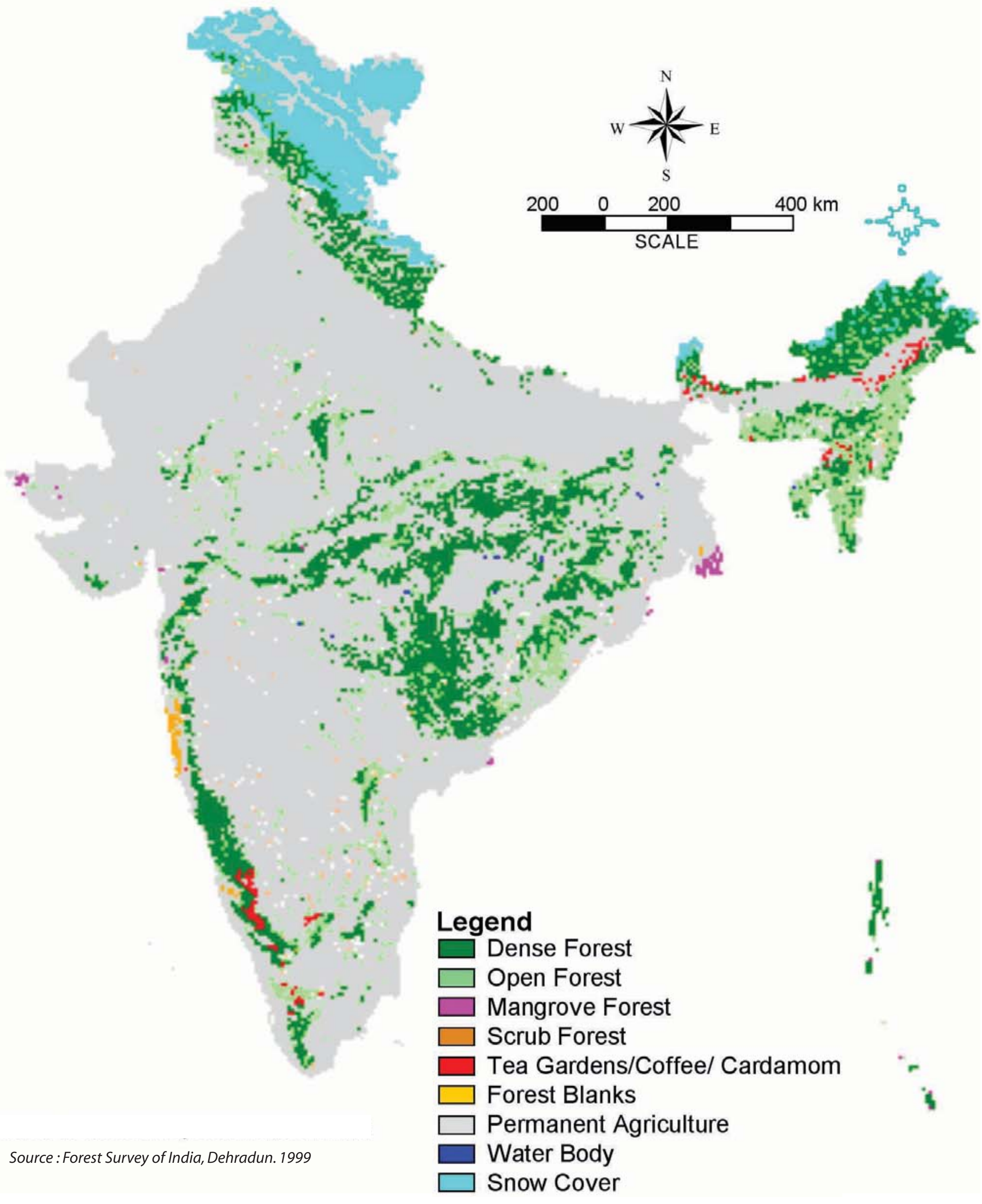
There have been various approaches to classifying forest ecosystems. One of the most comprehensive and detailed classifications of forests has been by Champion and Seth (1968), which is still in vogue in India. They adopted a hierarchical system, which has five major forest types: a) Tropical forests, b) Montane sub-tropical forests, c) Montane temperate forests, d) Sub-alpine forests, and, e) Alpine scrub. These are in turn classified into 16 major forest-type groups and 221 minor forest-type groups. Brief descriptions of the 16 major forest type-groups are given in *Annexure 6* and their extent is given in Table 4.2 and Map 4.5 (*Natural Terrestrial Ecosystems Thematic BSAP*). The recorded forest areas of the country have been classified as Reserve Forests (55%), Protected Forests (29%) and Unclassed Forests (16%). But the vegetation of forests varies according to climate, rainfall, soil topography and other habitat factors (http://envfor.nic.in/nfap/forest-distribution.html).

Table 4.2 Forest Types as Classified by Champion and Seth (1968)

S.No.	Vegetation Type	Area (Million ha)	Percentage of Forest Area
1.	Tropical wet evergreen forest	4.5	5.8
2.	Tropical semi-evergreen forest	1.9	2.5
3.	Tropical moist deciduous forest	23.3	30.3
4.	Littoral and swamp forest	0.7	0.9
5.	Tropical dry deciduous forest	29.4	38.2
6.	Tropical thorn forest	5.2	6.7
7.	Tropical dry evergreen forest	0.1	0.1
8.	Sub-tropical broad leaved forest	0.3	0.4
9.	Sub-tropical pine forest	3.7	5.0
10.	Sub-tropical dry evergreen forest	0.2	0.2
11.	Montane wet temperate forest	1.6	2.0
12.	Himalayan moist temperate forest	2.6	3.4
13.	Himalayan dry temperate forest	0.2	0.2
14. 15. 16.	Sub-alpine Moist alpine forest Alpine forest	3.3	4.3
	Total	**77.0**	**100.0**

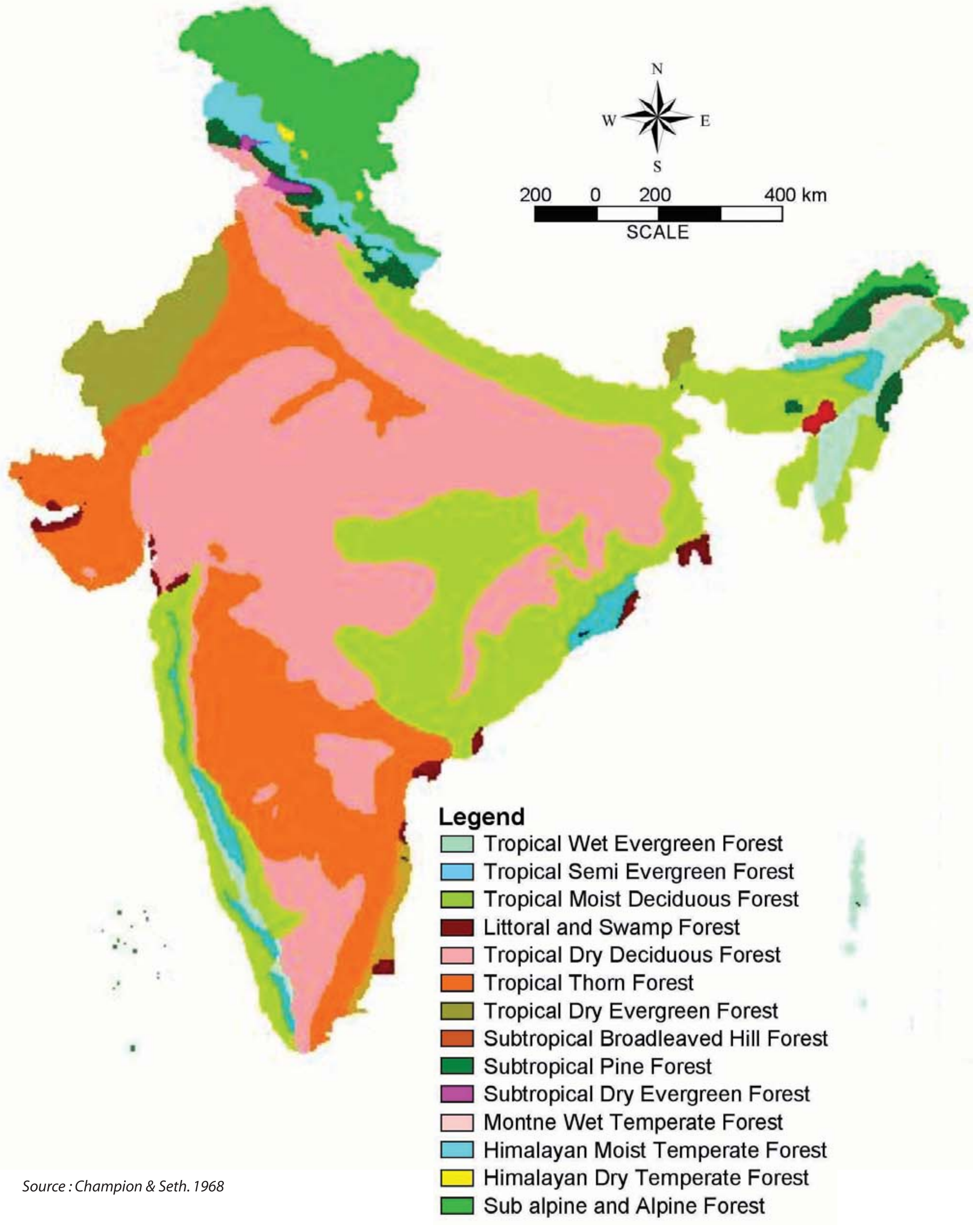
Source: MoEF 1999c

Map 4.4 Forest Cover and Land Use of India



Source : Forest Survey of India, Dehradun. 1999

Map 4.5 Forest Types of India



Source : Champion & Seth. 1968

Due to certain deficiencies in the classification system used by Champion and Seth (including the problem that it was based on extrapolation from some selected areas rather than on vegetation mapping of the whole country, and that it incorrectly distinguishes between southern and northern types), Gadgil and Meher-Homji (1990) proposed a more sophisticated classification based on detailed vegetation mapping by the French Institute, Pondicherry. Their system distinguishes 16 biogeographic zones and 42 vegetation types. The area under each of these, and the diversity of plants found in them, is given in *Table 4.3*.

Table 4.3 Area of each Vegetation Type and Its Floristic Diversity, Under Each Biogeographic Region

VEGETATION TYPE	MAXIMUM AREA ('OOO HA)	DIVERSITY OF PLANT SPECIES
Region I. Wet Evergreen Forests of West Coast and Western Ghats		
1. *Cullenia-Mesua-Palaquium*	645	200
2. *Dipterocarpus-Mesua Palaquium*	1166	1700
3. *Persea-Holigarna-Diospyros*	645	Not available
4. *Montane shoal*	123	850
5. *Memecylon-Syzygium-Actinodaphne*	180	400
6. *Bridelia-Syzygium-Terminalia Ficus*	212	100
Region II. Wet Evergreen Forest and Teak Forest Ecozone (Transitional Zone)		
1. *Tectona- Lagerstroemia lanceolata-Dillenia-Terminalia paniculata*	1240	1500
2. *Tectona- Terminalia*	598	450
Region III. Teak Zone		
1. *Anogeissus-Terminalia-Tectona*	7589	800
2. *Tectona-Terminalia*	7754	400
Region IV. Teak-Sal Transition Zone		
1. *Terminalia-Anogeissus latifolia*	1915	400
2. *Terminalia-Anogeissus-Cleistanthus*	2895	Not available
Region V. Sal Zone		
1. *Shorea -Buchanania-Cleistanthus*	3222	550
2. *Shorea- Cleistanthus- Croton*	1496	400
3. *Shorea- Buchanania- Terminalia*	9178	700
4. *Shorea- Terminalia- Adina*	90	700
5. *Shorea-Dillenia-Pterospermum*	170	160
6. *Shorea-Syzygium operculatum -Toona*	3284	850
7. *Toona-Garuga*	172	200
Region VI. Hardwickia Zone		
1. *Hardwickia binata-Anogeissus latifolia*	1514	475
Region VII. Albizia Amara Zone		
1. *Albizia amara-Acacia*	858	400
2. *Anogeissus latifolia Chloroxylon- Albizia amara*	17	Not available
3. *Manilkara- Chloroxylon*	131	300

Region VIII. Anogeissus Pendula Semi-Arid Zone of East Rajasthan		
1. *Acacia senegal- Anogeissus pendula*	149	600
2. *Acacia catechu- Anogeissus pendula*	1671	Not available
3. *Anogeissus pendula- A. latifolia*	255	400
Region IX. Deccan Thorn Forest		
1. *Acacia-Anogeissus latifolia*	27	Not available
Region X. Acacia-Capparis Scrub		
1. *Acacia-Capparis*	Negligible	500
Region XI. Indian Desert		
1. *Prosopis-Capparis-Zizyphus Salvadora-Calligonum*	Negligible	550
Region XII. North-West Himalaya		
1. Subtropical evergreen *sclerophyllous forest*	312	Not available.
2. Alpine steppe	232	Not available
Region XIII. North-West Himalaya to Eastern Himalaya		
1. Subtropical *Pinus roxburghii* forest		
2. Temperate mixed Oak and Coniferous forest	1288	Not available
3. Temperate coniferous forest	124	Not available
4. Sub-alpine forest	192	Not available
5. Alpine scrub	48	Not available
Region XIV. Eastern Himalaya and North-East India		
1. Tropical wet evergreen forest	860	Not available
2. Tropical moist deciduous forest	1784	Not available
3. Subtropical broad leaved hill forest	148	Not available
4. Montane wet temperate forest	180	Not available
Region XV. Andaman and Nicobar Islands		
Tropical wet evergreen forest	488	1000
Region XVI. Mangrove		
Mangrove	58	Not available

Source: Adapted from Gadgil and Meher-Homji 1990

Current Status

(See also Section 5.1.1.1)

The earliest systematic assessment of forest loss can be made from 1972 onwards, derived from studies carried out by the National Remote Sensing Agency (NRSA). NRSA's figures for 1972-75 and 1980-82 showed an alarming reduction of forest cover by about 91,710 sq km, or about 2.79%. However, the NRSA figures were at variance with the Forest Survey of India (FSI) figures for 1981-83, due to methodological differences. By reconciling their methodologies, the two agencies came up with another figure that suggested that the situation was not so grim.

However, no attempt seems to have been made to derive new figures for 1972-75, using the reconciled methodology, so it is not possible to say how much forest, if any, was lost in the 1970s. The NRSA and FSI figures seem to match with respect to the extent of dense forest in the early 1980s. If, therefore, the NRSA figure for dense forest is taken to be accurate for the period 1972-75 also, then a loss of very large magnitude (over 100,000 sq km, or 3% of the total) can be discerned in the case of dense forests during this period. The total loss in dense forest is more than the overall loss of forest cover, because, simultaneously, a large increase in the magnitude of open forests took place (IIPA 1996).

Table 4.4 Forest Cover Estimates From 1987 to 1999

Assessment	Year	Data period	Resolution of Sensors meters	Forest Cover (sq km)	% of geographic area
First	1987	1981-83	80	640,819	19.49
Second	1989	1985-87	30	638,804	19.43
Third	1991	1987-89	30	639,364	19.45
Fourth	1993	1989-91	30	639,386	19.45
Fifth	1995	1991-93	36.25	638,879	19.43
Sixth	1997	1993-95	36.25	633,397	19.27
Seventh	1999	1996-98	23.25	637,293	19.39

Source: Anon 2000

Since 1987, the Forest Survey of India (FSI) is assessing the forest cover of the country biennially, using remote sensing technology. The results of the last seven assessments are given in *Table 4.4*.

Table 4.5 Forest Cover as per 2001 Estimate

Class	Area in sq km	Percentage of Geographic area
Dense forest	416,809	12.68
Open forest	258,729	7.87
Total Forest Cover*	675,538	20.55
Scrub	47,318	1.44
Non-forest**	2,611,725	79.45
Total	3,287,263	100.00

**Includes 4,482 sq km under mangroves 0.14% of the country's geographic area)*
***Includes Scrub*
Source: FSI 2002

The estimate in 2001 places the forest cover at 675,538 sq km, equivalent to 20.55 % of the geographical area of the country. The dense forest constitutes 416,809 sq km (12.68%), open forest constitutes 258,729 sq km (7.87%) and mangrove constitutes 4,482 sq km (0.14%) of the geographic area in the country (FSI 2002).

To get an idea of changes for each of the forest types described by Champion and Seth (1968) or the French Institute (1990), an interesting analysis has been done by Gadgil and Meher-Homji for their 16-province, 42-type classification. Basing their analysis on the extensive mapping done by the French Institute in most parts of the country except the Himalayas, and supplementing these data with the work of Schweinfurth (1957), the maps of the National Atlas Organisation (1990) and the Forest Survey of India satellite imagery, they have roughly estimated actual area covered by each vegetation type as a percentage of its potential area (assuming no external hindering factor). Actual area has further been divided into:

a. Plesioclimax (approximating climax vegetation), and,
b. All physiognomies (climax and degraded stages).

A summary of the results is presented in *Table 4.6*.

Table 4.6: Area (Percentage of Potential) Under Plesioclimax and Under Other Degraded Physiognomies of Vegetation

S.No.	Vegetation type	% under Plesioclimax	% under other degraded Physiognomies
1.	Tropical wet evergreen forest of Andaman-Nicobar	70	90
2.	*Shorea_Buchanania-Terminalia*	15	90
3.	*Bridelia-Syzygium-Terminalia-Ficus*	41	77
4.	*Shorea-Syzygium operculatum-Toona*	25	66
5.	*Persea-Holigarna-Diospyros*	60	60
6.	Mangrove	30	60
7.	Temperate mixed oak and coniferous forest of Himalayas	–	55
8.	*Dipterocarpus-Mesua-Palaquium*	22	52
9.	Subtropical broad-leaved forest of Eastern Himalayas	–	49
10.	*Shorea-Terminalia-Adina*	37	47
11.	*Tectona-Terminalia*	15	45
12.	*Shorea-Buchanania-Cleistanthus*	14	39
13.	Montane Shola	8	35
14.	Tropical moist deciduous forest of NE India	–	33
15.	*Tectona-Terminalia-Adina-Anogeissus*	27	33
16.	*Cullenia-Mesua-Palaquium*	18	30
17.	*Terminalia-Anogeissus-Cleistanthus*	9	28
18.	*Tectona-Lagerstroemia-Dillenia-T. paniculata*	18	25
19.	*Memecylon-Syzygium-Actinodaphne*	12	25
20.	Subtropical evergreen sclerophyllous forest of NW Himalaya	–	23
21.	Subtropical *Pinus roxburghii* forest of Himalayas	–	19
22.	*Anogeissus-Terminalia-Tectona*	5	18
23.	*Toona-Garuga*	17	17
24.	*Terminalia-Anogeissus latifolia*	6	16
25.	Tropical evergreen forest of NE India	–	15
26.	Temperate coniferous forest of Himalayas	–	14
27.	*Shorea-Cleistanthus-Croton*	7	14
28.	*Hardwickia binata-Anogeissus latifolia*	12	13
29.	*Acacia catechu-Anogeissus pendula*	8	11
30.	Alpine scrub of Himalayas	–	9
31.	*Shorea-Dillenia-Pterospermum*	6	9
32.	Montane wet temperate forest of eastern Himalayas	–	6
33.	*Albizia amara-Acacia*	5	6
34.	*Anogeissus pendula-Anogeissus latifolia*	2	5
35.	*Manilkara-Chloroxylon*	0.2	5
36.	Alpine steppe of NW Himalayas	–	4
37.	Subalpine forest of Himalayas	–	4

38.	*Acacia senegal-Anogeissus pendula*	1	4
39.	*Acacia-Anogeissus latifolia*	0	0.3
40.	*Acacia-Capparis*	0	0
41.	*Prosopis-Capparis-Zizyphus-Salvadora*	0	0
42.	*Anogeissus latifolia-Chloroxylon-*	5	–
	Albizia amara		

Source: Gadgil & Meher – Homji, 1990

The data presented is the area under Plesioclimax and under Other Degraded Physiognomies of vegetation, as a percentage of the potential area of each vegetation type. (Note: This table is ordered in decreasing order of percentage area under all physiognomies; the symbol '-' denotes a lack of information.)

As can be seen, the status of different forest types in India is mixed, some having declined sharply in extent, others still relatively secure. Almost completely eliminated, along with much of their constituent biodiversity, are the dry zone vegetation types. For instance, the *Acacia-Capparis* Scrub, characteristic of the driest regions of the Deccan plateau of Andhra Pradesh, Karnataka, Maharashtra, Saurashtra in Gujarat, and the plains west of the Aravalli hills in Rajasthan, has been wiped out except for small patches like the Velavadar National Park in Gujarat. The Thorn Forest of the semi-arid zones of the Deccan plateau, once covered by *Acacia nilotica* and *Anogeissus latifolia*, is also almost exterminated. Other studies too have suggested that semi-arid and arid zones of India are the country's most severely degraded habitats (see, for instance, Daniels *et. al.*, 1990). But several Himalayan tracts are also severely threatened, including the Alpine steppe of the North-west Himalayas, the Sub-alpine forest of northern Uttar Pradesh and other parts of the Himalayas, and the Montane Wet Temperate Forest of eastern Himalayas. Indeed, if the stage of plesioclimax is considered to be the relatively intact stage of a forest type, only the Tropical Wet Evergreen Forest of Andaman and Nicobar Islands, and the semi-evergreen and moist deciduous *Persea-Holigarna-Diospyros* forest of the Western Ghats, with over 50% of their area under plesioclimax, can be considered secure.

Gadgil and Meher-Homji (1990) have also pointed out that almost all forest types have faced considerable fragmentation due to the spread of human settlements and agriculture, biotic and industrial pressures, and the invasion of exotics. According to their assessment, the median size of the largest remaining patch of each vegetation type is about 1100 sq km, compared to a potential median area of 49,000 sq km. Using the estimates of species loss given by scientists working on the problem of fragmentation in other countries (Soule and Wilcox 1980), Gadgil and Meher-Homji calculate that the process of habitat loss and fragmentation already set in motion in India is likely to lead to an extinction of over a third of the estimated 150,000 species of plants and animals in the near future. These estimates do not take into account the fact that a considerable amount of this diversity is not in forest areas, but in other habitat types; however, given the degradation and loss of the latter as well, the figure may not be too much off the mark. Even if it is somewhat of an over-estimate (as those challenging the Soule and Wilcox formulae may claim), the total loss is still of staggering magnitude.

Grasslands

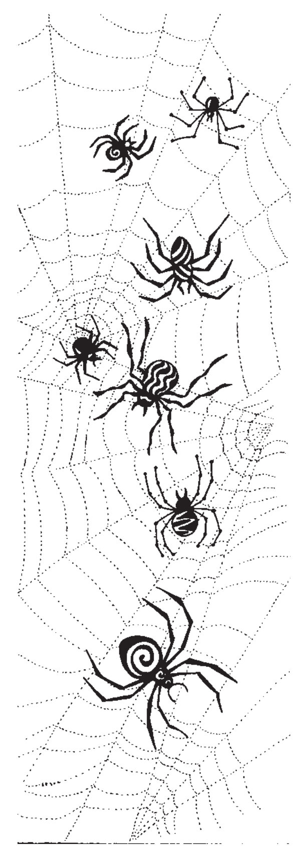
Diversity

Grasslands, variously called steppes, prairies, cerrados, pampas, savannahs, velds and rangelands in different parts of the world, are vegetation types with predominance of grass and grass-like species. In India, high-altitude grasslands of the Himalaya have been referred to as *marg* or *bugiyal*, and in Ladakh as *tsang*. Grasslands are plant communities with a more or less continuous layer of graminoids (grasses and grass-like plants), with or without a discontinuous layer of trees or shrubs. Grasslands are often associated with marked seasonality in precipitation, occurrence of fire and grazing by ungulates. Bamboo forests, though technically dominated by grasses, are not included under grasslands as they physically and in other respects resemble forests, and are usually mixed with a significant number of trees. Some research on this ecosystem was done by Yadava and Singh (1977), Singh and Gupta (1993), Pandey and Singh (1991), Melkania and Singh (1989) and Singh *et. al.*, (1983).

The grassland community builds an entirely different type of soil as compared to a forest, even when both start with the same parent material. Since grass-plants are short-lived as compared to trees, a large amount of organic matter is added to the soil. The first phase of decay is rapid, resulting in little litter, but much humus. Humification is rapid but mineralization is slow. Consequently grassland soils may contain 5-10 times as much humus as forest soils (Odum 1971).

As of 1992, the grassland coverage of the earth's terrestrial area was about 27% (Groombridge 1992). For India, Olson *et. al.*, (1983) put the cover of grass and shrub land at 12% of the total landmass; however, the Planning Commission (PC 1988) estimates grassland coverage at 3.7%, and scientists at the Indian Grasslands and Fodder Research Institute, Jhansi, give an estimate of 3.9%, or about 120 lakh (12 million) hectares (Singh and Misri 1993). The discrepancy in figures between Indian sources and Olson may not be due only to the difference in period of estimation (a full decade's gap), but also due to difference in definition (Olson has included shrubland in his category). The working figure for *this* report will be the 12 million ha given by Singh and Misri (1993).

The distribution of grasslands in India is quite uneven. For instance, in the western region, Rajasthan and Gujarat have 5.4% and 3.5% respectively of their land area under grasslands. In the eastern region, grasslands and pastures comprise less than 1% of the area, except in Sikkim, where they cover 13.3% of the land (IIPA 1996). The grasslands include such dissimilar ecosystems as the semi-arid pastures of the western part of the Deccan peninsula, the humid, semi-waterlogged tall grassland of the Terai belt, the rolling *shola* grasslands of the Western Ghats hilltops, and the high-altitude alpine pastures of the Himalayas.



The vast majority of grasslands in India – with the possible exception of those abutting the *shola* forests of the Western Ghats, those occurring in the alpine region of the Himalaya, and the *Lasiurus sindicus* grasslands of western India – owe their origin to destruction of forests and abandonment of cultivation, and have become widespread in a variety of habitats as seral communities maintained under the impact of such biotic factors as grazing, cutting and burning. Some ecologists point out, however, that the presence of grassland-dependent species like Nilgiri tahr, floricans etc. is evidence of the *natural* presence of grasslands (Asad Rahmani, personal communication 2002). Extensive areas in the sal belt, which have been prevented from regeneration into forest by fire, grazing, cutting and general deterioration of soil, now carry high savannah grasses, as on the higher *phantas* of Kheri and the *chaors* of Haldwani in Uttar Pradesh (both terms mean grass clearings within forests). Extensive grass downs are found in Nilgiri, Palni and Annamalai plateaus in South India, where grazing and burning are regularly practiced.

Marked differences in habitats (e.g. physico-chemical characteristics of soil, topography, etc.), age and mode of origin, and intensity of biotic processes all result in an array of very diverse grassland communities. Because of their occurrence within and adjoining forest and savannah lands, the grasslands are especially valuable habitats for wildlife, and support an extremely high population of livestock (*Natural Terrestrial Ecosystems Thematic BSAP*). For example, alluvial grasslands support hog deer, wild water buffalo, swamp deer or *barasingha* and Indian rhinoceros; arid grasslands support black buck, wild ass and *chinkara*; high-altitude grasslands support ibex, Tibetan wild ass, *tahr*, *goral*, *argali*, *urial*, *chiru*, Tibetan gazelle and *bharal*; secondary grasslands support black buck, *chital*, *gaur* and *chinkara*. Grasslands also occupy canopy gaps in open forests and form distinct associations. In arid and semi-arid regions, the association of grasslands with thorn forests and shrub vegetation often imparts a savannah-like aspect to the landscape. Grasslands are closely related to agro-ecosystems as they provide a rich gene pool, including species which serve as collateral hosts for many plant diseases, insects, and nematodes. Also, most of the agriculture in India depends on animal power, which gets its energy supply from the grasslands through grazing or stall-feeding of dried and cured herbage.

On the basis of a country-wide survey of grasslands in India, Dabadghao and Shankarnarayan (1973) have recognised five broad grass cover types:

1. **Sehima-Dichanthium Type:** Spread over peninsular India, southwest Bengal, southern Bihar, and the southern hilly plains of Uttar Pradesh and Rajasthan, this cover type consists of 24 perennial grasses, several annual grasses, and 129 other herbaceous species including 56 legumes. Key species include *Sehima nervosum*, *Heteropogon contortus*, *Dichanthium annulatum* and *Themeda triandra*. As Rahmani (1992) notes, *Sehima-*

Dichanthium cover occupies the largest area of grasslands in the country. The rainfall varies from 300 mm in Kachchh to 6,350 mm in the Western Ghats. The best development of *Sehima-Dichanthium* cover is seen with a rainfall of 500 to 900 mm. Therefore, the semi-arid tracts of Maharashtra, Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu are typical examples of this cover type. When the *Sehima-Dichanthium* cover is subjected to grazing, these communities are replaced by *Chrysopogon* and *Bothriochloa* communities respectively. Rollapadu grassland of Andhra, Gnanganga dry grassland of Buldhana district in Maharashtra, Sailana grassland in Ratlam district of Madhya Pradesh and Velavadar salt grassland of Gujarat are some of the important sites in this zone. As these grasslands are not at the climax stage and are affected by various edaphic factors, floral species composition varies. The floral composition also depends on the degree of protection to the grassland from fire and livestock grazing.

2. **Dichanthium-Cenchrus-Lasiurus Type:** Spread over northern parts of Gujarat, Rajasthan, western Uttar Pradesh, Delhi, and semi-arid Punjab, this type contains 11 perennial grasses, 19 legumes and 26 other herbaceous plants. Key species include *Dichanthium annulatum*, *Cenchrus ciliaris*, *C. biflorus*, *Lasiurus sindicus* and *Atylosia scarabaeoides*. The rainfall ranges from about 100 mm in the extreme west to about 750 mm towards the eastern boundary of this cover type. Several plant communities occur, depending upon the habitat conditions and intensity of biotic pressure. Rahmani (1992) notes that one of the largest extant grasslands of the country is present in this area – the Sewan (*Lasiurus sindicus*) grassland in Jaisalmer, which is 170 km long and 25 to 35 km wide. Another important grassland is Banni in Kachchh district.
3. **Phragmites-Saccharum-Imperata Type:** Spread over the alluvial plains of the Ganga and the delta plains of West Bengal and the Assam Valley, this consists of 19 perennial grasses, 16 legumes and 40 other herbaceous plants. Key species include *Phragmites australis*, *Saccharum spontaneum*, *Imperata cylindica* and *Desmostachya bipinnata*. The water table is high and soil is poorly drained. Rainfall is moderate (500 mm) to high (up to 5000 mm) in this region. Though this region contains some of the wet grasslands of the Terai and Bhabar, some areas are semi-arid, especially in southern Uttar Pradesh and Bihar due to the north-south moisture gradient. The wet grasslands of the seasonally flooded valleys of the Terai and northeast India are very ancient, which is proven by the presence of diverse herbivore fauna: elephant, rhinoceros, *barasingha* and hog deer, indicating the grassland's stable history (Rahmani 1992).
4. **Themeda-Arundinella Type:** Covering the northern plains to the outer humid hills of the Himalayas, in Assam, Manipur, West Bengal, Uttar Pradesh, Punjab, Himachal Pradesh, and Jammu and Kashmir, this type contains 16 characteristic perennial grasses and 34 other herbaceous plants including 9 legumes. Key species include *Themeda anaethera*, *Arundinella bengalensis*, *Bothriochloa bladhii*, *B. pertusa*, *Heteropogon contortus* and *Chrysopogon fulvus*.
5. **Temperate-Alpine Type:** Spread over the higher altitudes of Jammu and Kashmir, Uttaranchal, Himachal Pradesh, West Bengal, and Assam, this contains 35 characteristic perennial grasses, 6 legumes, and 62 other herbaceous plants. Key species include *Dactylis glomerata*, *Bromus inermis*, *Festuca pratense* and *Themeda anaethera*. Based on the altitude gradient, several community types have been recognized. In the Central Himalaya, five distinct types of *bugiyals* (high-altitude grasslands) have been identified locally by the semi-nomadic *bhotias* (Melkania 1983, Melkania and Tandon 1988). These are:

   i. *Dug or dudh bugiyal* – dominated by *Euphorbia stracheyii* (*Dudh bug*), common on drier slopes;
   ii. *Bas bugiyal* – dominated by *Sassurea graminicola* (*Bas bug*) on east facing slopes above 4200 m elevation;
   iii. *Mot bugiyal* – dominated by *Danthonia cachemyriana* (*Mot bug* or *phiji ghas*) and *Phleum alpinum* on slopes above 3200 m;
   iv. *Dhania bugiyal* – predominated by *Cortia lindleyi* (*Dhania bug*) in shady and marshy locations; and;
   v. *Dhati bugiyal* – characterized by preponderance of *Kobresia* spp. (*Dhati bug*) between 3000 to 4000 m.

In India, grasses form the largest family of flowering plants. Out of an estimated 17500 species of flowering plants, about 1200 are grasses. About 360 grass taxa (almost 30%), are endemic to India. 172 endemics occur in the peninsular region, 56 in the north-east, 30 in the north-west, 5 in the western arid regions, 12 in the lower Gangetic plain, 4 in the Andaman and Nicobar Islands, and 50 spread over more than one of the above regions. It has been estimated that presently about 1055 species occur naturally in India and about 130 other species have been introduced; some of the latter are now naturalised (Jain 1986).

Current Status

(*see also Section 5.1.1.1*)

Unfortunately, due to a greater neglect than even that suffered by forests, the status of grasslands is not so well known. Worldwide, it is estimated that from an original coverage of about 40% of the earth's land surface, grasslands have come down to anything between 16 and 27% (Groombrige 1992). Parallel figures for India are not available, largely because no base data exists for grassland coverage in the past, but also because grassland monitoring has been virtually non-existent even in the recent past. It is well-known that the semi-arid grasslands of western India are severely threatened by 'development' projects (like the Indira Gandhi Canal) and overgrazing, and are now restricted to a few small protected tracts only. This is also the case with the tall swamp grassland of the *Terai* belt, which has been seriously threatened with fragmentation and conversion to various human-dominated land uses. Because of the large livestock population, most of the grasslands remain under severe grazing pressure throughout the year. Many areas, especially the high-altitude grasslands and the grasslands of the arid and semi-arid regions, suffer from seasonal grazing stress caused by migrating livestock.

Box 4.1 Rock Outcrops

India has several types of rocky habitats dominated by herbaceous or shrubby vegetation in 'natural' or 'climax' stages. These 'rock outcrops' can be defined as portions of mostly freely-exposed bedrock protruding above the soil level due to geological activities. They are prominent growth sites for '**azonal plant communities**', which are characterized by particularities of their underlying substrate with soil typically lacking.

The most prominent rock outcrops in India are as follows: **Lateritic plateaus**, common in western India in high-rainfall areas. **Cliffs** form a distinct feature in all the hilly areas, e.g. in the Western Ghats. **Inselbergs** are isolated rock outcrops rising abruptly above their surroundings and are seen throughout south India and Bihar. **Outcrops of basalt**, **limestone**, **sandstone** and **quartzite** are locally common in certain parts.

Despite the fact that rock outcrops form striking landscape elements throughout India and often have an immense cultural and religious importance, not much is known about their floristic and faunistic diversity. In general, tropical rock outcrops (in particular inselbergs; see Porembski and Barthlott 2000), have only relatively recently become objects of interest to biologists.

Rock outcrops are characterized by extreme micro-climatic conditions and form centers of diversity for highly specialized plant life-forms which are well adapted to freely exposed, seasonally dry growth sites. Some of the plant adaptive strategies commonly observed on rock outcrops are: carnivory/insectivory, annuals, poikilohydry (desiccation tolerance), geophytes, lithophytes, succulents as well as hydrophytes and mat-forming species. Using physiognomic criteria, a number of habitat types can be distinguished (e.g. cryptogamic crusts, ephemeral flush vegetation, monocotyledonous mats, rock pools). **Based on preliminary observations it can already be concluded that the flora of rock outcrops in India is clearly distinct from that of other regions**. The highly specific nature of adaptations of the organisms have led to a high percentage of endemism in certain regions (e.g. Western Ghats). The fauna associated with rocky habitats include insects, fish, amphibia, reptiles, birds and small mammals. Biodiversity studies of rock outcrops in other parts of the world indicate that outcrops, particularly inselbergs, are like 'terrestrial islands'.

Rock outcrops feature prominently in human landscapes. Most inselbergs have temples on the hill tops (the best-known example is Shravanbelgola shrine in Karnataka). Natural rock pools formed on inselbergs and plateaus are important in village water management. Many rocky outcrops are centers for religious, aesthetic or nature tourism.

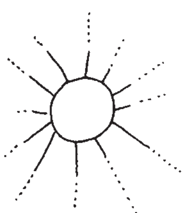
Although floristic inventories are available for a few rock outcrops, they are mostly not described as separate ecosystems. Owing to the lack of published literature, a comparison with global biodiversity studies of rock outcrops is impossible at present.

Source: Porembski and Watve 2003

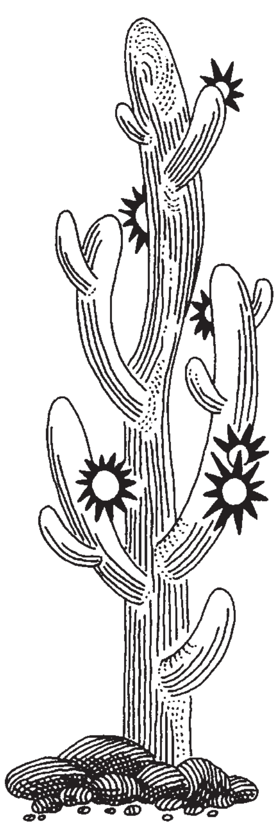
Deserts

Diversity

Deserts (as distinct from desertified areas) are natural ecosystems characterised by very low rainfall (<600 mm), aridity, and very sparse presence of vegetation. Though appearing to be lifeless at first glance, deserts can harbour an astonishing and unique diversity of species, and biological communities of high conservation value. India broadly has three kinds of deserts: sandy warm desert in the far western region of Rajasthan; salt desert in the western region of Gujarat; and cold desert in the trans-Himalayan region of Ladakh in Jammu and Kashmir and Lahaul-Spiti in Himachal Pradesh.



The **Great Indian Thar Desert** is an important bioregion of Rajasthan comprising about 61 percent of the state's total geographical area. It is one of the most biologically and culturally diverse deserts of the world, and houses distinct and unique ecosystems, landscapes and species of plants and animals. It is characterised by geomorphic forms and landscapes such as dunes, *magras*, *dhands* and *bhakars*, each with a distinct ecology of its own. It is an extension of the Sahara desert, through the Arabian and Persian deserts. It extends from Punjab through Haryana and Rajasthan to Gujarat. The desert results from the dryness of the prevailing monsoon winds, which do not bring sufficient rain to keep the region moist. The desert sands cover early Pre-Cambrian gneiss (granite-like metamorphic rocks formed in the oldest geologic era, which began 3.8 billion years ago), sedimentary rocks from about 2.5 billion to 570 million years old, and more recent material deposited by rivers (alluvium). The surface sand is aeolian (wind-deposited) sand of the Quaternary Period (the most recent geologic period, which began about 1.6 million years ago). The desert presents an undulating surface, with high and low sand dunes separated by sandy plains and low, barren hills, or *bhakars*, which rise abruptly from the surrounding plains. The dunes are in continual motion and take on varying shapes and sizes. Older dunes, however, are in a semi-stabilized or stabilized condition, and many rise to a height of almost 500 feet (150 m). Several saline lakes, locally known as *dhands*, are scattered throughout the region (*Rajasthan State BSAP*). Comprehensive studies on Faunal Diversity in the Thar desert have been done by Ghosh *et. al*., (1996). (Detailed information on the floral and faunal diversity in the Thar desert is discussed in the *Rajasthan State BSAP*).



Three types of major terrestrial habitats are recognised in the Indian desert in relation to flora and fauna (Bhandari 1990; Gupta and Prakash 1975; Saxena 1972):

Sandy: The sandy habitat occupies by far the largest area of the desert. Depending upon the soil type and topography, it can be further subdivided into (i) Younger alluvial plain, (ii) Older alluvial flat plains, (iii) Older alluvial hummocky plains, (iv) Saline flats, and, (v) Sand dunes. Mixed xeromorphic vegetation with trees such as *Tecommela undulata*, *Prosopis cineraria*, *Acacia nilotica* and *Salvadora oleoides*, shrubs like *Calligonum polygonoides* and *Haloxylon salicornicum*, forbs like *Tephrosia purpurea*, *Indigofera* spp., *Crotalaria burhia*, *Aerva tomentosa*, *Aerva persica* and grasses like *Cenchrus biflorus* and *Crotalaria ciliaris*, *Aristida* spp., is common.

Hills and Rocky Outcrops: Such outcrops are scattered all over the desert region. *Anogeissus pendula*, *Acacia senegal*, *Euphorbia caducifolia*, *Maytenus emarginatus*, *Commiphora wightii* and *Cordia garaf* are common trees, and *Sehima nervosum*, *Cymbopogon jawarancusa*, *Hackelochloa granularis*, and *Dichanthium annulatum* constitute the ground flora.

Ruderal: This habitat is associated with villages which are scattered all over the desert, over rocky outcrops, sandy plains, sand dunes, saline flats and river banks. The luxuriant trees such as *Azadirachta indica*, *Tamarindus indica*, *Prosopis cineraria*, *Acacia* spp. *Ficus* spp. and *Salvadora oleoides* are the major species found in these regions.

The **Salt Desert of the Rann of Kachchh** is distinguished from the Thar desert by its exceptional salinity (*Rann* in the local language means salt desert), caused by seasonal inundation by the sea into a vast area inland. The extraordinary intermingling of saline, marshy and coastal desert ecosystems found in the Rann is perhaps the only one of its kind in the world.

The Great Rann of Kachchh and the Little Rann of Kachchh, with an area of about 16780 sq km and 5180 sq km respectively, constitute the entire Rann of Kachchh. The average altitude is about 15 m above mean sea level, and it thus appears like a table-top surface. Ecologically, it represents one of the largest seasonal saline wetland areas, having water depth ranging from 0.5 to 1.5 m. The Little Rann of Kachchh is world famous for the last remaining population of the endemic Wild Ass, and almost the entire Little Rann is covered under Wild Ass Sanctuary (WAS) to protect this species (*Kachchh Sub-state BSAP*). The Rann fills up with clay and silt discharged from several seasonal rivers originating in the Aravalli Hills: Luni, Rakhari, Bhukhi, Banas, Nachhu, Demi, etc. These rivers flow through the Rann, and spread out into the vast floodplain in the monsoons to add to the inundation by the sea. The result is a massive, shallow sheet of water, 1-7 feet deep (Sinha and Goyal 1993), which covers the area for 2-3 months of the year. The only parts of land which escape this inundation are the low hillock islands (*bets*) of non-saline soil, sprinkled throughout the desert, which become the refuge of a large number of animals as well as the nomadic herding community of Maldharis during the floods. These *bets* harbour some of the few concentrations of vegetation in the Rann.

Box 4.2 Vertebrate Fauna of the Salt Desert

Common fishes – *Cirrhinus mirgala*, *Lobeo boggut*, *L. fimbriatus*, *L. potail*, *Punitus arulius*, *P. Sarana*, *Sciaena* spp, *Sciaenoides* spp., *Polynemus* spp., *Polynemus indicus*, catfishes, pomfrets, elasmobranchs, etc.

Common amphibians – Indian bullfrog (*Rana tigrina*), Skipper frog (*R. cyanophlyctis*), Cricket frog (*R. limnocharis*), Green frog (*R. hexadactyla*), *Bufo stomaticus*, Ornate frog (*Microhyla ornate*).

Common reptiles – Banded gecko (*Cyrtodactylus kachhensis*), Brook's gecko (*Hemidactylus brooki*), Bark gecko (*H. leschenaulti*), Northern house gecko (*H. flaviviridis*), Fan-throated lizard (*Sitana ponticeriana*), Common garden lizard (*Calotes versicolor*), *Agama agilis*, Short-tailed agama (*A. minor*), Little skink (*Mabuya macularia*), Common skink (*M. carinata*), Skink (*Ablepharus grayanus*), Snake skink (*Riopa punctata*), Yellow-bellied mole skink (*Eumeces taeniolates*), Sandfish (*Ophiomorus raithmahi*), Indiana fringe-toed lizard (*Acanthodactylus cantoris*), Jerdon's snake-eye (*Ophisops jerdoni*), *O. microlepis*, Common Indian monitor (*Varanus bengalensis*), Indian flap-shell turtle (*Lissemys punctata punctata*), Chameleon (*Chamaeleon zeylanicus*), Jerdon's worm snake (*Rhamphotyphlops braminus*), John's earth boa (*Eryx johni*), Checkered keel-back (*Xenochrophis piscator*), Leith's sand snake (*Psammophis leithi*), Himalayan sand snake (*P. condaranus*), Common Indian krait (*Bungarus caeruleus*), Indian cobra (*Naja naja*), and Saw-scaled viper (*Echis carinatus*).

Common birds – Black Stork (*Ciconia nigra*), Glossy Ibis (*Plegadis falcinellus*), Flamingo (*Phoenicopterus ruber roseus*), Little brown dove (*Streptopelia senegalensis*), Indian ring dove (*S. decaocta*), Crow pheasant (*Centropus sinensis*), Jungle crow (*Corvus macrorhynchus*), Blue rock pigeon (*Columba livia*), Roseringed parakeet (*Psittacula krameri)*, Common myna (*Acridothares tristis*), Grey partridge (*Francolinus pondicerianus*), Common babbler (*Turdoides caudatus*), Black drongo (*Dicrurus adsimilis*), and Hoopoe (*Upupa epops*).

Common mammals – Long-eared hedgehog (*Hemiechnus auritus*), Pale hedgehog (*Paraechinus micropus*), Large rat-tailed bat (*Rhinopoma microphyllum kinneari*), Sheath-tailed bat (*Tophozous kachhensis*), Tomb bat (*Tadarida aegyptica*), Indian pigmy pipistrelle (*Pipistrellus minus minus*), Indian hare (*Lepus nigricollis*), Indian gerbille (*Tatera indica*), Indian desert gerbille (*Meriones hurrianae*), Indian bush rat (*Golunda ettioti gujerati*), and Softfurred field rat (*Millardia meltado*), *Suncus murinus sindensis*, *Rhinopoma hardwickei hardwickei*.

Source: Baqri 1993, Baqri and Bohra 2001

The **Cold Desert**, sprawled over a vast area north of the Himalayan ranges, is an ecosystem of exceptionally low temperatures (down to -75˚C) and rainfall (500-800 mm annually). It forms a plateau at a height of 4,500 to 6,000 meters above mean sea level, and is encompassed by the Trans-Himalayan Biogeographic Zone of Rodgers and Panwar (1988). This zone extends into the Tibetan plateau, to cover an area of 2.6 million sq km, from which originate the great river systems of the Indus, Sutlej, Brahmaputra and Yangtze.

In India, cold deserts cover a vast area of 1,09,990 sq km, about 87,780 sq km in Ladakh (Kashmir), and 22,210 sq km in Lahaul-Spiti (Himachal Pradesh). Lahaul and Spiti is delimited by the Pir Panjal range, the Great Himalayan range, and the Zanskar range. The Great Himalayan range with a mean elevation of 5,500 m extends from Kunzam range to Baralacha and Pin Parvati range, separating the Chamba-Beas basin from the Sutlej-Spiti basin around Pooh, and pierced by the Sutlej at Kalpa. The Zanskar range, beyond the Great Himalayan range extends from Kinnaur, bordering China, and separates Spiti from Kinnaur and Tibet, which is pierced by the Sutlej at Shipkila. The Cold Deserts in Himachal Pradesh cover about 35 percent of its geographical area (*Lahaul-Spiti-Kinnaur Sub-state Site BSAP*). The Great Himalayan Range divides the better-watered mountain systems of the Himalayas from this cold arid desert area, which itself contains three mountain ranges – Zanskar, Ladakh and Karakoram. To the east, the Ladakh and Zanskar ranges diminish towards the southern margin of the Tibetan plateau and the beginning of an internal drainage marsh and lake system. To the north, much of the area is above the snowline. Throughout the area, precipitation is mostly in the form of snow. Ladakh constitutes the bulk of the Trans-Himalaya. It is distinguished by highly evolved life forms, including a variety of aromatic and medicinal plants, several wild relatives of domesticated plants (barley, gooseberry, garlic) and animals (four species of wild sheep and goats) and a charismatic mega-fauna, still preserved in its entirety, unlike in most other parts of the world. Ladakh is a repository of vibrant traditions and indigenous knowledge which have evolved in harmony with its natural wealth (*Ladakh Sub-state BSAP*).

Box 4.3 Flora of the Cold Desert

Nichar, Sangla and Kalpa areas of Lahaul-Spiti-Kinnaur are dominated by tree species like *Cedrus deodara*, *Pinus wallichiana*, *Picea smithiana*, *Abies pindrow*, *Taxus wallichiana*, *Quercus floribunda*, *Q. semecarpifolia* and *Q. ballot* (Peo and Kalpa region). Lahaul and Kinnaur are greener than Spiti. Mini Manali at Udaipur has a thick forest patch of Deodar (*Cedrus deodara*). Vast tracts of hill slopes are covered by *Juniperus macropoda* between Udaipur and Keylong (*Lahual-Spiti-Kinnaur Sub-state BSAP*).

Along river courses and depressions are *Salix daphnoides*, *Myricaria elegans* and *Morus alba* scrub. Slopes covered with perpetual snow have plants like *Polygonum affine*, *Potentilla bifurca*, *Pedicularis hookeriana*, *Parnassia palustris*, *Geranium himalayense*, *Bupleurum longicaule*, *Stachys sericea*, *Brachyactis roylei*, *B. pubescens*, *Origanum vulgare*, *Gentiana decumbens*, *Anaphalis nubigena*, *Galium boreale*, *Mentha sylvestris*, *Euphrasia vulgaris*, *Lactuca tatarica*, *Cirsium arvense* and *Swertia thomsonii*. Eastwards, hardy species such as *Carex nivalis*, *Oxyria digyna*, *Polygonum corydalis*, *Draba lasiophylla*, *Sedum ewersi*, *Saxifraga sibirica*, *Allardia tomentosa* and *Dianthus antolicus* thrive, being representative of Tibet up to 5,700 m. Other plants found are *Oxytropis minima*, *Potentilla multifida*, *Nepetica tibetica*, *Plantago minima*, *Delphinium brownianum*, *Lychnis macrorrhiza*, *Atriplex crassifolia*, *Polygonum sibiricum*, *Sedum tibeticum*, *Arabis tibetica*, *Braya thomsonii* and *Corydalis crassifolia*. The plants are prostrate with small leaves, growing in rosettes due to high winds. At Nubra and Leh, plants like *Acantholimon lycopodioides*, *Myricaria elegans*, *Lindelofia anchusoides*, *Scopolia praelta*, *Echinospermum sedowski*, *Tanacetum artemisioides*, *Nepeta floccosa*, *Arnebia guttata var. guttata*, *Potentilla nivea var. himalaica*, *Euphorbia tibetica*, *Lancea tibetica*, *Iris ensata*, *Carum carvi*, *Lepidium apetalum*, *Astragalus ciliatus*, *Stachys tibetica*, *Draba glomerata* grow along with trees like *Salix alba*, *S. daphnoides*, *Populus deltoides* and *Juglans regia var*. *kumaonia* which are cultivated (Rau 1975; Puri *et. al.*, 1983).

The faunal diversity of cold deserts is quite distinctive from other deserts or high-altitude areas. The high-altitude insect life of the Himalaya as a whole is remarkable for the very high species endemism in all groups – over 70% of the species restricted to high elevations are strictly endemic (Mani 1974). The area has the richest wild sheep and goat community in the world, with 8 distinct species and sub-species (Rodgers and Panwar 1988). Also distinctive is the fact that, perhaps as an adaptation to the fragility and sparseness of the ecosystem, populations of animals live at low densities and often have extensive ranges involving considerable altitudinal migration. Many species congregate in valley areas during the harsh winters (Rodgers and Panwar 1988).

The cold desert harbours the Tibetan wild ass or kiang (*Equus hemionus kiang*), a close relative of the Indian wild ass (*Equus hemionus khur*) found in the Rann of Kachchh. Other distinctive mammals include snow leopard (*Uncia uncia*), wolf (*Canis lupus*), Himalayan marmot (*Marmota bobak*), long-tailed marmot (*M. caudata*), wooly hare (*Lepus oiostolus*), wooly flying squirrel (*Eupetaurus cinereus*), yak (*Bos grunniens*), wild goats (*Capra hircus*), shapu or urial (*Ovis orientalis*), Great Tibetan sheep or Nayan (*Ovis ammon hodgsoni*), Marco Polo's sheep (*Ovis ammon polii*), chiru (*Panthelops hodgsonii*), Tibetan gazelle (*Procapra picticaudata*), bharal or blue sheep (*Pseudois nayaur*), ibex (*Capra ibex*), and Kabul Markhor (*Capra falconeri megaceros*). Other species included are Himalayan weasel (*Mustela ermenia*), beach marten (*Martes foina*) and Tibetan polecat (*M. putorius*). The severely endangered black-necked crane (*Grus nigricollis*) is found in Ladakh and the bar-headed goose (*Anser indicus)* breeds here.

Current Status

(*see also Section 5.1.1.1*)

As is the case worldwide, no overall estimate is available on the loss of each of India's desert types, though it is clear that such loss has taken place, especially in the Indian (sand) desert. In the estimation of Gadgil and Meher-Homji (1990), almost none of the hot desert of western India remains intact, but this could be an overstatement. The Indira Gandhi Canal changed the soil moisture, soil texture and vegetation composition, threatening the indigenous biodiversity of the desert ecoystem (Baqri and Kankane 2001). Certainly parts of the salt desert are still relatively untouched, though many of the sparsely wooded stretches along the Rann periphery and on the bets have been transformed into exotic *Prosopis* scrub. *Prosopis juliflora* has also encroached upon three ecologically important areas in Kachchh, the Narayan Sarovar Sanctuary, Khadir island and the Wild Ass Sanctuary in the Little Rann of Kachchh. Another threat to the biodiversity of the Little Rann of Kachchh is the uncontrolled expansion of salt pans (*Kachchh Sub-state BSAP*). The salt desert is also seriously threatened by extensive salt manufacture, hydrological changes caused by irrigation (including severe threats by the upcoming Narmada project canals) and other problems (*Kachchh Sub-state BSAP*). In the cold desert regions of Ladakh and Lahual-Spiti-Kinnaur, the degradation of biodiversity is mainly due to the rapid developmental activities in the recent past. Loss of biodiversity in these regions is also due to destruction of habitats for construction of large hydro-electric dams, roads and buildings, thereby leading to deforestation and excessive landslides. Due to extreme and prolonged winters, heavy demand for fuelwood takes a toll of existing vegetation, shrubs, bushes and perennial species along with their roots. Rapid tourism development activity in Ladakh region is another cause of concern for the loss of biodiversity in the region (*Ladakh Sub-state BSAP* and *Lahual-Spiti-Kinnaur Sub-state BSAP*).

Box 4.4 Hotspecks

Hotspecks are comparatively tiny areas of wild habitat containing large clusters of species (as distinct from the larger 'hotspots'), which are usually not found in such diversity or density in other areas. Wilson (1992) in his book *Diversity of Life* emphasizes the importance of recognising small areas, sometimes nichés that contain very high concentrations of 'lower' life forms such as fungi, invertebrates, lower vertebrates and lower plants. These places could lie either within a broader conservation area or outside. Such species-rich areas are critical to conservation of biodiversity for they could be ideal breeding-grounds from where species disperse to other areas.

Mangroves are a good examples of hotspecks, not only for their relatively small areas, but also for their ability to support varied life forms which include fungi, invertebrates, algae, fishes (estuarine and marine), angiosperms, sea grasses, and many other forms. Mangroves on the east coast do not come under the hotspots and are ideal candidates to be projected as hotspecks, and therefore as critical conservation areas. The Sundarbans, not currently in any hotspot, could be included under the hotspeck banner, though of course it is quite extensive in nature.

Dr. P.T. Cherian of the Zoological Survey of India coined the term 'Hotspeck' and listed from his and his colleagues' experience some places within the country that could be termed hotspecks (Cherian 1996).

1. A small shrubby speck around a spring at Kolasib in Mizoram – ca. 5 sq m, more than 325 species of insects observed in less than 7 hours – 25 species and 2 genera new to science.
2. Nangpo forest in Meghalaya – 1 sq km, 350 species of insects collected in a day.
3. Andhari Khola in Darjeeling district, West Bengal – 25 sq m.
4. Thenmala forest in Quilon district, Kerala – 50 sq m.
5. Muzhiyar forest in Pathanamthatta district in Kerala – 100 sq m.
6. Junction of Kosi river and its tributaries – A few hundred sq m – 446 primary freshwater fishes of India
7. Gandak – Ganges junction – few hundred sq m.

8. Achennkovil – Pamba junction – 200 sq m. – many crustaceans, fishes and aquatic life
9. Athimudu in river Pamba – 200 sq m. in summer.
10. Hogenakkal waterfall in the river Kaveri.
11. Wetland area of Keoladeo NP at Bharatpur – 8.5 sq km – for cladocerans.

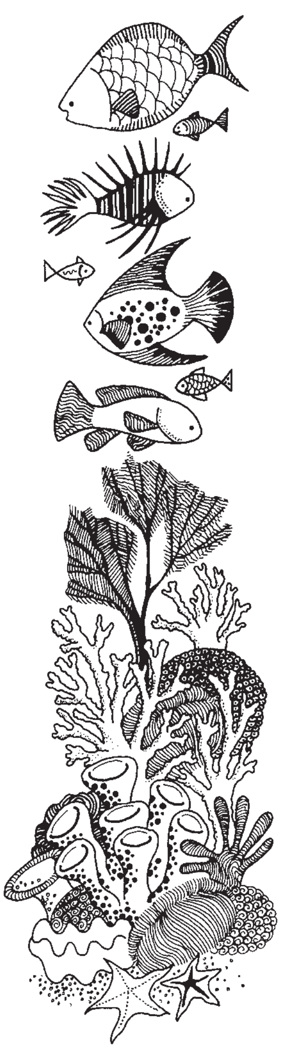
Some other good examples of hotspecks are the Kempholey forests in Karnataka (for rich herpetofaunal diversity along with other 'lower' forms) and the Valley of Flowers.

Source: Wilson 1992; Cherian 1996; Sanjay Molur, personal communication 2002

4.1.1.2 Natural Aquatic Ecosystems

India has a rich variety of wetland and aquatic habitats, ranging from small streams and village ponds through large lakes and reservoirs, some of the longest rivers in the world, coastal lagoons, estuaries and backwaters, the unique Rann of Kachchh, coral reefs and mangroves, to open coastal and oceanic waters. To this must be added the numerous human-made wetland waterbodies, like reservoirs behind dams and impoundments, salterns and aquaculture ponds. Notwithstanding this enormous variety, India's wetlands can be grouped, based on salinity, into two major categories – marine, and brackish or freshwater, within each of which there are several different ecosystems.

Marine Ecosystems



Diversity

India has a long coastline, estimated to range between about 8000 km (Ramakrishna and Venkataraman 2001) and 8130 km (CMFRI 1998-99), the discrepancy arising probably because of the inclusion or otherwise of the coastlines of all offshore islands. India occupies the tenth place in terms of coastline length of all maritime countries and seventh place in terms of the extent of the Exclusive Economic Zone[1] (2.02 million sq km) adjoining the continental region and the offshore islands.

The long coastline and the tropical climate favour a multitude of coastal and offshore marine ecosystems. The most important among them, in terms of abundance of biological components as well as their use, are the coastal waters. The width, and hence the spread, of the coastal waters has been defined variously. Geomorphologically, this comprises the region from the shoreline up to the continental shelf.[2] The Land-Ocean Interaction in the Coastal Zone (LOICZ) project, that evaluates the impacts of land-borne activities on marine ecosystems, defines the coastal zone as the area comprised between the shoreline and the 200 m depth line. In terms of exploited fisheries, the coastal zone is generally taken as extending up to the 50 m depth line, which is essentially an operational definition, as the endurance of the traditional crafts can take them only this far. As the conventional fisheries extend, irrespective of the width of the shelf, up to the shelf break in almost all Indian states, the shelf area is considered here as representing the coastal zone. This covers an area estimated between 0.4 and 0.5 million sq km (CMFRI 1998-99).

Oceanic waters make up the remainder of the Exclusive Economic Zone and cover an area of about 1.5-1.6 million sq km. Besides being differentiated from the coastal regions by the shelf break, oceanic waters are relatively low in nutrients and biological productivity. The oceanic environment has often also been thought to be low in biological diversity but this stems from lack of sampling and analysis rather than a true paucity of species. Estimates (made from subjective, and hence possibly erroneous, extrapolations) suggest that the number of bottom-dwelling species in the deep sea alone may be between half a million to 10 million (May 1992). Even the lower estimate is double the number of species known to science today.

Ecosystems supported on the coast are estuaries,[3] coral reefs,[4] mangroves,[5] sea grass beds, sandy beaches, rocky beaches, lagoons and salterns. *Table 4.7* gives the area covered by various types of coastal marine ecosystems, compiled from remote sensing data (Garg *et. al.*, 1998; Bahuguna and Nayak 1998). Among these, the estuaries, mangroves and coral reefs are important in terms of ecosystem values and economic uses, besides being critical habitats.

Table 4.7 Extents of some Coastal Marine Ecosystems in India

S.No.	Ecosystem type	Area (sq km)
1.	Estuaries	1540
2.	Lagoons	1564
3.	Creeks	192
4	Back water	171
5.	Tidal/Mud flat	23621
6.	Coral reefs	2330
7.	Mangroves	3401
8.	Sandy beaches/bars/spits	4210
9.	Rocky coasts	177
10.	Salt marshes	1698
11.	Salt pans	655
12.	Aquaculture ponds	769
13.	Other vegetation (including sea grass beds)	1391

Source: Garg et. al.,1998, Bahuguna and Nayak 1998

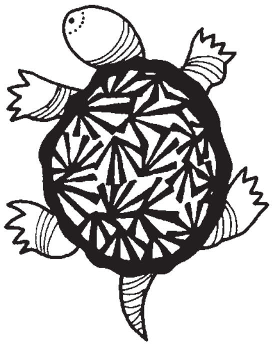
As the estuaries are regions of confluence between the coastal seas and rivers, they are characterized by spatial and/or temporal gradients of salinity ranging from freshwater to seawater. While major estuaries on both the coasts retain the estuarine characteristics throughout the year, most of the minor ones alternate in character between being true estuaries (during wet periods) and tidal creeks (during dry months). Some estuaries form extensive backwater and lagoon systems (e.g. Cochin backwater in Kerala, Pulicat lake in Andhra Pradesh and Chilika lake in Orissa) before joining the sea. The more than 100 major and minor estuaries of India occupy an area of about 1540 sq km, their backwaters 171 sq km and their lagoons 1564 sq km. Several estuaries also sustain vast tidal mudflats, mangroves, marshes and other vegetated wetlands.

Mangroves in India cover an estimated area of 3401 sq km as of 1999, and extend over 380 km of the mainland coast and 260 km of the Andaman and Nicobar island coasts. It is likely that these numbers are not precise – a near threefold increase in the mangrove area of Gujarat, from 397 sq km in 1991 to 1031 sq km in 1999, even making allowance for a re-plantation over 160 sq km, seems improbable. The cause for this discrepancy lies in the non-inclusion of the mangroves in the creeks of Rann of Kachchh in the early estimates but their inclusion in the later ones (Anjali Bahuguna, personal communication 2002). The Sundarbans is a unique mangrove ecosystem in West Bengal. It is one of the most biologically productive and taxonomically diverse ecosystems of the Indian Sub-continent (*see Box 4.5*) (*West Bengal State BSAP*).

Coral reefs occur as fringing reefs around the islands in the Gulf of Kachchh, the Gulf of Mannar, Andaman and Nicobar, and as atolls in Lakshadweep. Based on satellite imagery, the area covered by reefs and reef-associated structures and ecosystems has been estimated as 2330 sq km (Bahuguna and Nayak 1998). This would, in all probability, be an underestimate, because of the difficulties of detecting coralline structures below one optical length without reliable ground truths. For example, large submarine banks with corals, like the Passas de Pedro, Sesostris Bank and Cora Divh in northern Lakshadweep generally do not get included because they do not 'show up' in satellite images, though dredging over these banks did yield several species of live corals.

Wafar (1986) estimated a total reef area of about 18,000 sq km for the Indian reefs; that includes surface reefs, their lagoons and the submerged banks. A combination of ground truth and improved processing of satellite images of the Andaman and Nicobar reefs (Turner *et. al.*, 2001) gave an estimate of 11,075 sq km, which was remarkably similar to that estimated earlier by Wafar for this reef region (11000 sq km).

Apart from the four major reef regions, corals are also found in patches in the intertidal region along the west coast of India. These corals are remnants of the drowned reefs on the west coast and comprise no more than 8



species at present (Wafar 1990).

Sea grass beds constitute another productive coastal marine ecosystem. As the name implies, these are large meadows formed by the prolific, and often monospecific, growth of sea grasses (which are the only known flowering plants in the sea). The sea grass beds are generally associated either with coral reefs, where they are often found in the lagoons, or with shallow littoral areas with low freshwater influx, e.g. Gulf of Mannar and Gulf of Kachchh. The total extent of sea grass beds is about 32 sq km. The ecological importance of sea grass beds lies in their role as exclusive source of food for the sea cow (*Dugong dugong*).

Two human-made coastal ecosystems – salt pans (655 sq km) and aquaculture ponds (769 sq km) – deserve particular attention. Both these have had their ecological characteristics altered substantially by human interference and hence have a restricted range of biodiversity, either as a result of tolerance to extreme environmental situations like high salinity in saltpans or as a result of suitability for aquaculture.

Current Status

(*see also Section 5.1.1.1*)

Most information on degradation (physical loss and decrease in habitat quality) of marine habitats is only from sites closest to human habitation or sites of intense resource harvest. The common form of physical loss is conversion to uses unrelated to the sustainability of the natural habitats. In the case of mangroves this happens as reclamation for urban development (as in Mumbai and Kochi, for example) or conversion into aquaculture ponds, as in many stretches of the coasts. Precise estimates of the extent of loss are difficult to come by, because of subjective extrapolations in most studies. About 40% of mangroves are believed to be already destroyed (GOI 1987). Estuaries and coastal waters suffer in terms of water quality rather than actual physical loss. The extent of degradation can be judged from the quantity of pollutants entering the Indian coastal seas (*see Table 4.8*), almost all of which are transported through the estuaries. In the case of coral reefs, physical loss due to mining was a major cause but its impact was confined to reefs near human habitation. However, the bleaching event[6] of 1998 has had a devastating effect, with as much as 80% loss of live coral cover in some reefs. Most reefs are yet to recover even partially. Open ocean waters are still pristine, except for some shipping routes affected by oil spills and pollution.

Table 4.8 Estimates as of 1998 of Pollutants Annually Entering the Coastal Seas of India

Type of Pollutant	Quantity
Domestic sewage	13.17×10^9 m^3
Industrial effluents	1.32×10^9 m^3
River-transported sewage and effluents	75×10^9 m^3
Solid wastes and garbage	105×10^6 tonnes
Fertilizers	2.6×10^6 tonnes
Pesticides	20600 tonnes
Detergents	31250 tonnes
Others	81500 tonnes

m^3 = cubic metres

Source: Sengupta and Qasim 2001)

Marine habitats are increasingly being given protection, either as reserves or national parks or sanctuaries (for a list of marine protected areas (MPAs) in India, *see Annexure 8*).

Fresh and Brackishwater Systems (Wetlands)

Diversity

The Ramsar Convention[7] (*see Section 6.1.1.2*) defines wetlands as 'areas of submerged or water saturated lands, both natural or artificial, permanent or temporary, with water that is static or flowing, fresh or brackish, or salty including area of marine water, the depth of which at low tide does not exceed six meters' (IUCN 1971). This definition is widely used in the Indian context, thus including all inland water bodies – even rice fields – as wetlands.

The freshwater ecosystems encompass a wide spectrum of habitats covering both lentic[8] and lotic[9] water bodies. The former includes either temporary or permanent ponds, lakes, floodplain marshes and swamps while the latter relate to rivers and streams. Brackishwater ecosystems like the estuaries and coastal lagoons are also classified as wetlands and hence often grouped along with the freshwater ecosystem, thus overlapping with the categories under marine ecosystems discussed above (*see Table 4.9*). The natural freshwater wetlands can be broadly classified into three major categories with 15 predominant wetland types.

Table 4.9 Categories of Natural Freshwater Wetlands

Type	Nature of flow	Sub-types
Riverine	Perennial	i. Permanent rivers and streams, including waterfalls ii. Inland deltas
	Temporary	i. Seasonal and irregular rivers and streams ii. Riverine floodplains, including river flats, flooded river basins, seasonally flooded grasslands
Lacustrine	Permanent	i. Permanent freshwater lakes (>8 ha), including shores subject to seasonal or irregular inundation ii. Permanent freshwater ponds (<8 ha)
	Seasonal	Seasonal freshwater lakes (>8 ha), including floodplain lakes
Palustrine	Emergent	i. Permanent freshwater marshes and swamps on inorganic soil with emergent vegetation whose bases lie below the water table for at least most of the growing season ii. Permanent peat-forming freshwater swamps, including tropical upland valley swamps dominated by *Papyrus* or *Typha* iii. Seasonal freshwater marshes on inorganic soil, including sloughs, potholes, seasonally flooded meadows, sedge marshes, and dambos iv. Peatlands, including acidophilous, ombrogenous, or soligenous mires covered by moss, herbs or dwarf shrub vegetation, and fends of all types v. Alpine and polar wetlands, including seasonally flooded meadows moistened by temporary waters from snowmelt vi. Volcanic fumaroles continually moistened by emerging and condensing water vapour
	Forested	i. Shrub swamps, including shrub-dominated fresh-water marsh, shrub carr and thickets, on inorganic soils ii. Freshwater swamp forest, including seasonally flooded forest, Wooded swamps on inorganic soils iii. Forested peat lands, including peat swamp forest

Source: Scott 1989; Dugan 1990

There are also numerous human-made wetland habitats, as also those that have developed in areas influenced by human activities. For example, seepage of water from reservoirs or spillover from irrigation channels creates substantial waterlogged areas, which support wetland vegetation (e.g. wetlands in the Damodar Valley and the Chambal Command Area). There are more than 1550 large reservoirs covering a total area of more than 14,500 sq km, and more than 100,000 small and medium reservoirs that cover another 11,000 sq km. Numerous small reservoirs have been built in the drier regions. Innumerable fishponds and extensive paddy fields are also wetland habitats, modified from the former marshes (Garg *et. al.*, 1998). *Table 4.10* lists the types of human-made freshwater wetlands.

Table 4.10 Categories of Human-Made Freshwater Wetlands

Aquaculture	i.	Aquaculture ponds, including fish ponds and shrimp ponds
Agriculture	i.	Ponds, including farm ponds, stock ponds, small tanks
	ii.	Irrigated land and irrigation channels, including rice fields, canals and ditches
	iii.	Seasonally flooded arable land
Urban/Industrial pools	i.	Excavations, including gravel pits, borrow pits and mining
	ii.	Wastewater treatment areas, including sewage farms, setting ponds and oxidation basins
Water-storage areas	i.	Reservoirs holding water for irrigation and/or human consumption with a pattern of gradual, seasonal, drawdown of water level
	ii.	Hydro-dams with regular fluctuations in water level on a weekly or monthly basis

Source: Scott 1989; Dugan 1990

In the first survey of wetland areas in India undertaken by the Department of Science and Technology in 1976, a figure of 39,045 sq km was arrived at (Biswas 1976). This included a total of 1,193 wetlands, of which 572 were natural wetlands, 542 were human-made, and 7 included both natural and human-made habitats (the remainder were unclassified). Some 938 wetlands were freshwater, 134 brackishwater and 19 coastal. Most of the wetlands were small. Over 690 had an area of less than 100 ha, and only 5 were larger than 1,00,000 ha. 418 of the wetlands were used for irrigation purposes, 369 sites for fishing, 90 for fish culture, 161 for grazing, 30 for waste disposal and 19 for reed-gathering. At many sites there were multiple uses – for example, 138 sites were used both for fishing and irrigation.

A second survey gave the total area of wetlands (excluding rivers) in India as 5,82,860 sq km, equivalent to 18.4% of the country's area (Scott 1989). However, over 70% of this includes waterlogged areas under paddy cultivation. As the latter could more appropriately be called domesticated ecosystems rather than natural aquatic ecosystems, these could be excluded from the purview of this section.

Another survey made by the Ministry of Environment and Forests gave an estimate of about 40,000 sq km (MoEF 1990) (*see Table 4.11*). This is similar to the estimate arrived at in the survey done by the Department of Science and Technology (1976). However, comparison of these results with the number of water bodies in *Table 4.11* leads to interesting observations. The phenomenal increase in the numbers of wetland water bodies (2167 natural and 65,254 human-made) is because of the inclusion of wetland water bodies that are less than 100 ha. It is unclear, however, how many of the smaller water bodies (of the order of 1 ha or so) could have escaped recording.

From *Table 4.11* it is evident that the waterbodies surveyed by the Ministry of Environment and Forests include brackishwater bodies like estuaries or mangroves that should more appropriately be called coastal marine ecosystems. As the estimate made by the Department of Science and Technology (39,045 sq km) is closer to that of the MoEF and also includes brackishwater habitats, it is reasonable to assume that the actual freshwater bodies would cover no more than 30,000 sq km (40,000 sq km minus the area occupied by brackishwater and coastal habitats given in *Table 4.9*). As human-made reservoirs account for about 25,500 sq km, a conservative estimate of wild natural freshwater bodies would be no more than 5,000 sq km. That this is conservative is reinforced by the facts that (i) water bodies less than 50 ha are not mapped by remote sensing whereas most of the village ponds in India are much smaller than this size and could hence have gone unrecorded, and, (ii) minimum cut-off size in physical surveys do not seem to be clearly defined. Besides, the area occupied by the rivers and canals do not seem to have been taken into account. The length of the rivers in India is about 28,000 km and that of the canals and irrigation channels is about 1,13,000 km. If an overall average width of 20 m can be assumed, then another 3000 sq km can be added to the freshwater wetlands. It is important therefore to recognise the uncertainty associated with these estimates, despite progress in using modern tools like remote sensing. There is also inability in our estimates to focus on true freshwater bodies, leaving out those under marine influence and hence subjected to a different set of ecological controls.

Table 4.11 Distribution of Wetlands in the States and Union Territories of India

S. No.	State	Geographical Area (Sq Km)	Natural		Human Made		Total Area
			No.	Area (ha)	No.	Area (ha)	
1.	Andhra Pradesh	275069	219	100457	19020	425892	526349
2.	Arunachal Pradesh	83743	2	20200	NA	NA	20200
3.	Assam	78438	1394	86355	NA	NA	86355
4.	Bihar	173877	62	224788	33	48607	273395
5.	Goa	3701	3	12360	NA	NA	12360
6.	Gujarat	196024	22	394627	57	129660	524287
7.	Haryana	44212	14	2691	4	1079	3770
8.	Himachal Pradesh	55673	5	702	3	19165	19867
9.	Jammu and Kashmir	222236	18	7227	NA	21880	29107
10.	Karnataka	191791	10	3320	22758	539195	542515
11.	Kerala	38863	32	24329	2121	210579	234908
12.	Madhya Pradesh	443446	8	324	53	187818	188142
13.	Maharashtra	307690	49	21675	1004	279025	300700
14.	Manipur	22327	5	26600	4	13824	40424
15.	Meghalaya	22400	2	400	NA	NA	400
16.	Nagaland	16579	2	210	NA	NA	210
17.	Orissa	155707	20	137022	36	148454	285476
18.	Punjab	50367	33	17085	6	5391	22476
19.	Rajasthan	342239	9	14027	85	100217	114244
20.	Sikkim	7096	42	1101	2	3.5	1104.5
21.	Tamil Nadu	130100	31	58868	20030	201132	260000
22.	Tripura	10477	3	575	1	4833	5408
23.	Uttar Pradesh	294411	125	12832	28	212470	225302
24.	West Bengal	88752	54	291963	9	52564	344527
	Sub-total	**3343970**	**2164**	**1459738**	**65250**	**2601788.5**	**4061526.5**
25.	Chandigarh	114	NA	NA	1	170	170
26.	Pondicherry	492	3	1533	2	1131	2664
	Sub-total	**606**	**3**	**1533**	**3**	**1301**	**2834**
	Grand total	**3344576**	**2167**	**1461271**	**65254**	**2603089.5**	**4064360.5**

Source: Garg et. al., 1998

A special mention should be made of Rann of Kachchh (Gujarat), which is often classified as wetland. The Rann of Kachchh, a saline desert, was part of the open sea in the past (*see Section 4.1.1.1*).

Among the freshwater wetlands, the following are classified as Ramsar sites: Chilika lake (Orissa), Keoladeo Ghana National Park (Rajasthan), Wullar (Jammu and Kashmir), Loktak (Manipur), Sambar (Rajasthan) and Harike (Punjab) (*see Box 4.5*).

Current Status

(*see also Section 5.1.1.1*)

Most of the lotic (flowing) waters suffer from two major problems: pollution and obstruction to the flow. Disposal of pollutants into the rivers and streams is a common enough practice.

Pollution is in the form of both urban sewages and industrial effluents. For example, along the Ganga river system more than 100 towns have been discharging as early as 80s untreated sewage into the river, at rates rang-

Box 4.5 Wetlands in India: Some Prominent Examples

(for a list of Ramsar Sites in India, *see Section 6.1.1.2*)

In Rajasthan, two of the wetlands, the Keoladeo National Park (Bharatpur) and Sambhar Lake (Nagaur), are recognised as wetlands of international importance under the Ramsar Convention. Deedwana, Pachbhadra, and Jaisamand lake are other important wetlands of the state (*Rajasthan State BSAP*). The Keoladeo National Park comprises a freshwater swamp, which is part of the Indo-Gangetic Great Plains. The wetland area is about 1,000 ha. The area is usually flooded during the monsoon (July-September), to an average depth of 1-2 m. From October to January the water level gradually falls, and from February the land begins to dry out. By June only some water remains. The site supports some 364 species of birds and is considered to be one of the world's best and richest bird areas (http://www.wcmc.org.uk/igcmc/s_sheets/worldh/keoladeo.html).

In Assam there are more than 3000 wetlands of various sizes. The Deepor *beel* located near Guwahati supports more than 150 species of resident and migratory birds. Majuli in Jorhat District, Assam, with an area of 900 sq km, is one of the biggest river islands in the world. Majuli is basically a cluster of islands rich in riverine vegetation, aquatic flora and fauna and migratory birds. In recent years it has witnessed a severe flood problem associated with large-scale bank erosion and consequent rapid degradation of biological resources. The wetlands in the island – Bhereki beel and Chakuli beel – attract a large number of migratory and resident birds (*Assam State BSAP*).

Loktak lake in Manipur has been identified as one of the sites for conservation under the Indian national wetland programme. The state government has also constituted Loktak Development Authority for development of the wetland area on a sound ecological basis. It is the largest natural wetland in north-east India, west of the river Imphal. The catchment area is about 98,000 ha; run-off from the catchment area drains into the lake mainly through seven streams, which originate primarily on the northern and western flanks of the lake. Thick floating mats of weeds covered with soil, called *phumdis*, are a characteristic feature of this lake. The main fish fauna present are minnows and minor carps. Keibul Lamjao National Park, habitat of the threatened brow-antlered deer (*Cervus eldi eldi*) known locally as sangai, is located in the south-east area of the lake (*Manipur State BSAP*).

Harike is the largest wetland in northern India. It is a vital staging post and winter home or an enormous concentration of migratory waterfowl, rivalled only by Keoladeo National Park near Bharatpur (http://www.ramsar.org/forum_india_harike.htm). A number of globally threatened species have also been recorded in Harike. The wetland is spread over an expanse of about 148 sq km (*Punjab State BSAP*). Some of the main problems here include silting and shrinking of the water body, water hyacinth infestation, encroachment, fishing, plantations, water pollution, and grazing.

Another wetland of national significance is Wular lake in Jammu and Kashmir surrounded by high mountain ranges to the north-east. The river Jhelum passes through the lake at Babyari and leaves it at Ningli. A number of wetlands, such as Malgam, Hygam and Nawgam, located on the fringes of the lake in the Baramulla district of Kashmir, are important for sustaining a large population of both migratory and resident birds. The lake is covered by dense growth of macrophytes, particularly *Trapa natans*, which provides substantial revenue for the state government. The wetland acts as a huge reservoir and absorbs the high flood waters of the River Jhelum (http://www.unep-wcmc.org/igcmc/s_sheets/ramsar/wular.html).

The Chilika lake in Orissa, spreading over an area of 1100 sq km, is the largest brackishwater lake in the country. It stretches across the length of the three districts of Pun, Khurda and Ganjam, and joins up with the Bay of Bengal through a narrow mouth, forming an enormous lagoon of brackish water. The lagoon is on the terminus of the migratory flyways and is the habitat for the largest congregation of aquatic birds in India. Chilika hosts approximately 160 species of birds of which 97 are intercontinental migrants during peak migratory seasons. The *Irrawady* dolphin is an elusive species found in various parts of the Chilika Lagoon. The unique spatial and temporal salinity gradient gives rise to a multitude of niches inhabited by a large diversity of plant and animal species. Chilika Lagoon is extremely important to local communities, 70% of whom depend upon fishing as their only means of livelihood (*Orissa State BSAP*).

The Sundarbans is a stretch of impenetrable mangrove forest of great size and biodiversity. It is a UNESCO World Heritage Site covering 10,000 sq km of land and water (more than half of it in India, the rest in Bangladesh) in the Ganges delta. It contains the world's largest area of mangrove forests. A number of rare or endangered species are found here, including tigers. 70% of the area is under saline water and the area is criss-crossed by hundreds of creeks and tributaries (*West Bengal State BSAP*).

Kolleru Lake in Andhra Pradesh is the largest freshwater lake in the country (*Andhra Pradesh State BSAP*). It receives water from four rivers, namely Budameru, Ramileru, Tammileru and Errakalva and 18 drains. This lake supports a rich biodiversity and high biomass of plankton and fish that forms the source of food for birds. It retains water only for about 6 months and then empties it into the Bay of Bengal through the outlet. The lake is the largest pelican refuge in India, and is a haven for migrating birds.

There are 831 wetlands in Gujarat out of which 438 are coastal and 393 are inland wetlands (including 231 small and big reservoirs). The coastal and inland wetlands cover 92.3% and 7.7% of the total wetland area respectively (*Gujarat State BSAP*).

Source: Compiled based on information extracted from some BSAPs and websites quoted above.

ing from 16 million litres per day (MLD) (e.g. Bhagalpur) to 850 MLD (Kolkata) (Jhingran 1991). The industrial effluents come from various sources – tanneries, refineries, paper industries, textile industries, distilleries – the volume of effluents varying from city to city. For example, at Kanpur, about 185 MLD of effluents were discharged in 1980s and at Kolkata, it was 1260 MLD during the same period (*Gangetic Plain Ecoregional BSAP*).

Construction of barrages for power generation and irrigation has also been undertaken systematically almost in all rivers, affecting the ecology and biodiversity downstream. India is a major dam-builder among the developing countries. India has 4291 large dams (of which 695 are presently under construction). The majority have been constructed for irrigation purposes, and hence impoundment and abstraction of water from the natural course is an immediate effect. In the case of the Ganga, abstraction of water into the Upper Ganga canal at Haridwar deprived the downstream flow by 1000 million m^3 per year. Notably the barrages also prevent the migration of fish upstream. For example, the Hilsa fishery in the upstream reaches of the Ganga collapsed after the construction of the Farrakka barrage in 1975. Dams also flood forested lands. About 500,000 ha of forestlands have been flooded between 1950 and 1975 as a consequence of construction of dams (*Dams and Biodiversity Sub-thematic Review*).

The single most important factor affecting all lentic (still) water bodies is reclamation for a variety of purposes. Form various estimates available until now, it is likely that close to 50,000 small and medium water bodies have already been lost. This loss is most acute in metropolitan cities. For example, of the 204 lakes listed in 1960 at Ahmedabad, very few remain now. Even among the 137 officially shown as existing, as many as 65 have already been reclaimed for a variety of purposes. In several other cases, though numbers remain the same, encroachments have reduced the water-spread substantially. For example, the encroachments have reduced the size of the most important lake, Saroonayar Lake at Hyderabad, from 74 ha in 1964 to 25 ha now (Joshi 2002).

4.1.2 Wild Plant/Animal/Micro-Organism Taxa

4.1.2.1 Wild Plant and Fungi Diversity[10]

About 45,000-47,000 plant species are reported to occur in India, representing 11% of the known world flora (Mudgal and Hajra 1999; Sharma *et. al.*,1997; Karthikeyan 2000). About 33% flowering plant species and 29% of the total Indian flora are endemic (*see Table 4.12*).

Indian flora shows affinity with the flora of several countries and regions, due to the continuity of the northern part of India's landmass with the Middle East, the former USSR, Central Asia, China and east Asia. Some elements in Indian flora belong to distant places like Africa and Australia and thus show discontinuous distribution. Besides, the flora of north-eastern India has rich admixture of floristic elements of Malaysian, Burmese, Sino-

Tibetan, Japanese and, to a lesser degree, even of Australian region. Similarly, certain floristic elements of Western India and the Ghats of the peninsular region are common with Sri Lanka and eastern parts of South Africa. The flora of the Andaman group of islands has more in common with the flora of Myanmar, while the flora of the Nicobar group of Islands show affinity with the flora of Indonesia and Malaysia (Jain and Sastry 1983).

Table 4.12 Floristic Diversity in Different Groups

Groups	Species	Endemic	References
Angiosperm	17672	5725 (32.4%)	Nayar 1996; Wild Plant Diversity BSAP
Gymnosperms	48	7 (14.5%)	Singh and Mudgal 1997
Pteridophytes	1135	193 (17%)	Ghosh and Ghosh 1997
Lichens	2021	466 (23%)	Singh and Sinha 1997
Bryophytes	2850	938 (33%)	Vohra and Aziz 1997; Singh 1997
Algae	6500	1924 (29.6%)	Rao and Gupta 1997
Fungi	14500	3500 (24.1%)	Sharma 1997

Table 4.13. Comparison of Estimated Number of Plant Species in the World and in India

Groups	Number of species		Share of India in World (%)
	World	India	
Bacteria[2&3]	2700	850	31.48
Virus[1]	4000	Unknown	–
Fungi[2&3]	10,0000	14500[2]-23000[3]	23.00
Algae[1&4]	40,000[1]	6500[4]	16.25
Bryrophyta[3&5]	16,0000	2850[5]	1.78
Liverworts[2&6]	7,500	852[6]	11.36
Mosses[2]	7,000	1,980	28.3
Lichens[9]	13,500	2021	14.97
Pteridophyta[10]	>13030	1135	8.71
Gymnosperms[7]	750	48	8.00
Coniferophyta[3]	550	55	10.00
Cycadophyta[3]	100	5	5.00
Gingkophyta[3]	1	0	0.00
Gnetophyta[3]	70	4	5.71
Flowering plants[1,8&11]	250,000[1]	17672[8&11]	7.07

Source: 1. MoEF 1999b; 2. Sharma et. al., 1997; 3. Sharma, 2000; 4. Rao and Gupta, 1997; 5. Vohra and Aziz 1997; 6. Singh and Semwal 2001; 7. Singh and Mudgal 1997; 8. Wild Plant Diversity Thematic BSAP; 9. Singh and Sinha 1997; 10. Ghosh and Ghosh, 1997; 11. Nayar, 1996.

Angiosperms

The reported number of species for the angiosperms or flowering plants varies between 16,500 and 19,395 taxa (including intraspecific categories) under 247-315 families and represents roughly 7% of the described species in the world (Mudgal and Hajra 1999; Sharma *et. al.*, 1997; Karthikeyan 2000). However, the analysis and review of available information by the *Wild Plant Biodiversity Thematic Working Group* suggests the presence of 17672 species in the country. Family *Poaceae* is the largest in India, being represented by 1291 species, followed by *Orchidaceae*, *Fabaceae*, *Asteraceae*, *Rubiaceae*, *Cyperaceae*, *Euphorbiaceae*, and *Acanthaceae*, *Lamiaceae* and *Scrophulariaceae* (*Table 4.12*). About 42 families have more than 100 species; however, 33 families have only one species. Among genera, *Impatiens* with 205 taxa is the largest genus in Indian flora followed by *Primula* (135), *Ficus* (132), *Carex* (117), *Crotalaria* (104), *Habenaria* (100), *Dendrobium* (100), *Pedicularis* (98), *Rhododendron* (97) and *Syzygium* (91). About 189 genera are monotypic (Uniyal and Mathur 1994). These genera add significantly to the conservation of genetic resources of the world, as there are no closely related genomes of these genera anywhere else in the world.

Table 4.14 Distribution of the Species in Dominant Angiospermic Families in India

Family	No. of genera	No. of species
Poaceae	263	1291
Orchidaceae	184	1229
Fabaceae	133	1192
Asteraceae	166	800
Rubiaceae	113	616
Cyperaceae	38	545
Euphorbiaceae	84	527
Acanthaceae	92	500
Lamiaceae	72	435
Scrophulariaceae	62	368

Source: Sharma 2000

The Indian region has approximately 107 species of aquatic angiosperms, which represent nearly 50% of the total aquatic plant species of the world (Rao 1994). The presence of insectivorous plants such as *Aldrovanda* (1 species), *Drosera* (3), *Nepenthes* (1), *Pinguicula* (1), *Utricularia* (36), parasites (*Balanophora*, *Boschniakia himalaica*, *Orobanche* spp., *Aeginetia indica*, *Rhopalocnemis phalloides*, *Saparia himalayana*) and saprophytes (*Monotropa* spp., *Cymbidium macrorhizon*) makes this a rich source of botanical curiosities in Indian flora (Sharma and Singh 2000).

Table 4.15 Distribution of Ancient Genera in Different Families

Families	Genera
Magnoliaceae	*Magnolia*, *Manglietia*, *Michelia*, *Pachylarnax*, *Paramichelia*, *Talauma*
Tetracentraceae	*Tetracentron*
Annonaceae	*Alphonsea*, *Annona*, *Artabotrys*, *Cythocalyx*, *Desmos*, *Fissistigma*, *Friesodielsia*, *Goniothalamus*, *Melodorum*, *Miliusa*, *Mitrephora*, *Orophea*, *Polyalthia*, *Trivalvria*, *Unona*, *Uvaria*
Myristicaceae	*Horsfieldia*, *Knema*, *Myristica*
Schisandraceae	*Kadsura*
Lauraceae	*Actinoodaphne*, *Alseodaphne*, *Beilsahmiedia*, *Cinnamomum*, *Cryptocaria*, *Dehaasia*, *Endiandra*, *Lindera*, *Litsea*, *Machilus*, *Neocinnamomum*, *Persea*, *Phoebe*
Chloranthaceae	*Cholaranthus*
Menispermaceae	*Pycnarrrhena*, *Haematocarpus*, *Aspidocarya*
Lardizabalaceae	*Decaisnea*, *Holboellia*, *Stauntonia*, *Parvatia*
Hamamelidaceae	*Exbucklandia*, *Distylum*, *Altingia*
Piperaceae	*Houttuynia*
Myricaceae	*Myrica*
Betulaceae	*Betula*, *Alnus*

Source: Nautiyal and Kaul 1999; Takhtajan 1969

Among the angiosperm plants certain families have immense ornamental value. For example, the orchids, represented in India by over 1200 species with maximum representation in the Eastern Himalaya and Northeast region; the *Rhododendron*, 90 taxa in India, of which 80 species are confined to the Eastern Himalaya. Besides these, the diversity of *Hedychium* (40 spp.), *Primulas* (135 spp.), *Pedicularis* (98 spp.), *Corydalis* (53 spp.), and *Geranium* (32 spp.) are noteworthy. Furthermore, on account of the presence of over 131 species of primitive angiosperms, the region is considered a 'Cradle of Flowering Plants' (Takhtajan 1969). Some important ancient genera are given in *Table 4.15*.

India is one of the world's 12 Vavilovian Centres of origin and diversification of cultivated plants, known as the 'Hindustan Centre of Origin of Crop Plants' (Vavilov 1951). These wild relatives of crop plants (WRCPs) constitute a rich reservoir of genetic variation of immense value to plant breeders. They have evolved to survive drought and floods, and extreme heat and cold, and have been adapted to cope with natural hazards (Hoyt 1988). They have often developed resistance to pests and diseases and are thus crucial to crop improvement. About 320 species of these wild relatives (116 genera and 48 families) are known to have originated in India (Arora and Nayar 1984). The distribution of these crop groups is presented in *Table 4.16*.

Table 4.16 Distribution of Wild Relatives in Different Crop Groups

Crop Groups	No. of Species
Cereals and millets	51
Legumes	31
Fruits	109
Vegetable	54
Oilseeds	12
Fibre plants	24
Spices and condiments	27
Others	26

Source: Arora 2000

Despite the migration of floristic elements from other contiguous or neighboring regions, India has a very high number of endemic elements. About 33% of the Indian flowering plants (5725 species, 146 genera, 47 families) are regarded as endemic; they are mainly located in 24 centers of the country (Nayar 1996). Besides endemics, nearly 10% of flowering plants are assessed under various categories of threatened species. *The Red Data Book of Indian Plants* listed 620 threatened species. Of these, 28 are presumed extinct, 124 endangered, 81 vulnerable, 160 rare and 34 insufficiently known (Nayar and Sastry 1987, 1988). However, the IUCN Red List for India lists 290 species (*see Table 4.17*).

Table 4.17 Threatened Floral Species in India by Threat Category (2002 Red List)

Threat Category	Plants
Extinct (EX)	7
Extinct in the Wild (EW)	2
Critically Endangered (CR)	44
Endangered (EN)	113
Vulnerable (VU)	87
Lower Risk/ Conservation Dependent (LR/cd)	1
Lower Risk/ Near Threatened (LR/nr)	22
Data Deficient (DD)	14
Total	**290**

Source: 2002 IUCN Red List of Threatened Species (http://www.redlist.org)

Gymnosperms

Gymnosperms occupy an extensive tract of the sub-tropical and temperate regions of the Himalaya and the hilly areas of Andhra Pradesh and Andaman Island (Singh and Mudgal 1997). However, they are not found in Central

India (Basu 1994). They are represented by members of *Cycadales*, *Coniferales*, *Ginkgoales*, *Taxales* and *Gnetales* (Biswas 1933; Sahni 1953; Raizada and Sahni 1960).

Of the total 750 species (53 genera) of gymnosperms in the world, about 60 species (17 genera) occur in the Indian subcontinent. Of these, 48 species and 10 varieties under 15 genera are known to be growing in the wild. Out of the 11 families of living gymnosperms found in India, 3 families – *Ginkgoaceae*, *Araucariaceae* and *Taxodiaceae* – are exotic. Among the remaining 8 families, *Pinaceae* is the richest family represented by 6 genera and 17 species.

Out of the 48 species found in India, 23 species (48%) occur in the Western Himalaya region, and 28 (58.3%) species in Eastern Himalayan region, 5 (10.4%) species in the Andaman and Nicobar Islands and 4 (8.3%) species are known to occur in the Western Ghats.

Apart from 48 indigenous species, about 26 species are exotics which are now flourishing profusely in India, mostly in gardens. These include *Cycas revolute*, a native of Japan and China, *Ginkgo biloba*, a living fossil and native of Chekiang and Anhewi provinces, and three species of *Araucaria* (*A. bidwillii*, *A. columnaris*, *A. cunninghamii*), which are found in Southern Hemisphere.

Conifers are the most dominant among the gymnosperms and are largely confined to the Himalayan landscapes, except *Podocarpus wallichianus* (Peninsular India and Andaman) and *P. nerifolius* (Eastern Himalaya and Andaman). The present coniferous flora of India is dominated by the genera of the Northern Hemisphere like *Pinus*, *Abies*, *Cedrus*, and *Picea*, whereas the genera from the Southern Hemisphere, like *Agathis* and *Araucaria*, have only recently been introduced. In the Himalaya, the species diversity is not prevalent in the Western Himalayan region but the coniferous forests are more extensive and dense than in the Eastern Himalayan region (Singh and Mudgal 1997). Out of the 48 species of gymnosperms, 7 are endemic to Indian flora: *Cycas beddomei*; *Amentotaxus assamica*; *Pinus wallichiana*; *Gnetum montanum*; *G. contractum*; *G. latifolium*; *Ephedra przewalskii* (Basu 1994).

Box 4.6 Rattans (Canes) of India

Rattans or canes are found in the evergreen, semi-evergreen and moist deciduous forest of the Western Ghats, eastern and northeastern India and the Andaman and Nicobar Islands. Over 70 species of canes from five genera – namely *Calamus*, *Daemonorops*, *Plectocomia*, *Korthalsia* and *Zalacca* – occur in different bioclimatic regions of the country. It is estimated that 73% of the species are endemic to India (Basu 1992; Renuka 1995). The Western Ghats' tropical evergreen forest is an ideal habitat of rattans. Out of the 5 genera, only one genus – *Calamus* – is present here with about 21 identified species (Renuka 1999; Thomas *et. al.*, 1999). *Calamus thwaitesii* is probably the only species that is widely distributed from Goa in the north to Kerala in the south, along the Western Ghats. *Calamus rotang* is distributed from Andhra Pradesh in the North to Kerala in the South. *Calamus nagbettai* is endemic to the Subramanya area of Dakshina Kannada district. The tropical rainforests of the Andaman and Nicobar Islands harbour about 18 rattan species, of which nearly 11 are endemic to this region. The species in this region belong to three types of genera: *Calamus*, *Daemonorops*, *Korthalsia*. The north-eastern region of the country is remarkably rich in genetic resources of rattan. The region contains a third of the rattan species in India. About 23 species covering over 5 genera are found in this region (*North-east Ecoregional BSAP*).

Rattans are one of the most widely-used species for a variety of household and commercial purposes. A number of them are over-exploited, and now threatened.

Source: Basu 1992; Renuka 1995; Renuka 1999; Thomas et. al., 1999; North-East Ecoregional BSAP.

Like other plant species, gymnosperms are also under threat, on account of the great demand for timber and other factors like the extraction of resin from the very young trees of *Pinus* species. About 6 species and 2 varieties are reported to be threatened (*see Table 4.18*).

Table 4.18 Status of Threatened Gymnosperms

Species	Status	Remark/causes of threat
Amentotaxus assamica	Vulnerable to extinction	Deforestation, shifting cultivation, grazing and road building,
Pinus gerardiana	Restricted distribution	Seeds of economic product
Cedrus deodara	Endangered	Deforestation
Picea brachytyla	Restricted	Ruthless and reckless cutting
Gnetum ula	Scarce	Planting of Eucalyptus, Pinus and other fast growing species
Cephalotaxus mannii	Very scarce	Shifting cultivation

Source: Basu 1994

Pteridophytes

In the Indian sub-continent, the Himalaya, the Gangetic plains and the Thar Desert are recognised as important centers of pteridophyte diversity (ferns and allied species). The maximum diversity of pteridophytes is observed in the Himalaya. The lower rainfall from the Eastern to the Western Himalaya is responsible for the decline in species number towards the west. There are about 10,000 species of pteridophytes in the world; of these 1135 species occur in India. *Polypodiaceae* is the largest (137 species) family and *Selaginella* is the largest genus. An analysis of species diversity in different pteridophytic zones is given in *Table 4.19*.

Nearly 17% (193 species) of the pteridophyte flora of the world are endemic to India. Considering the richness and uniqueness of pteridophytic flora, the Himalaya constitutes a very significant and phytogeographically important region of the world. Of the total 480 fern species in the Himalayas, about 12% are endemic (Dhir and Saiki 1984). The majority of endemic species are reported from the eastern Himalayan region (Dixit 1984).

Table 4.19 Distribution of Pteridophytes in Different Pteridophytic Zones

Pteridophytic zones	No. of species
Eastern India	810
Southern India	336
Western India	321
Andaman and Nicobar Island	125

Source: Ghosh and Ghosh 1997

Box 4.7 Monotypic Genera of Pteridophytes

About twenty monotypic genera of pteridophytes occur in India. The species represented in these genera are considered in the category of threatened taxa, by virtue of their representation by a single species; even a slight disturbance in their habitat may be responsible for turning them from endangered into extinct category. The monotypic genera are: *Ampeloptris prolifera*, *Blechnedium molanopus*, *Brainia insignis*, *Cheilanthopsis stramine*, *Christensenia aesculifolia*, *Diacalpe aspidiodes*, *Dictyocline griffithii*, *Didymochlaena truncatula*, *Gymnogramitis dareiformis*, *Helminthostachys zeylanica*, *Idiogramma microphylla*, *Kuniwatsukia cuspidata*, *Leptogramma totta*, *Lithostegia foeniculacea*, *Lauerssenia kehdingiana*, *Lycopodiastrum casuarinoides*, *Palhinhaea cernua*, *Pseudodrynaria coronans*, *Quercifilix zeylanica*, and *Sinephropteris delavayi*.

Source: Dixit and Mondal 1994

Bryophytes

The bryophytes, a hitherto lesser-known group of plants, consisting of 2850 species, are the second largest group of green plants in India (Vohra and Aziz 1997). They are considered to be the first colonizers of terrestrial habitats. They usually inhabit narrow ecological niches, with a preference for damp and shady conditions. The vast areas in the Himalayas and peninsular India with abundant precipitation and high humidity are rich in bryophytes, as compared to the plains stretching over larger parts of the country. Based on their structure and characteristics, bryophytes have been broadly grouped into mosses (*Musci*) and liverworts (*Hepaticae*).

Mosses

Mosses constitute the major component of Indian bryoflora with about 2000 species (342 genera and 54 families) (Vohra and Aziz 1997). Of these, 1030 occur in the Eastern Himalaya, 751 in the Western Himalaya and 540 in the Western Ghats (*Table 4.20*). About 608 taxa of mosses are endemic to India and the eastern Himalaya supports the maximum number of endemic species (270), followed by the Western Ghats (190) and the Western Himalaya (144).

Table 4.20 Distribution of Mosses in Different Bryological Zones

Zone	Family	Genera	Species	No. of endemic species
Eastern Himalaya	53	276	1030	270 (26.2%)
Western Himalaya	47	215	751	144 (19.2%)
Western Ghats	42	171	540	190 (35.2%)

Source: (Vohra and Aziz 1997)

The Eastern Himalaya is considered richest both in number of species as well as their abundance. The semi-evergreen and evergreen forests support luxurious moss vegetation. The maximum number of taxa occurs at high elevation. The Eastern Himalaya, with a high proportion of endemics (270 spp.), is considered a region of active speciation. The genus *Fissidens* shows the highest number of endemic species (17), followed by *Calymperes* (10), *Entodon* (9) and *Brachymenium* (6). Many of the species have been collected only once and remain represented by type specimens only. Many of them are generally confined to small areas and have a preference for a particular habitat or a niche. For example: *Andreaea commutata*, *A. densifolia*, *A. indica*, *A. rigida*, *Polytrichastrum xanthopilum*, *Polytrichum densifolium*, *Pleuridium tenue*, *Ditrichum laxissimum*, *Trematodon megapophysatus* and *Dicranoweisia alpina* (Vohra and Aziz 1997).

The Western Ghats support over 540 species of mosses (171 genera and 42 families). The humid tropics of Southern Western Ghats (500-1500 m) show richness in moss vegetation (Vohra *et. al.*, 1982). These areas are among the least-explored areas of the country. The region has a higher number of endemics (190 spp., 35%). Of the reported species, 30 species are confined to the Western Ghats of Maharastra and Karnataka, and the remaining species are endemic to Palni, Nilgiri or some other places in peninsular India.

The Western Himalaya has 751 species (215 genera and 47 families) of mosses. About 144 species (19.2%) are endemic to the area. There are a few monotypic genera endemic to the region: *Cyathothecium*, *Mitrobryum*, *Octogonella*, *Orthotheciadelphus* and *Retidens*. Except for *Mitrobryum koelzii*, which was collected from its type locality from Tehri Garhwal in recent years, no specimens of these genera have been collected again. The genus *Brachythecium* contains a large number of endemic species (21). Most of the endemics are confined to the high-altitude areas of the Himalaya (Kashmir and Himachal Pradesh). Also, endemics occurring in Kumaon and Garhwal are considerable in number. Some of the important endemic plants are *Buxbaumia himalayensis*, *Andreaea kashyapii*, *Campylium gollani*, *Hygroamblystegium gangulianum*, *Hygrohypnum nairii*, *Brachythecium chakratense*, *B. garhwalense*, *Pseudoleskea laevifolia*, *Thuidium contortulum*, *Plagiothecium dehradunense*, *Hydrogonium mussoorianum* and *Anoectangium kashmiriense*.

Liverworts

The liverworts are represented by 852 species (141 genera and 52 families) and account for nearly 14% of global liverwort flora (Udar 1976; Kachroo *et. al.*, 1977; Srivastava and Udar 1979; Singh and Semwal 2001). The order *Jungermanniales* (629 spp.) alone accounts for over 74% of the taxa (D.K. Singh 2001). The varied phytoclimatic conditions seen in different parts of the country are fully manifested in the distribution pattern and composition of liverwort flora in India. They show maximum diversity in the Eastern Himalaya, with about 548 species accounting for over 64% of the total liverwort flora of the country. The Western Ghats (280 species, 30%) and the Western Himalaya (235 species, 28%) are two other liverwort-rich areas. Considering bryological territories, three major centers of diversity and diversification of liverworts are present in India. The rest of the country put together accounts for only 135 species (15.8%). Based on the liverwort vegetation in different regions, seven bryogeographic units have been identified in India (Pande 1958; Singh 1992; Singh and Semwal 1995). The distribution of liverworts in different bryogeographical territories is presented in *Table 4.21*.

Table 4.21 Distribution of Liverworts in Different Bryogeographical Territories

Bryogeographical region	Family	Genera	Species
Eastern Himalaya	44	111	548
Western Himalaya	40	77	235
Punjab & West Rajasthan	13	17	34
Gangetic plains	9	11	18
Central India	21	32	61
Western Ghats	32	79	280
Eastern Ghats & The Deccan Plateau	14	14	33
Andaman and Nicobar	12	40	53

Source: Singh 2001a

About 260 species (30%) of the Indian liverwort taxa are endemic to the country (Srivastava 1994; Singh 1997; 1999; 2001). This includes one family *Aitchisoniellaceae* and four genera. The Eastern Himalayan region hosts the maximum of 150 (58%) of the total endemic taxa of the country. Out of these, 90 taxa are confined to this territory alone; the rest are common with other bryogeographical regions (except the Gangetic Plains, Central India and the Andaman and Nicobar Islands). This is followed by the Western Ghats (65 taxa, 25%) with 4 taxa restricted to this region alone. The Western Himalaya (54 taxa, 21%) has 34 taxa (including the monotypic family *Aitchisoniellaeae*) confined to this territory. Of the remaining bryogeographical regions, Punjab and West Rajasthan have 12 taxa, Andaman and Nicobar Island 8, the Central Indian region 6, the Gangetic plain 5, and the Eastern Ghats and the Deccan plateau have only one (*Antoceros bharadwajii*) endemic taxon, which also occurs in the Himalaya, Central India and the Western Ghats.

Lichens

Lichens are an interesting group of plants representing a symbiotic association of fungi and algae. They constitute one of the dominant life forms (a little over 8%) on the earth's surface (Ahmandjian 1995). The diverse climatic and altitudinal conditions coupled with varied ecological habitats of the country have contributed immensely to the rich lichen wealth of India. At present about 2021 species of lichens in 248 genera are known to be distributed on various substrata in different lichenogeographical regions of India (Singh and Sinha 1997). The Western Ghats are the richest with 800 species (39%), growing predominantly in tropical and subtropical *shola* forests, followed by the Eastern Himalaya with 759 species (37%) and the Western Himalaya with 550 species (27%). The other regions have comparatively poor representation of lichen species, primarily due to meagre efforts at survey and collection. For example, the Andaman and Nicobar islands are represented by about 307 species, followed by the Gangetic plains (224), Central India (48), Western Dry Region (39), Eastern Ghats and Deccan Plateau (31) (*see Table 4.22*).

Table 4.22 Distribution of Lichens in Different Lichenographical Regions

Region	No. of genera	No. of species
The Western Himalayan region	119	550
The Eastern Himalayan region	147	559
The Western dry region	24	39
The Gangetic plain	63	224
The Central India	23	48
The Western Ghats	140	800
The Eastern Ghats	23	31
Andaman and Nicobar Island	66	307

Source: Singh and Sinha 1997

A large number of Indian lichen species are cosmopolitan in distribution and show phytogeographical affinities with the flora of adjacent as well as distant regions. The Eastern Himalaya lichen flora has several species in common with Sino-Japanese and south-east Asian countries. The lichens from the Western Himalaya show closer affinity to the northern European elements. As far as rare lichens are concerned, it is difficult to pinpoint these in Indian flora because a vast area (90%) of the country remains either unexplored or underexplored, and the data on exact location, taxonomy, population studies and distribution of species is not adequate. However, estimates suggest that over 300 species in Indian lichen flora are rare. Similarly, endemic lichens are quite large in number (446 species, 23%); a majority of them are microlichens.

Fungi

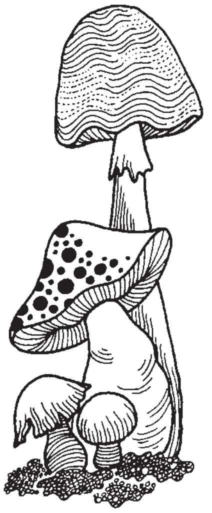
Fungi, previously considered a part of the plant kingdom but now separated into a distinct kingdom of their own, contain an extremely diverse range of organisms, which include popularly-known ones like mushrooms and bracket fungi. They constitute a group of heterotrophic organisms, subsisting as parasites or as saprophytes on other organisms or their residue. Both globally as well as in India, fungi are the second most diverse major group of non-animal organisms (after angiosperms).

In India, the total number of fungi species reported ranges from 14,500 (Bilgramani et. al., 1991; Sharma 1997) to 23,000 (Sharma 2000). *Deuteromycotina*, *Ascomycotina* and *Basidiomycotina* account for more than 88% of the Indian mycoflora (*see Table 4.23*). It is interesting to note that out of 2300 genera of Indian fungi, 1050 (46%) have only one species, while 1237 (53%) have 2-100 species. *Cercospora* is the genus having over 500 species, followed by *Puccinia* (320), *Phyllosticta* (280), *Aspergillus* (140), *Meliola* (130), *Phyllachora* (116) and *Aecidium* (100). Of the total 14500 species, 3500 (24%) species are endemic to India.

Table 4.23 Distribution of Fungi in Various Groups

Groups	Genera	Species	Endemic
Myxomycota	50	365	30
Mastigomycotina	87	710	140
Zygomycotina	45	300	40
Ascomycotina	680	3500	900
Basidiomycotina	520	3400	500
Deuteromycotina	900	6000	1850

Source: Sharma 1997



Algae

Algae are represented by over 6500 species in 666 genera. They are found growing in a variety of habitats – freshwater, terrestrial and marine. The freshwater algae are dominated by *chlorophyceae* (green algae), *bacillariophyceae* (diatoms) and *cyanophyceae* (blue-green algae). These represent the majority of Indian algal flora, accounting for 390 genera and 4500 species, followed by terrestrial algae (125 genera and 615 species), soil algae (80 genera and 1500 species) and marine algae (169 genera and 680 species) (Rao and Gupta 1997).

A total of 680 species of marine algae are known from Indian coasts. Among them, the rhodophytes (red algae) are the dominant (50%), followed by chlorophytes (25%), phaeophytes (brown algae) (22%) and cyanophytes (3%). The macroalgal forms among these comprise about 120 species of seaweeds and 14 species of sea grasses. *Gelidiella* and *Gracilaria* are important sources of agar agar. Marine algae are most abundant along the Gujarat coast, the Gulf of Mannar and the offshore coral islands of Lakshadweep, Andaman and Nicobar. The total standing crop of seaweeds in the country as estimated so far is 2,60,876 tonnes.

Orchids

Orchidaceae with about 800 genera and over 20,000 species are distributed all over the world, with over 30,000 varieties (Chadha 1994). Orchids are well represented in India. The occurrence of nearly 1200 species in 166 genera has so far been authenticated, and this number is likely to swell further as several areas in the major orchid-rich belts in the Himalaya, north-east India and peninsular regions are yet to be botanically explored. The maximum representation of orchids has been reported from northeast India with 825 species (*see Table 4.24*), followed by the Eastern Himalaya with 612 species. They are known for their therapeutic importance. They are inherently slow growers and regenerate poorly in nature because of their pollinator specificity and requirement for mycorrhizal associations. They have adapted to a variety of life modes – terrestrial, epiphytic and saxalitic – and live in a delicately balanced equilibrium with their surroundings.

Table 4.24 Distribution of Orchids in Various Regions of India

Region	Species	Endemic	Extinct	Endangered
Peninsular India	250	13	5	25
Eastern India	130	6	–	5
Northeastern India*	825*	186	18	376
Eastern Himalaya	612	88	18	105
Western Himalaya	250	16	–	44
Andaman and Nicobar Islands	80	15	2	2
Central India	60	–	–	–
Western India	5	–	–	–

*Source: Shanker 2001; * Hegde 2000*

Box 4.8 Bamboos of India

Bamboos play an important role in the economy of the country and are associated with humankind since time immemorial. Tropical Asia (including India) is the main centre of bamboo diversity. Bamboo forests come up both in tropical and temperate regions, and today approximately 12.8% of the total forest area in India is covered by bamboo. A total of 18 genera, with 130 species of wild and cultivated bamboos, have been recorded in India, out of a total of 1250 species occurring in the world. Though widely distributed in the country, bamboo is concentrated in the Eastern Himalaya, Western Ghats and the Andaman and Nicobar Islands.

In the Eastern Himalaya, seven sites of extremely high species richness identified are Sikkim, Meghalaya, Assam, Arunachal Pradesh, Nagaland, Manipur and West Bengal. Out of 18 genera and 130 species so far known in India, 16 genera and 58 species are represented in the Eastern Himalaya. In the Western Ghats, there are three areas with distinctly high concentration of bamboo species: northern Karnataka (30 species), followed by the area in the north of the Palghat gap (27 species) and the area south of the Palghat gap (21 species). These two regions, which harbour exceptionally high number of species, could be regarded as 'micro-hotspots' or hotspecks (*see Box 4.4*) of bamboo. Besides the Eastern Himalayas and Western Ghats, bamboos are also distributed sparsely in the plains of central and north India, in the states of Madhya Pradesh, Haryana and Himachal Pradesh.

Region-wise distribution of Bamboo:
Eastern India (including Eastern Himalayas): 58 spp. in 16 genera
Western Ghats: 24 spp. in 8 genera
Western Himalayas: 14 spp. in 5 genera
Indo-Gangetic Plains: 8 spp. in 4 genera
Andaman and Nicobar: 7 spp. in 6 genera

Source: Chalvaraju et. al., 2001; Bahadur and Jain 1983

Box 4.9 Profiles of Aquatic Plant Species

Indian wetlands range from Himalayan lakes to offshore islands, and vary in size from less than an acre to the 2 million sq km of the India's Exclusive Economic Zone (EEZ). Given the extent and diversity of wetlands, the current inventory of approximately 28,000 aquatic species is too small. Again there is a vast disparity in the size of inventories of different groups as well. While certain groups have been studied extensively, several others are known only by occasional records. For example, in the marine biosphere, while the inventory of fishes is near complete, that of several groups like soft corals and sponges that are potential sources of bioactive molecules is far lower than the number actually present. Besides, inventories are made quite often from easily accessible sites, thus leaving out remote areas, which may have more interesting biological components. A case in point is a recent rediscovery of a mangrove species *Xylocarpus* (that was last known 4 decades ago) from a remote site on the west coast of India (Wafar and Untawale undated).

Marine

Mangroves, sea grasses and seaweeds are generally considered to constitute the floral components of the marine waters. In the proper sense of the term, phytoplankton (diatoms, dinoflagellates, photosynthetic bacteria) are also floral components, but they are rarely indicated as such. The sea grasses in Indian waters number 14 species, the mangroves 60 species (34 on the west coast and 47 on the east coast) and the seaweeds 650 species (159 species of *Chlorophyta* (green algae), 141 species of *Phaeophyta* (brown algae) and 307 species of *Rhodophyta* (red algae).

Freshwater

The floristic component of freshwater biota is dominated by algae in open waters, whereas higher plants (macrophytes) dominate the confined wetlands There are also many bacteria and fungi but very few bryophytes. The estimated number of species of different plant groups in Indian freshwater ecosystems is given in *Table 4.25*. Table 4.26 shows the estimated number of aquatic/wetland species of plants in India, and the number of vascular plant species in different states in India is shown in *Table 4.26*.

Table 4.25 Estimated Number of Aquatic/Wetland Species of Plants in India

Taxa	Number of species
Algae	650
Pteridophytes	90
Angiosperms	700

Note: Estimated number of species of fungi, bryophytes etc. are not available.
Source: Natural Aquatic Ecosystem Thematic BSAP

Table 4.26 Estimated Number of Aquatic Vascular Plant Species in Different States of India

States	Number of species
Andaman and Nicobar Islands	134
Andhra Pradesh	180
Arunachal Pradesh	51
Assam	264
Bihar	184
Delhi	100
Gujarat	145
Goa	168
Himachal Pradesh	95
Haryana	29
Jammu and Kashmir	92
Kerala	372
Karnataka	370
Lakshadweep	25
Meghalaya	142
Maharashtra	265
Manipur	98
Madhya Pradesh	282
Mizoram	51
Nagaland	52
Orissa	242
Punjab	145
Rajasthan	241
Sikkim	141
Tamil Nadu	345
Tripura	52
Uttar Pradesh	270
West Bengal	373

Source: Natural Aquatic Ecosystems Thematic BSAP

Microbial Component

Very little is known about the diversity of aquatic micro-organisms such as bacteria and fungi that decompose dead organic matter and thus contribute to recycling of nutrients and other minerals. Whereas the bacterial populations are often reported from polluted waters, in the context of their role as pathogens or in wastewater treatment, decomposition, methanogenesis and other processes, rarely have attempts been made to identify or refer to specific taxa.

Box 4.10 North-East India

The north-eastern region forms a distinct geographical unit in the country, and is unique in many ways. It is a treasure house of biological and cultural diversity, has high ethnic plurality with more than 225 tribal communities and contains rich indigenous knowledge systems. The region still has more than 64% of its total geographical area under forest cover. About 50% of the total number of species of vascular plants (7000- 8000 species) of India are found within this region. The fact that a large number of primitive flowering plants have been found in the north-eastern region of India indicates this area as one where, perhaps, the evolutionary development of several angiosperms like *Magnolia*, *Michelia*, *Rhododendron*, *Camellia*, and orchids could have taken place.

Different micro-ecosystems, such as cultivated plains, grasslands, meadows, marshes, swamps, scrub forests, mixed forests, deciduous forests, semi-evergreen forests to evergreen tropical rain forests are found here.

The region has at least 7,500 species of flowering plants (Darlong 1998). Out of 315 families of flowering plants, more than 200 are represented in this region. Many monogeneric families are represented, e.g. *Coriariaceae*, *Nepenthaceae*, *Turneraceae*, *Illiciaceae*, *Ruppiaceae*, *Siphonodontaceae*, and *Tetracantraceae*. Orchids are represented in India by over 1200 species of which 825 species are represented in the Eastern Himalaya and the north-east region (Hegde 2000). Some rare ornamental orchids are *Paphiopedilum fairieanum*, *P. venustum*, *P. insigne*, *P. villosum*, *P. spicerianum*, *P. hirsutissimum*, *Anoectochilus sikkimensis*, *Cymbidium eburneum*, *Vanda coerulea*, *Renanthera imschootiana*, *Pleione maculata*, *Dandrobium nobile*, *D. hookerianum*, and *D. densiflorum*.

Rhododendrons are well represented in the Eastern Himalaya, with 80 out of 90 taxa in India, being confined to this region. According to Sastry and Hajra (1983) approximately 50% of Rhododendron species are rare and threatened, like *Rhododendron nuttalli*, *R. falconeri*, *R. edgeworthii*, *R. elliotii*, *R. hookeri*, *R. macabeanum* and *R. wattii*. Of about 130 species of Indian bamboos, 58 species are found in north-east India. Rare bamboo species include *Arundinaria mannii*, *A. rolloana*, *Phyllostachya assamica* and *P. mannii* (*North-east Ecoregional BSAP*).

The largest root parasite, *Sapria himalayana*, occurs in Manipur's Mishmi hills and Akka hills. Among interesting saprophytic plants are *Monotropa uniflora*, *Epipogium roseum* and the giant orchid *Galeola falconeri*. Among the insectivorous plants, *Drosera burmanii*, *D. peltata*, *Aldrovanda vesiculosa* and the endemic *Nepenthes khasiana* are important.

Various plant species endemic to north-east India include *Uvaria lurida*, *Magnolia gustavi*, *M. paeliana*, *Pachylarnax pleiocarpa*, *Ilex embellioidea*, *Distylium indicum*, *Merilliopanax cordifolia*, *Amblaganthus multiflorus, Ardisia quinqueangularis*, *A. rhycophylla*, *Hoya manipurensis*, *Boehmeria tirapensis*, *Acanthophippium sylhetensis*, *Aphyllorchis vaginata*, *Eria barbata*, *Gastrodia exilis*, *Paphiopedilum insigne*, *Hedychium calcaratum*, *H. dekianum*, *H. marginatum* and *Nepenthes khasiana*.

The region is rich in faunal diversity. An estimated 3,624 species of insects, 50 molluscs, 236 fishes, 64 amphibians, 137 reptiles, 541 birds (excluding migratory birds) and 160 mammalian species have been described so far (Darlong, 1998). The golden langur (*Presbytis geei*) and the brow-antlered deer (*Cervus eldi eldi*) of Manipur are two species/sub-species not found elsewhere in the world. Other animals like the hispid hare (*Caprolagus hispidus*), the pigmy hog (*Sus salvanius*) and the great Indian one-horned rhinoceros (*Rhinoceros unicornis*) now survive in this region in scattered, isolated pockets. Malayan or Chinese species such as the clouded leopard (*Neofelis nebulosa*), the marbled cat (*Felis marmorata charltoni*), the golden cat (*Felis temminicki*), the spotted linsang (*Priondon pardicolor*), the large Indian Civet (*Viverra zibetha*), the binturong (*Arctictis binturong*), the crab-eating mongoose (*Herpestes urva*), the red panda (*Ailurus fulgens*), the ferret badger (*Melogale moschata* and *M. personata*), the hog badger (*Arctonyx collaris*), the bay bamboo rat (*Cannomys badius*), the hoary bamboo rat (*Rhizomys pruinosus*) and the hoolock gibbon (*Hylobates hoolock*) have their range of distribution starting from this region. This region is an interesting meeting ground of the Indian and Indo-Chinese (part of Oriental fauna) and palaearctic species (Choudhary 2001)

The Great one-horned Rhinoceros is now confined to a few pockets of suitable habitat in the Brahmaputra valley and two small sanctuaries in North Bengal. With an extant population of less than 2000, the species is still considered on the verge of extinction. The Golden langur is endemic to this region and was only recently discovered, in 1955-56. Its range of distribution is a small area of reserved forest between the Manas and Sankosh rivers along the foot of the Bhutan Himalayas. Within India, the total population may be around 2000 (Choudhary 2002) The Pygmy hog, thought extinct till its rediscovery in 1972, has disappeared from most of its range. However, it is still known to exist in Manas and Bornadi Wildlife Sanctuaries. The surviving population would be around 500-600 animals.

The Manipur brow-antlered deer or the *sangai* is the world's most endangered sub species of deer. The animal is confined to a small area in Keibul Lamjao National Park in Manipur. The population of *sangai* was 180 as per a March 2003 census released by the Government of Manipur (Salam Rajesh, personal communication 2003). The captive population of this species in 2002 was 142. The primary habitat of this deer is the swamp with *phumdi* vegetation (aquatic and marsh plants such as *Phragmites karka*, *Saccharum* spp., *Alpinia allughas*, *Arundo donax*, and *Salix* spp.)

Sources (except as otherwise mentioned): IIPA report 1996; Arora and Nair 1983; Bahadur and Jain 1983; Hooker 1849; Lahan 1992; Rao and Hajra 1986; Rao and Murti 1990; North-east Ecoregional BSAP; Manipur State BSAP

4.1.2.2 Wild Animal (Including Protozoan) Diversity

(This section is based on the *Wild Animal Diversity Thematic BSAP*).

India has a very rich range of fauna, which is still far from completely documented. The efforts of the Zoological Survey of India (ZSI) have been quite detailed in documenting India's faunal wealth (ZSI 1991; Alfred *et. al.*, 1998), though there has been no replacement for the comprehensive *Fauna of British India* (Boulengar 1890; Fraser 1933; Bhatia 1936; Talbot 1939; Pocock 1939; Cameron 1939). Detailed information on certain groups has been published, e.g. birds by Ali and Ripley (1983) and mammals by Corbet and Hill (1992) and Prater (1993). Revised checklists of some vertebrate taxa have been published fairly recently, incorporating new species and new records (e.g. Nameer 2000 for mammals, Dutta 1997 for amphibians, Das 1997 for reptiles).

Many scientists (e.g., ZSI 1998) admit that the faunal documentation is far from complete for many invertebrate taxa. This is particularly striking in the case of several marine phyla like *Porifera*, *Cnidaria*, *Phoronida*, *Bryozoa*, *Sipuncula*, and *Echiura* and some major phyla such as *Nematoda*, *Annelida*, and *Arthropoda*. This situation is not very surprising, since the described species on Earth form only a small part of the nearly 10-30 million species that are estimated to exist (Pimm and Raven 2000). Most of the undiscovered species belong to a few terrestrial invertebrate taxa such as insects.

It should also be noted that the species inventory for India as a whole is incomplete to varying extents even among vertebrates, except perhaps birds.

In addition to incomplete documentation, taxonomic revisions and ambiguities often confound comparisons of species richness and endemism across regions. Following the popularity of the phylogeographic species concept in place of the biological species concept, some faunal revisions have increased the number of species considerably, e.g. that of non-human primates in India from 15 to 21 (Groves 2001). In contrast, some revisions have drastically reduced the number of species, e.g. *Porifera* and *Cnidaria*.

Faunal Species Richness and Endemism

Nearly 90,000 species of fauna has been reported from India, a little over 7% of the world's reported animal diversity (*see Table 4.27*).

There is considerable variation in the representation of different phyla and subphyla, with the percentage of species in India varying from as low as 1% (*Sipuncula*) to as high as about 40% (*Echiura*). However, much of this variation is due to several minor phyla and subphyla, which are primarily marine, and might reflect inadequate species documentation rather than real differences. Among the more speciose phyla or lower taxa, India has between 4 and 12% of the global species.
Endemism varies considerably among the different taxa. It is generally very low or even absent among the phyla

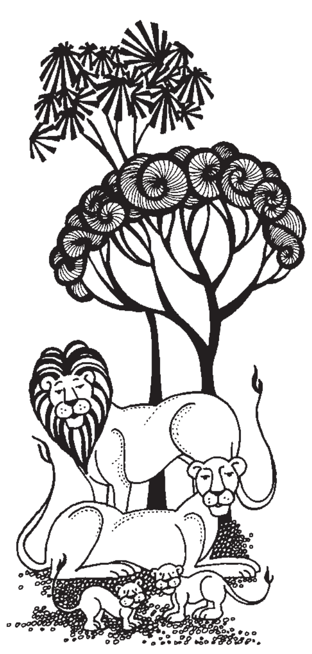


Table 4.27 Comparison Between the Number of Faunal Species in India and the World

Taxonomic group	No. of species World	No. of species India	Share of India in World (%)
Protista			
Protozoa	31250	2577	8.24
Total (Protista)	31250	2577	8.24
Animalia			
Mesozoa	71	10	14.08
Porifera	4562	486	10.65
Cnidaria	9916	842	8.49
Ctenophora	100	12	12.00

Platyhelminthes	17500	1650	9.43
Nemertinea	600	–	–
Rotifera	2500	330	13.00
Gastrotricha	3000	100	3.33
Kinorhyncha	100	10	10.00
Nematoda	30000	2850	9.50
Nematomorpha	250	–	–
Acanthocephala	800	229	28.62
Sipuncula	145	35	24.14
Mollusca	66535	5070	7.62
Echiura	127	43	33.86
Annelida	12700	840	6.61
Onychophora	100	1	1.00
Arthropoda	987949	68389	6.90
Crustacea	35534	2934	8.26
Insecta	867391	59353	6.83
Arachnida	73440	5818	7.90
Pycnogonida	600	16	2.67
Pauropoda	360	–	–
Myriapoda			
Chilopoda	3000	100	3.33
Diplopoda	7500	162	2.16
Symphyla	120	4	3.33
Merostomata	4	2	50.00
Phoronida	11	3	27.27
Bryozoa (Ectoprocta)	4000	200	5.00
Entoprocta	60	10	16.67
Brachiopoda	-300	3	1.00
Phogonophora	80	–	–
Priapulida	8	–	–
Pentastomida	70	–	–
Chaetognatha	111	30	27.02
Tardigrada	514	30	5.83
Echinodermata	6223	765	12.29
Hemichordata	120	12	10.00
Chordata	48451	4952	10.22
Protochordata	2106	119	5.65
(Cephalochordata + Urochordata)			
Pisces	21723	2546	11.72
Amphibia	5150	216*	5.07
Reptilia	5817	495*	8.50
Aves	9702***	1225**	13.66
Mammalia	4629	390	8.42
Total (Animalia)	**11,96,903**	**86,874**	**7.25**
Grand Total (Protista + Animalia)	**12,28,153**	**89,451**	**7.28**

*Source: Alfred et. al., 1998; *Das, I. 2001; ** BNHS 2002, *** Sibley and Monroe 1993* that are exclusively or primarily marine. This is understandable, given the wide distribution of most marine species and their dispersal capabilities. There are important exceptions among some minor phyla; 12 out of 43 species in *Echiura* (28%), 7 out of 10 species in *Kinorhyncha* (70%), and 64 out of 100 species in *Gastrotricha* (64%). Although this has been attributed to highly specialised microhabitat associations of these species, it is just as likely due to our highly incomplete knowledge of their distribution (Alfred *et. al.*, 1998). Among terrestrial animals, the extent of endemism is relatively well established, and is highest among the lower vertebrates. This is especially true of amphibia (>50%), which are considered autochthonous (indigenous) to peninsular India. Freshwater fish and reptiles also show relatively high endemism (>30%). Endemism among mammals and birds is relatively low (<10%), reflecting the fact that these are relatively recent elements in Indian fauna. Endemism among invertebrates has been poorly quantified at the level of phyla or class. At this level, endemism probably varies between 10 and 20%; however, *Hymenoptera* has been reported to have very high levels of endemism, comparable to that in *Amphibia*.

The rich faunal diversity in India, especially the terrestrial fauna, is not uniformly distributed. There are two

Table 4.28 Estimated Number of Endemic Species in India

Group	Total No. of Species	Endemic Species	Percentage (%)
Protozoa			
Freeliving	1247	90	7.21
Parasitic	1330	550	41.35
Mesozoa	10	10	100.00
Porifera			
Freshwater	31	13	41.93
Cnidaria	842	10*	–
Platyhelminthes	1622	1160	71.51
Rotifera	330	23	6.96
Gastrotricha	100	64	64.00
Kinorhyncha	10	7	70.00
Nematoda	2850	400*	–
Acanthocephala	229	203	88.64
Mollusca			
Terrestrial	1487	498	33.50
Freshwater	183	77	42.07
Echiura	43	12	27.90
Annelida			
Oligochaeta	473	368	77.80
Hirudinea	59	25	42.37
Arthropoda			
Crustacea	2934	501	17.07
Insecta	59353	20717	34.90
Arachnida	5818	2623	45.08
Phoronida	-3	1	33.33
Bryozoa	200	12*	–
Endoprocta	10	1	10.00
Chaetognatha	111	3	2.70
Chordata			
Pisces	2546	223	8.75
Amphibia	216**	53	24.53
Reptilia	495**	182	36.76
Aves	1225***	176	14.36
Mammalia	390	36	9.23

**Complete data not available, hence percentage not calculated.*

*Source: Alfred et. al., 1998; ** Das, I. 2001; *** BNHS.*

major centres of species richness, the Western Ghats and the Eastern Himalaya. While the former also shows high levels of endemism, the latter shows low endemism due to shared international borders with several countries. Species richness and endemism in the Western Ghats is well established in the case of vertebrates. For instance, excluding the migratory birds, there are 938 species of vertebrates in the Western Ghats, 36% being endemic (*see Table 4.29*). Information on species richness and endemism among invertebrates is not comprehensive except for some taxa, e.g. butterflies (27% of the Indian fauna and 11% endemism). There are localities in the north-east with extremely high species richness and endemism. According to Tikader (1983) 21 mammals, 17 birds, one reptile and one amphibian are supposed to be endemic to the north-east region. However, some scientists refute these views, as many of these animals may be found in the adjacent countries. Sangai (*Cervus eldi eldi*) is found only in Manipur and is endemic to the region. However, sangai as a sub-species is endemic but not as a species, as other sub-species are found in Myanmar and Thailand. In the case of amphibians, at least two may be endemic to this region, as specimens from other areas are yet to be obtained. These amphibians are Garo hills tree toad (*Pedostibes kempi*) and *Kalophrynus orangensis* (Anwaruddin Choudhary, personal communication 2003). Sikkim, which is less than 5% of the Western Ghats in area, has more species of mammals, birds, and butterflies.

Table 4.29 Distribution of Endemic Vertebrates in the Western Ghats

Class/States	Gujarat	Maharashtra	Goa	Karnataka	Tamil Nadu	Kerala	Total
Mammals	0	1	1	8	10	12	14
Birds	2	9	13	17	19	18	19
Reptiles	4	13	17	36	71	69	97
Amphibians	3	19	9	50	44	65	94
Fishes	2	30	7	50	43	72	116
Total	11	72	47	161	187	236	340
Per cent	3.0	21.0	14.0	47.0	55.0	70.0	

Source: Nair and Daniel 1986; Swengel 1991; Daniels 1992, 1993, 1997 a&c; Dutta 1997; Das 1997; Easa 1998; Menon 1999; Nameer 1998; Kunte et. al., 1999; Rema Devi, personal communication 2002; Gaonkar 1996; Johnsingh 2001.

Quantitative information on the distribution of fauna in different parts of India is not readily available. The best description of the distribution of fauna, although not quantitative, is perhaps the biogeographic classification of India (Rodgers and Panwar 1988, Rodgers *et. al*., 2000). The Zoological Survey of India has brought out lists of fauna of several states in India, and the others are in the process of publication (J.R.B. Alfred, personal communication 2002).

Threatened Species

Global trends in threatened fauna over a period ranging from 1996 to 2002 indicate a distinct increase in the number of threatened species both among vertebrates (from 3,314 in 1996 to 3,521 in 2002), and invertebrates (from 1891 in 1996 to 1932 in 2002) (IUCN 2002).

India unfortunately figures fairly high up in global assessments of threatened species using the revised IUCN threat criteria and categories (Critically Endangered, Endangered and Vulnerable) across taxa. It contains 366 species of animals categorized as 'Threatened' by IUCN (*2002, IUCN Red List of Threatened Species*); this is approximately 6.73 % of the world's total number of threatened faunal species (5,453 species). This includes 148 species of mammals, 138 birds, 32 reptiles, 3 amphibians, 17 fish and 28 invertebrate species (*see Annexure 7*). Threatened Fauna from India by Taxonomic Groups). The analysis of the data on threatened species by threat categories (*see Table 4.30*) reveals that out of 366 species listed as threatened, 18 are critically endangered (Cr), 52 species are endangered (En), 150 species are vulnerable (Vu), while 10 species are at lower risk or conservation dependent (LR/cd), 101 species are at lower risk but near threatened (LR/nt), while the data for 35 species is not available (DD). On analysis of the threat categories by groups (at global level), it is found that out of 366 species of threatened Indian fauna, 220 species are at significant risk, of which 88 species are of mammals, 72 birds, 25 reptiles, 3 amphibia, 9 fishes and 23 species of invertebrates (IUCN 2002). Further analysis of the critically endangered list reveals that, out of 18 species, 5 are mammals, 7 are birds, 4 reptiles, and one insect.

Of these 366 species, the populations of only three species are stable, 101 species are showing distinct deteriorating trends and the population status of 75 species is uncertain, while the population trends of 187 species have not been assessed. None of the species is, however, showing an upward population trend.

Table 4.30 Threatened Faunal Species in India by Threat Category (2002 Red List)

Threat Category	Animals
Extinct (EX)	0
Extinct in the Wild (EW)	0
Critically Endangered (CR)	18
Endangered (EN)	52
Vulnerable (VU)	150
Lower Risk/Conservation Dependent (LR/cd)	10
Lower Risk/Near Threatened (LR/nt)	101
Data Deficient (DD)	35
Total	366

Source: 2002 IUCN Red List of Threatened Species (http://www.redlist.org)

The analysis of the threatened species by ecosystems shows that 295 of the 466 species are terrestrial, 79 are freshwater, 45 are marine; 36 species occur both on land and in freshwater, 10 species are common in freshwater and marine ecosystems, and one species, *Lutra lutra* (Common Otter), is common to terrestrial, freshwater and marine ecosystems.

A more recent and comprehensive assessment on Threatened Species by Kumar and Khanna (2003) is given in *Table 4.31*. The assessment presented below is based on the series of Conservation and Management Planning (CAMP) Workshops. CAMP has not assessed the categories for birds.

Table 4.31 Number of Threatened Species

	Total Number of Species Assessed	No. of Threatened Species	No. Extinct Species
Soil Invertebrates	95	57	–
Amphibians	163	93	–
Reptiles	362	168	–
Mangrove Invertebrates	41	10	–
Marine Fishes	52	10	–
Freshwater Fishes	323	217	–
Mammals	228	94	4
Total	1212	639	4

Source: Kumar and Khanna 2003

Box 4.11 Extinct Species

The IUCN definition for extinction is as follows: 'A taxon is extinct when there is no reasonable doubt that the last individual has died.' Very often the major concern for wild fauna and flora is not extinction but a step before that, which is extinction from the wild. The IUCN definition for extinct in the wild goes: '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.'

It is clear from these definitions that it is not easy to declare a species as extinct, even though it may have gone extinct several years ago. A high level of sustained effort is required to confirm the extinction of a species. By the time this is done, it is too late for the species being assessed. At least in the time scales that conservation is planned for, only extinction being caused by human mediated causes is being dealt with, not that due to natural evolutionary forces. So far 23 species of larger animals are reported to be extinct from India, including the Asiatic cheetah (*Acionyx jubatus veneticus*), the lesser one-horned rhino (*Rhinoceros sondaicus*), and the pink-headed duck (*Rhodonessa caryophyllacea*). The Malabar civet (*Viverra civettina*), listed as 'possibly extinct' in the Red Data Book in 1978, was 'rediscovered' when skins of recently killed animals were obtained by ZSI in 1987 from northern Kerala; live animals have however not been sighted for several decades.

(Compiled by Ravi Chellam and Ajith Kumar)

Protozoa

These microscopic organisms are now considered a separate kingdom. In India 2577 species have been reported so far, constituting about 8% of the world's known species (Alfred *et. al.*, 1998). Out of the total Indian Protozoa species, 1247 are freeliving (52%) and 1330 are parasitic species (48%). These species belong to 161 families and 358 genera. Endemism in Indian protozoans varies very greatly, from about 90 species among free-living protozoans to 550 in parasitic species.

Porifera

This phylum includes sponges, a group of sedentary, multicellular, predominantly marine, filter-feeding animals that have a porous body (hence the name '*Porifera*', which means 'pore-bearers'). With an evolutionary history of about 570 million years, these are amongst the oldest of living animals. Sponges are of special importance to physiologists and immunologists, due the fact that they have no histological (specialised tissue) systems but only functional ones; their cells can change their structure, function and position whenever necessary (Thomas and George 1993).

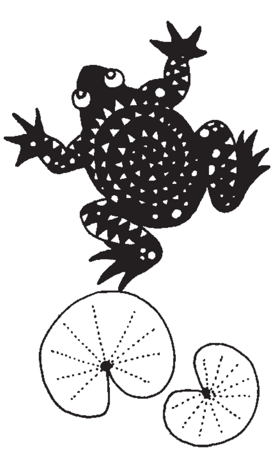
Porifera are represented in India by 486 species, about 10.65% of the world's known diversity of about 4562 species. Sponges are widely distributed along India's coasts, and in the island clusters. The Gulf of Mannar and the Palk bay are rich in sponge growth; 275 species have been reported from this area. 25 species have been reported in the Gulf of Kachchh and 61 species in the Andaman and Nicobar islands (Alfred *et. al.*, 1998).

Endemism is very high among the freshwater sponges, with 13 of the 33 freshwater species recorded in India being endemic (Alfred *et. al.*, 1998). Endemism in the group of sponges as a whole is not known.

Cnidaria

Cnidaria includes radically symmetrical multicellular organisms. Their body wall is made up of two layers of cells, the ectoderm and endoderm, with an intervening jelly-like substance called mesoglea.

The global diversity of *Cnidaria* is about 10000 species (Alfred *et. al.*, 1998), of which India has about 842 (8.49%). Cnidarians show great diversity in habit and habitat. Their body size ranges from less than a millimeter like in *Halammohydra* to several metres in pelagic forms like *Physalia*. Cnidarians are predominantly marine but three of the families of the hydrozoan Order (*Hydroida*, *Hydridae*, *Limnocnidae* and *Moersiidae*) are exclusively freshwater or brackishwater inhabitants, while two others (*Clavidae* and *Olindiidae*) have freshwater or brackishwater representatives.



The monotypic genera endemic to India are *Coeloseris* (*Scleractinia*), *Mena* and *Nevadne* (*Actiniaria*) and *Mansariella*. Some of the species endemic to India are *Amphicaryon intermedia*, *Anactinia pelagia*, *Bythocellata cruciformis*, *Limmocnida indica*, *Moersia gangetica*, *Phialucium multitentaculatum* and *Limnocnida indica*. The only freshwater medusa in India occurs in the Krishna headwaters in the Western Ghats.

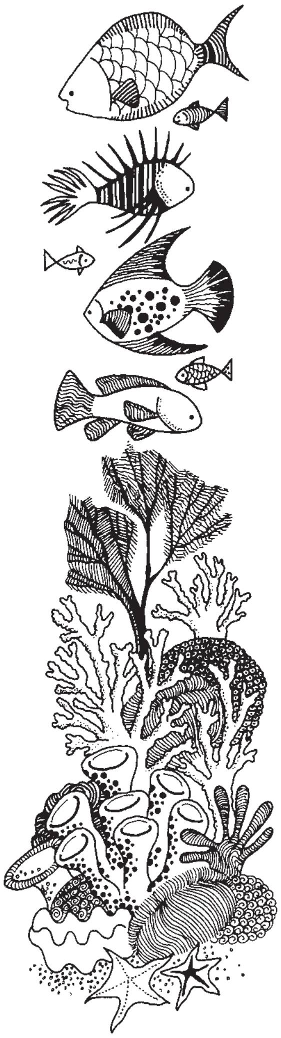
Scleratinia

Commonly known as stony corals, these exclusively marine animals (polyps) excrete a calcareous substance which forms an exoskeleton (outer casing). Corals can be either colonial or solitary and sedentary in habit; the former are the builders of the massive coral reefs that are found in tropical seas.

In India there are 344 species (M.V.M. Wafar, personal communication 2003). No endemic species has so far been recorded from India. However, the Andaman and Nicobar Islands have several species that are not found in other parts of India, including those belonging to the genera *Pectinia*, *Scapophyllia*, *Coeloseris*, and *Oulophyllia* (Pillai 1983).

Gorgonids

Consisting of horny corals, sea fans and sea whips, gorgonids number 408 species worldwide. In India, information on gorgonids is available only from the Gulf of Mannar, Andaman and Nicobar Islands and the Gulf of Kachchh. A total of 80 species have been recorded (Thomas and George 1993). However, recent surveys by the Central Marine Fisheries Research Institute indicate that there may be more than 100 species in the Indian seas, representing as much as 25% of the worldwide diversity (*ibid*).



Ctenophora

Transparent marine animals resembling coelenterates, these organisms are also called comb-jellies due to their paddle-like comb plates stretching along the length of the body. They appear to have evolved from the same ancestor as did coelenterates, and are known to be at least 400 million years old.

Of a global total of 100 species, India has recorded 12 species (Alfred *et. al.*, 1998). However, not much more appears to be known about these creatures.

Platyhelminthes

Commonly known as flatworms, platyhelminthes are bilaterally symmetrical and ribbon-shaped. They are more complex than coelenterates in that their organs are made up of tissues that are further organised into systems. These animals are mostly parasitic. Three classes are distinguished: *Turbellaria* (free-living flatworms), *Trematoda* (flukes), and *Cestoda* (tapeworms).

Worldwide, some 17,500 species have been recorded, of which India contains 1650 species, 9.43% of the world total (R.K. Ghosh 1993, Alfred *et. al.*, 1998). There appears to be no information on endemicity amongst flatworms, nor on threatened and exotic species, if any.

Nemertina

Called ribbon-worms, they are characterised by a long anterior proboscis which can extend to as much as three times the body length, and which is used for capturing prey and exploring the surroundings. They differ from flatworms in possessing an anus and a blood vascular system. Exclusively marine, they may be as old as coelenterates – from the Cambrian period, over 500 million years ago.

No information is available on the diversity of nemertines in India (ZSI 1991).

Gnathostomulida

These are microscopic worms which have a typical feeding apparatus made of hard non-cellular material. These animals are mostly found in saltwater, in the spaces between sand grains, or on algae and seagrass. They are likely to have evolved between 200 and 500 million years ago.

No information is available on their diversity in this country (ZSI 1991).

Gastrotricha

This consists of a group of predominantly marine invertebrates that are characteristically meiobenthic (small fauna in marine substratum). These worms are extremely minute, from 0.05 to 4 mm in length. Some species live in brackishwater and freshwater ecosystems as well. Free-living and bilaterally symmetrical, these animals have over 200 adhesive tubes extending from their posterior end, which are used for clinging to the substratum.. They have probably originated from nematodes or flatworms.

Of a world total of 3000 species, India has recorded about 100, or 3.33% (Alfred et. al., 1998). An extremely high degree of endemism characterises this group. About 60 of the species are recorded only within India (ZSI 1991).

Rotifera

This is a group of microscopic organisms, whose name, *Rotifera* is derived from a peculiar disc-like anterior which looks like a pair of revolving wheels due to the synchronised beating of their coronal cilia (ZSI 1991). They may have evolved from flatworms. These creatures are mainly found in freshwater habitats, but about 5% of the species have now managed to occupy other aquatic habitats as well. Rotifers are critical links in the food web and in the ecosystem, aiding biological productivity by a very rapid turnover rate and metabolism, and feeding on bacteria and detritus. They are in turn food for fry, fingerlings, and adult of several fish species.

Of a global diversity of 2500 species, India harbours a recorded 330 species. (Sharma 1997 as quoted in Alfred *et. al.*, 1998). This represents 13.2% of the world total. The group has a very wide distribution in India.

Endemism has been recorded among 23 Indian species, about 7% of the total diversity. These endemic taxa include *Lepadella kostei*, *L. triprojectus*, *Lepadella ovalis larga*, *L. nartiangensis*, *L. patella elongata*, *Platyllas quadricornis andhraensis*, *Euchlanis brrahmae*, *Pseudoeuchlanis longipedis*, *Proales indirae*, *Ascomorpha saltaus indica*, *Trichocerca tropis*, *Asplanchropus bimavaerensis*, *Conochilus arboreum*, *C. dossuarius asetosus*, *Ptygura stephanion*, *Sinantherina triglandularis*, and *Rotaria ovata* (ZSI 1991).

Kinorhyncha

Descended from flatworms, *Kinorhyncha* are microscopic, invertebrate animals living in the meiobenthic zone of marine areas and estuaries. They are occasionally seen associated with littoral algae and a number of invertebrate animals. Their name comes from their mode of movement – in which they pull themselves along by the rings of spines on their heads. Most of them are over 1 mm long.

Worldwide, a total of 100 species have been recorded. Of this, 10 (10%) are found in India. (Alfred *et. al.*, 1998). All the 6 families recorded in the world are found in India. The *Kinorhyncha* are distributed all along the east and west coast including the Lakshadweep and Andaman and Nicobar islands.

Endemic species number 7, or 70% of the Indian species. These are *Echinoderes bengalensis*, *E. ehlersi*, *E. andamanensis*, *Condyloderes paradoxus*, *Sphenoderes indicus*, *Cateria gerlachi*, and *Neocentrophyes satyai* (ZSI 1991).

Acanthocephala

Acanthocephala are a group of thorny-headed, endoparasitic worms. These animals parasitise all groups of vertebrates, and also some invertebrates such as molluscs, crustaceans and insects (Alfred *et. al.*, 1998).

Of a world total of 800 species, India has recorded 229, or 28.62% of the species. Out of 229 species of Acanthocephala reported from India, 203 species have been reported from the Indian region alone, a very high rate of endemism (*ibid*).

Nematoda

Commonly called roundworms and threadworms, these animals are cylindrical invertebrates with a non-segmented body and no appendages. A large number are parasites on vertebrate and invertebrate animals, e.g. *Ascaris lumbricoides*, *Dracunculus medinensis*, *Ancylostoma dudenale*, *A. Caninum* and *Enterobium vermicularis*, while others are parasites of plants and free-living nematodes, e.g. *Tylenchorhynchus mashhoddi*, *Hoplolaimus indicus*, *Pratylenchus zea*, *P. indicus*, *P. thornei*, *Hirshmanniella oryzae*, *H. gracillis*, and *Heliocotylenchus* spp. (Baqri 1993).

Of a world figure of 30,000 species, India has a total of 2,850 species, or 9.5% (Alfred *et. al.*, 1998). There appears

to be no information on endemism in this phylum.

Bryozoa (Ectoprocta)

These are invertebrates with an exoskeleton usually made of calcareous material, occasionally with cuticular (outermost chiton layer) or gelatinous material. These animals are mostly marine. An ectoprocta colony resembles seaweed or moss, forming gelatinous or hard mats on algae, rocks, and the bottoms of sea vessels.

Worldwide, about 4000 bryozoan species have been recorded. In India, the reported number is 200 species, about 5% of the global total (Alfred *et. al.*, 1998).

Entoprocta

Akin to bryozoa, entoprocta are also predominantly marine invertebrates. The difference is that whereas bryozoa have an anus that opens outside the circle of tentacles surrounding the mouth, entoprocta have both anus and mouth within this circle. Except for one single freshwater genus *Urnatella*, all other entoprocta are marine, occurring most frequently attached by stalks to rocks, shells, algae, or other animals.

Entoprocta in India include a total of 10 species, or 16.67% of a total of 60 species in the world.

Phoronida

This is an extremely small phylum of slender worm-like creatures which secrete a leathery, membranous, or slimy tube around themselves, and have over 1500 hollow tentacles for food gathering. They can range from 1 mm to 50 cm in length.

Only 11 species are known from the world's marine areas, three of these from India (Alfred *et. al.*, 1998). *Phoronis australis* is reported from Gujarat coast, *Phoronis psammophila* is reported from Porto Novo in Tamil Nadu and the Gulf of Mannar, while *Phoronis bhaduraii* has been recorded on the sandy beaches of Digha, West Bengal. Only the latter is endemic to India (Alfred *et. al*., 1998).

Brachiopoda

Commonly called lamp shells, these marine creatures have two opposed hard shells. They differ from clams and other molluscs in having a dorsal and ventral shell, rather than a left side and a right side shell, as also in possessing a lophophore (an organ with several tentacles, surrounding the mouth). The earliest fossil record is of 400 million years ago. Two classes are distinguished: *Inarticulata* (hingeless) and *Articulata* (hinged).

Worldwide, some 300 species have been recorded, of which India harbours just 3 (ZSI 1991; Alfred *et. al.*, 1998). No further information is available.

Mollusca

Containing the animals commonly known as 'shells', this group consists of small, soft-bodied creatures, most of which are covered with a hard calcareous shell. Molluscs include mussels, oysters, clams, snails, slugs, squids, and cuttlefishes. A radula – a hard strap made of chitinous material and used for gathering food and scraping or boring the ground – is unique to these animals (Subba Rao 1993).

Molluscs are one of the animal kingdom's most diverse groups, with a worldwide recorded total of 66,535 species. Of these, India has 5,070, or about 7.62% (Alfred *et. al.*, 1998).

Some genera have their major distribution centres in India, such as slugs of the genera *Mariaella*, *Incillaria*, *Kasperia* and *Anadenus*.

Mysorella and *Mainwaringia* are the monotypic genera. The genus *Cremnoconchus* is endemic to the Western Ghats. The genera *Scaphula*, *Novaculina*, *Tanysiphon*, and *Modiolus* (all in the Gangetic plains) provide interesting material for evolutionary studies.

Endemism is very high among freshwater molluscs, with about 66% of the Indian genera and 41.8% of the species not recorded anywhere else in the world. Among land molluscs, 33.5% endemism has been recorded, while endemism among marine molluscs has not yet been estimated.

Some regions display very high endemism. For instance, 71 of the 101 recorded species in the Andaman and Nicobar Islands are endemic. However, many of these molluscs were collected in the last century, and their current status is not known. Some may now be extinct or threatened. This is also the case with Meghalaya, where only 131 of the 213 species of land molluscs earlier recorded have been recently reported.

Rare molluscs include *Charonia tritonis*, *Conus milnedwardsi*, *C. bengalensis*, *Lambis violacea*, *Strombus listeri*, *Tibia powisii*, *Lilliotis tumida*, *Arcidopsis footei*, *Acostaea dalyi*, *Boysia boysia*, *Camptonyx theobaldi*, *Cremnoconchus syhadrensis* and *C. carinatus*. Of these, *Lilliotis tumida*, *Arcidopsis footei* and *Acostaea dalyi* are freshwater molluscs endemic to the Western Ghats, not collected for the last 100 years, and therefore possibly extinct.

Priapulida

Short, plump, and ranging from a mere 0.05 cm to about 20 cm in length, these animals have a short proboscis covered with spiny papillae and a retractable mouth. They inhabit mud or sand, and are known from fossil records dating back to 530 million years ago.

No estimate exists of their diversity in the country (ZSI 1991). So far, only 8 species have been recorded in the world.

Sipuncula

Also called 'peanut worms' these invertebrates have characteristic ciliated bushy tentacles around the mouth. They inhabit coral, rocky, sandy and muddy ecosystems of marine or estuarine areas. As a group they have wide adaptability and are commonly found in polar, temperate, and tropical seas, though most inhabit the intertidal zone of warm seas (ZSI 1991).

Worldwide, a total of 145 species have been recorded, of which India has 35, or about 24.14%,

None of the Indian species are endemic. There are two monotypic genera, *Antillisoma* and *Cloeosiphon*.

Echiura

Commonly known as spoonworms, these soft-bodied marine invertebrates have a mobile proboscis, and have evolved at least 450 million years ago. They are widely distributed, being found in the polar, temperate and tropical seas.

Worldwide, 127 species have been recorded. Of these, 33 species have been recorded from the Indian coasts, and 43 (33.86%) from the Indian Ocean as a whole (Haldar 1993; Subba Rao 1993). The Indian species belong to 4 families (of the 5 found in the world) and 14 genera.

The maximum concentration of species has been recorded from the Gulf of Khambat and the Gulf of Kachchh (Haldar 1993). High concentrations are also found in the islands of Lakshadweep, Andaman and Nicobar, and Gulf of Mannar. A few mud-dwelling forms are found on the coasts of Kerala, West Bengal, and Orissa.

12 of the Indian species are known to be endemic (Alfred *et. al.*, 1998).

Annelida

True worms (in that they have segmented bodies), *Annelida* are also one of the more diverse groups of animals. Three classes are distinguished: *Polychaeta* (marine bristle worms), *Oligochaeta* (terrestrial worms), and *Hirudinea* (leeches).

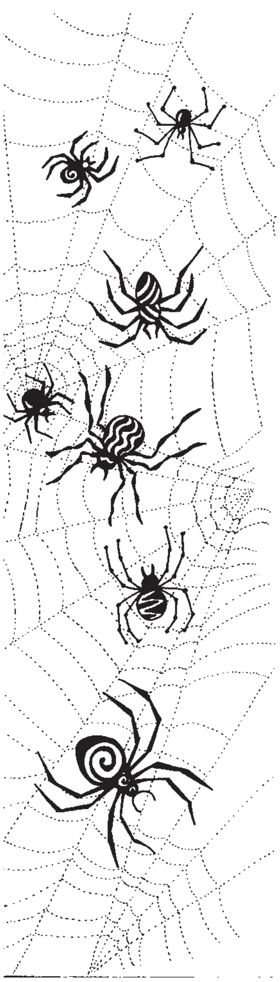
Worldwide, about 12,700 species have been recorded, of which India has 840, or 6.61% (Julka 1993; Alfred *et. al.*, 1998).

Endemism varies between different classes within the group. 87% of the known terrestrial worms are endemic, while 42% of the leeches are also not found anywhere else in the world. Endemism amongst marine worms is not known.

There are a large number of introduced species, including 49 species of earthworms (13% of the total diversity), and 3 species of leeches. In the Andaman and Nicobar Islands, 20 (74%) of the 27 species of earthworms are introduced.

Tardigrada

Tradigrades are commonly called 'Water Bears'; these creatures have a head and forebody covered with a thick, non-chitinous protein cuticle which is periodically moulted. Their locomotion consists of a slow, deliberate movement on four pairs of unjointed stumpy legs.



Out of a world total of 514 species, India harbours about 30 species, or 5.83 % (Alfred *et. al.*, 1998).

Onychophora

A very small group of animals named after their pincer-like appendages, this is believed to be the connecting link between *Annelida* and *Arthropoda*. Also called 'Velvet Worms', there are about 100 species recorded in the world. In India, only one species, *Typhloperipatus williamsoni*, has been recorded from the north-eastern Himalayan area (ZSI 1991). Since this record in 1911-12, there has been no further report of this species.

Arthropoda

Distinguished by their segmented bodies and appendages, with the former divided into head, thorax, and abdomen, arthropods are the most numerous and diverse of animals on earth.

Worldwide, a total of 9,87,949 species has been recorded. Of these, 68,389, or about 6.9%, have been found in India (Alfred *et. al.*, 1998). The major classes are described below:

- **Crustacea:** A large and diverse group of animals that are mainly aquatic, with a body covered by a chitinous cuticle, and the head displaying a pair of antennae. This group consists of prawns, crabs, hermit crabs, shrimps, woodlice, fish-lice, barnacles, lobsters, and other commonly known animals of saltwater and freshwater ecosystems. The majority of these are aquatic, breathing with gills or through the general surface of the body. They are well distributed among freshwater and saltwater ecosystems. India has 3,220 species (Venkatraman and Krishnamoorthy 1993). This comprises 8.3% of the world total of about 38,840 species.

  The vast majority (nearly 95%) of Indian crustaceans are marine, spread mainly over the Andaman and Nicobar Islands, the Gulf of Mannar, the Gulf of Kachchh, and the Lakshadweep Islands. Crustacean diversity is mainly among marine crustaeans (94.85%), knowledge about which is far from complete. 500 species of crustaceans are endemic to India and only 2 species are considered threatened. The threatened species are *Birgus latro* and *Uca* sp. (Venkataraman and Krishnamoorthy 1993)

- **Myriapoda:** Worm-like, segmented arthropods that include commonly known animals like millipedes and centipedes (Khanna 1993). Worldwide, there are an estimated 10,500 species, including 7500 species of *Diplopoda* (millipedes) and 3000 species of *Chilopoda* (centipedes) (ZSI 1991). In India, there is a total recorded diversity of 262 species (2.4% of the world total), including 162 species of *Diplopoda* and 100 of *Chilopoda*.

- **Arachnida:** Arachnids are a diverse group of arthropods, consisting of scorpions, spiders, and related animals, found throughout India. Worldwide, there are an estimated 73,440 species, of which India harbours 5818, or about 7.9% of the total. Nearly 50% of the species found in India are considered endemic (Alfred *et. al.*, 1998).

- **Acari:** A class that includes animals like ticks and mites, sometimes included within the class *Arachnida*. One of the most widely adapted classes, these animals can be found in virtually every known habitat, including severe desert and tundra environments, mountain peaks, deep subsoil layers, subterranean caves, hot springs, and ocean beds (Sanyal 1993). The class is also one of the better-studied among the invertebrates.

About 36,800 species are known from the world over, with India harbouring 2,025 recorded species, or about 5.50% of the total. Interestingly, nearly 45% of the species found in India were new to science (Sanyal 1993), and are considered endemic.

- **Insecta:** The largest class of living beings in terms of both numbers and species diversity, insects are also one of the most widely adapted. The diversity of their physiological forms and behavioural characteristics is also remarkable, though all are characterised by three pairs of legs, three body sections, one pair of antennae, and one or two pairs of wings.

  Of a total world estimate of 8,67,391 known species, India has a recorded 59,353 species, or about 6.83% of the total (Alfred *et. al.*, 1998, *see Table 4.32*). A large number of insects are threatened and are listed in Schedule I of the Wild Life (Protection) Act, 1972.

Table 4.32 Comparison of Numbers of Insects in India and the World

Insect Order (Common names in brackets)	No. of Species in India	No. of Species in World	% of Species in India
Thysanura (Silver-fishes, Bristle tails)	31	1250	2.48
Diplura (Diplurans)	16	355	4.50
Protura (Proturans)	20	260	7.69
Collembola (Spring tails)	210	5500	3.81
Ephemeroptera (Mayflies)	106	2200	4.81
Odonata (Dragonflies and Damselflies)	499	6000	8.31
Plecoptera (Stoneflies)	113	2100	5.38
Orthoptera (Grasshoppers and Crickets)	1750+	17250	10.14
Phasmida (Leaf insects, Stick insects)	146	2262	6.45
Dermaptera (Earwigs)	320	2000	16.00
Embioptera (Web-spinners)	33	200	16.50
Blattariae (Cockroaches)	186	5000	3.72
Mantodea (Mantids)	162	2310	7.04
Isoptera (Termites)	253	2000	12.65
Psocoptera (Psocids, Book lice)	90	2500	3.60
Phthiraptera (Animal and Bird Lice)	400	3000	13.33
Hemiptera (Bugs, Leafhoppers, Aphids, Coccids, Cicadas, Bedbug)	6500	80000	8.12
Thysanoptera (Thrips, Fringe-wings)	693	6000	11.55
Neuroptera (Lacewing flies, Ant lions)	335	5000	6.70
Coleoptera (Beetles, Weevils, Fireflies, Ladybirds, Wood Borers)	15500	350000	4.42
Strepsiptera (Stylops)	18	554	3.25
Mecoptera (Scorpionflies)	15	350	4.28
Siphonaptera (Fleas)	52	2000	2.60
Diptera (Flies, Mosquito, Gnats, Midges)	6093	100000+	6.09
Lepidoptera (Butterflies and Moths)	15000	142500	10.52
Trichoptera (Caddisflies)	812	7000	11.60
Hymennoptera (Wasps, Bees, Ants, Bumblebees, Sawflies)	10000	120000	8.33
Total	**59353**	**867391**	**6.83**

Source: Alfred et. al., 1998

Echinodermata

These exclusively marine animals are characterised by the presence of tube feet, which are bulbous structures, part of a water vascular system. They have the amazing ability to regenerate lost body parts. They include animals such as starfish, sea cucumbers, and sea urchins.

Of a worldwide recorded diversity of 6223 species, India harbours some 765, or over 12.3% (Alfred *et. al.*, 1998).

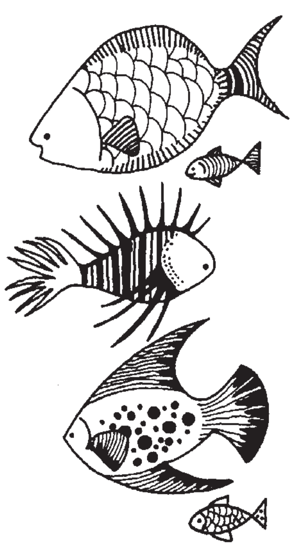
Chaetognatha

Having elongated, transparent bodies with movable hooks or spines at the mouth, these animals are exclusively marine. Also called arrow worms, they can range from 0.5 to 15 cm. in length. They evolved over 300 million years ago.

Of a world diversity of about 111 species, India contains about 30 (2.70%). Three species -*Sagitta bombayensis*, *Eukrohnia minuta* and *Pterokrohnia arabica* – are endemic to the Indian Ocean (Alfred et. al., 1998).

Hemichordata

Worm-like, bilaterally symmetrical creatures which are exclusively marine, they resemble chordates (see below) in having gill slits in the throat, and in possessing a nerve chord. *Hemichordata* is divided into three classes, namely *Enteropneusta* (acorn worms), *Pterobranchia* and *Planctosphaeroidea*.



The global diversity of these animals is low. A total of 120 species have been recorded globally, of which 12, or 10.0%, are found in India (Alfred *et. al.*, 1998).

Hemichordata are distributed throughout the marine areas of India, including the Gulf of Kachchh, the Andaman Sea, the Lakshadweep Islands, the Tamil Nadu coast upto Cape Comorin, and the mangroves of the Sundarbans.

Chordata

This is a category which is clearly distinguished from all those discussed above in that it consists of animals with (a) a notochord, or cartilagenous dorsal rod, in the early embryo stage; (b) a single, dorsal nerve chord which in mammals becomes the brain and spinal chord; and; (c) the presence of gill slits at some stage of the life cycle. *Chordata* includes not only most of the animals that human beings are most familiar with, but humans themselves. It is not surprising that the major classes under *Chordata* (fish, amphibia, reptiles, birds, and mammals) are better understood by humans than any other animal groups, at least partly because of their size and conspicuousness.

- **Protochordata:** These are exclusively marine organisms characterized by the presence of a notochord; some 2,106 species have been recorded worldwide. Of these, 119 are reported from India, 5.65% of the global total (Alfred *et. al.*, 1998).

- **Pisces:** Fishes are aquatic vertebrates which have gills to facilitate respiration, and are aided by fins in locomotion and balancing. Fish display an enormous diversity of forms, and can survive in both freshwater and saltwater ecosystems. The worldwide recorded number is 21,723 species, of which India has 2,546, or about 11.72% (ZSI 1991; Alfred *et. al.*, 1998). Maximum diversity is found along the western coast with about 1440 species. There are 223 species endemic to India (Paul 1994). IUCN (2002) lists 16 species as threatened. Kumar *et. al.*, (2003), however, estimate the figure to be 217 out of 323 freshwater species assessed.

- **Amphibia:** Possibly the first four-footed creatures to emerge on earth, amphibians evolved out of fish-like creatures in the Devonian period, over 200 million years ago. They have a soft moist skin, and breath through gills (as tadpoles), lungs, and skin. The term 'amphibia' denotes the peculiar characteristic of these animals of living partly in water and partly on land. Indeed, the habitat of *Eogyrinus*, one of the earliest known amphibians, appears to have been temporary waterbodies in arid zones, where the drying of the pools would have forced it to make overland journeys to other waterbodies (Hawkins 1986).

Of an estimated species diversity of 5,150 in the world, India harbours 216, or about 5.07% (Das 2001).[11] The largest concentrations of species are in the North-East and the Western Ghats of the peninsular region. Very little is known of endemic amphibians – their ecology, taxonomy and distribution. 8 genera including Caecilians (*Indotyphlus*, *Gegeneophis*, *Uraeotyphlus*) and Anurans (*Bufoides*, *Melanobatrachus*, *Ranixalus*, *Nyctibatrachus*, *Nannobatrachus*) have been classified as endemic. Of these, except *Gegeneophis* and *Bufoides*, which occur in the Eastern Himalaya, all others are exclusive to the Western Ghats (Daniels 1993). The Himalayan newt, *Tylototriton verrucosus*, is the sole representative of the family *Salamandridae* in India. This newt is found only around the hills of Darjeeling in West Bengal, Sikkim, Manipur and Arunachal Pradesh. It is getting increasingly rare in the wild due to over-collection for biological studies, deforestation and erosion of hill habitats. The Malabar tree toad (*Pedostibe tuberculatus*) from Malabar (Kerala) and the Garo hill tree toad (*Pedostibes kempi*) from Tura Garo hills (Meghalaya) have also become extremely rare and IUCN lists their status as Indeterminate.

Overall endemism is remarkable – in the Western Ghats, a total of 92 species are endemic, while 35 species are endemic to north-east India (Alfred *et. al.*, 1998). IUCN (2002) lists 3 species as being globally threatened; Kumar *et. al.*, (2003), however, estimate that 93 of the 163 assessed species (57%) are threatened.

- **Reptilia:** Displaying a large diversity of forms, reptiles are cold-blooded vertebrates with an exoskeleton made of a double layer of dry epidermal scales and bony epidermal scales. They are egg-laying. Snakes, crocodiles, turtles, and lizards belong to this class.

  Of a global diversity of 5,817 species, India has 495, or about 8.5% (Das 2001). Their distribution in India is extremely widespread, from the Himalayan heights to the open seas.

  The Gangetic gharial (*Gavialis gangeticus*) inhabits the Ganga and its tributaries in the north and extends as far south as the Mahanadi in Orissa. The Leatherback turtle (*Dermochelys coriacea*) is the sole representative of the family *Dermochelyidae*. *Batagur baska*, the type species of the monotypic genus *Batagur*, is found in the estuaries of the Sundarbans. *Chitra indica*, the Chitra softshell turtle, is also a monotypic species, found in the Gangetic and Indus river systems of India, Nepal and Pakistan. Of the lizards, the Golden gecko (*Calodactylodes aureus*), found in the Eastern Ghats is monotypic and endemic (Alfred *et. al.*, 1998). The Southern forest gecko (*Dravidogecko anamallensis*), another monotypic species, is found in the Western Ghats.

  Several species of reptiles are considered threatened in India. The Egg-eating snake (*Elachistodon westermanii*) might be facing extinction. It has been reported from a few isolated pockets in the border districts of Purnea and Jalpaiguri in West Bengal (Murthy 1993). As such, very little information exists on it, with only a few preserved specimens in museums (Whitaker and Whitaker 1990). A number of other species are on Schedule I of the Wildlife (Protection) Act 1972. The IUCN Red List (IUCN 2002) estimates 30 threatened species. Kumar *et. al.*, (2003), however, list 168 out of an assessed 362 (over 50%) as being threatened.

- **Aves:** Warm-blooded creatures, distinguished by their feathered (and thereby insulated) bodies, forelimbs modified into wings, and true flying abilities, birds represent an extraordinary evolutionary step.

  There is no doubt that India occupies an extremely important global position in the case of bird diversity. Of a world total of 9,702 species (Sibley and Monroe 1993), India has 1,225 (BNHS 2002), or about 12.62%.

  IUCN (2002) lists 139 species as being threatened. About 176 species contained in 106 genera and 39 families are endemic to the Indian subcontinent. Many of them spill over to Pakistan, Nepal, Bhutan, Bangladesh, Myanmar and Sri Lanka. 50 species in 11 genera are endemic exclusively to India (Alfred *et. al.*, 1998). Interestingly, birds are also one of the few animal groups with a large number of species migrating long distances; India is therefore host to over 350 migrating species, most of which come to winter at various spots in the country.

At least four species were till recently believed to have become extinct: the Mountain quail (*Ophrysia superciliosa*), the Pink-headed duck (*Rhodonessa caryophyllacea*), the Jerdon's courser (*Rhinoptilus bitorquatus*), and the Forest spotted owlet (*Athene blewitti*). Of these, the latter two have been rediscovered in small pockets in eastern India and western India respectively.

- **Mammalia:** Mammals, considered to be the highest on the evolutionary scale, are warm-blooded animals characterised by a hairy body (with some exceptions), warm-bloodedness and the suckling of young.

  Worldwide, there are 4629 recorded species (Wilson and Reeder 1993). India harbours 390 species or about 8.42% (*see Table 4.33*) (Alfred *et. al.*, 1998). *Chiroptera* (bats) and *Rodentia* (rats, mice) with 109 and 99 species respectively are among the most speciose mammalian orders in India. These two orders account for more than 50% of the Indian mammalian fauna (Kumar *et. al.*, 2002).

Table 4.33 Diversity of Mammals in India

Orders	Family (Nos.)	Genera (Nos.)	Species (Nos.)
Insectivora (Shrews, moles, tenrecs)	3	11	28
Scandentia (Tree shrews)	1	2	3
Chiroptera (Bats)	6	36	110
Primates (Monkeys)	3	6	15
Pholidota (Pangolins)	1	1	2
Carnivora (Dogs, bears, cats, etc.)	7	33	55
Proboscidia (Elephants)	1	1	1
Sirenia (Dugongs, manatee)	1	1	1
Perissodactyla (Horse, ass, rhinoceros, tapir)	2	2	3
Artiodactyla (Pig, hippopotamus etc.),	5	20	32
Lagomorpha (Pikas, rabbits, hares)	2	3	10
Rodentia (Rodents)	4	43	101
Cetacea (Whales, dolphins, porpoises)	6	21	29
Total	**42**	**180**	**390**

Source: Alfred et. al., 1998

Mammalian fauna is richest in diversity in north and north-eastern India, with other regions of high diversity being the Western and Eastern Ghats and the Indian desert. Out of the 180 genera, 61 genera are monotypic and 36 species endemic. Of the endemic species, 9 are endemic to the Andaman and Nicobar groups of islands, 14 to the Western Ghats, 7 to peninsular India, 4 to Northeast India and the remaining two to the western Himalaya (Alfred *et. al.*, 1998). IUCN (2002) lists 152 species as being threatened, comprising an alarming 39% of India's total diversity; Kumar *et. al.*, (2003) put the figure at 94 out of 228 species assessed.

Box 4.12 Freshwater and Marine Species Diversity[12]

It is unlikely that the inventories presented in *Table 4.34* below represent the true status of marine biodiversity. Except in the case of commercially exploited groups such as food fishes or macroalgae, or those that have a fewer number of species (e.g. 14 species of sea grasses), inventories of other groups are likely to be gross underestimates. This can be amply illustrated with the case of corals known from the Andaman and Nicobar Islands. The inventory of 135 coral species until a few years back rose to more than 200 within a span of 2 years, when extensive surveys covering more islands and deep waters were made. This again represents only reef-building corals and not the hundreds of other species that inhabit the reefs. Again, the Andaman and Nicobar reefs are only one among the several tens of specialized ecosystems on the Indian coasts. It would be difficult to hypothesize on the true extent of India's marine biodiversity but if May's (1992) arguments are acceptable,

Contd. on page 150

Table 4.34 Diversity of Marine and Freshwater Faunal Species in India

Taxonomic Group	No. of Marine Species	No. of Freshwater Species	Total no. of Species
Protista			
1. *Sarcomastigophora*	–	550	550
2. *Ciliophora*	750	–	750
Animalia			
1. *Porifera*	–	33	33
2. *Cnidaria*	500	10	510
3. *Ctenophora*	790	–	790
4. *Platyhelminthes*	10	50	60
5. *Rotifera*	–	320	320
6. *Gastrotricha*	350	23	373
7. *Kinorhyncha*	88	–	88
8. *Nematoda*	–	150	150
9. *Acanthocephala*	–	50	50
10. *Annelida*	9	350	359
11. *Mollusca*	440	183	623
12. *Bryozoa*	3370	35	3405
13. *Entoprocta*	170	1	171
14. *Phoronida*	8	–	8
15. *Brachiopoda*	3	–	3
16. *Arthropoda*	3	–	3
a) *Crustacea*	2430	800	3230
b) *Pycnogonida*	16	–	16
c) *Merostomata*	2	–	2
d) *Insecta*	–	3000	3000
e) *Arachnida*	–	250	250
17. *Sipuncula*	38	–	38
18. *Echiura*	33	–	33
19. *Tardigrada*	5	10	15
20. *Chaetognatha*	30	–	30
21. *Echinodermata*	765	–	765
22. *Hemichordata*	12	–	12
23. *Chordata*	–	–	–
a) *Protochordata*	116	–	116
b) *Pisces*	1800	742	2542
c) *Amphibia*	3*	150	153
d) *Reptilia*	31	24	55
e) *Aves*	145	200	345
f) *Mammalia*	30	25	55
Total	**11,947**	**6,956**	**18,903**

Source: Ramakrishna and Venkataraman 2001; Alfred et. al., 1998; Alfred and Nandi 2000.

** in estuaries and mangroves*

then the number of species that has gone unrecorded until now could be at least 10 times what is known or even more. Several species under different taxa are endemic to India or have highly restricted distribution. It would be difficult to list all of them here but mention may be made of the hemichordate *Balanoglossus* which is found in only a few islands in the Gulf of Mannar, or the horse-shoe crab *Limulus*, which is found only along the Orissa coast.

Four different components – permanently aquatic, temporarily aquatic, freshwater-dependent and freshwater-associated – comprise the faunal diversity of freshwater ecosystems in India.

Animals belonging to all taxonomic categories, from protozoa to mammals, occur in wetlands. Among the invertebrates, *Arthropods* represented by *Crustacea* and 11 orders of *Insecta*, and the molluscs are the most dominant components of wetland fauna. Oligochaetes are also abundant. Among the vertebrates, amphibia, fish and birds are dominant. Mammals like otters occur exclusively in wetlands, whereas others like deer and water buffalo use wetlands principally for grazing.

The faunal diversity of freshwater wetlands is estimated at 7.7% of the total fauna in India (Alfred *et. al.*, 1998; Alfred and Nandi 2000). However the faunal diversity cannot be accurately estimated due to inadequate exploration of wetlands as well as the lack of an appropriate identification key for many invertebrate groups, especially those like larval insects. The knowledge base is most inadequate in case of microfauna and meiofauna that occur in the freshwater wetlands (Alfred and Nandi 2001).

4.1.2.3 Micro-Organisms

Micro-organisms are ubiquitous in distribution. They represent the earliest life forms and have been around for 3.6 to 4.0 billion years on the earth. Fossil evidence of microbial life has been found in rocks containing diverse prokaryotes (simple unicellular organisms without a defined nucleus). The origin of eukaryotic (complex, multicellular organisms with a well defined nucleus) life has also stemmed from the fundamental contributions of bacteria, in the form of chloroplasts and mitochondria (*Micro-organic Diversity Thematic BSAP*)

The number of microbial cells is estimated to be about 4-6x10^{30}, containing nearly half the total carbon and 90% of the nitrogen and phosphate on this planet. It may be noted that micro-organisms are the only living forms which are present under the most difficult of habitats and extreme environments. Boring water, deep sea vents, salt pans, the interiors of rocks, acid mine drainage, extreme cold environments and almost all other conceivable conditions harbour micro-organisms. Unlike animals and plant species that are restricted in terms of geographical areas due to the climate and natural borders between the continents, most micro-organisms (especially *bacteria* and *archaea*) are found across the continents and are truly cosmopolitan. Many species exhibit unique habitat preference, but their general distribution is ubiquitous.

The existence of micro-organisms in the interiors of plants, animals and human has been known for long but their functional and practical significance has been realized only recently. It indicates a unique and protected habitat, where the presence of several species is governed by the natural metabolism. It is estimated that over 1.3 million endophytic microbes await discovery. Diversity of microbes in different ecosystems is important not only in isolated species but in consortia as well. In addition, human-made habitats also contain diverse type of microbes.

It has been estimated that out of the microbial diversity worldwide, only about 5-10% is known based on the analysis of cultureable microbes. *Table 4.35* gives approximate numbers of known and estimated micro-organisms of various categories.

The major component of microbial diversity remains uncultureable, but the use of molecular tools permits analysis of the existing gene pool. *Table 4.36* gives estimates of the proportion of 'uncultureable' micro-organisms in various terrestrial and aquatic biotopes.

As far as India is concerned, not much work has been done in the area of microbial biodiversity and limited information is only available about the microbial cultures held at various centers in India (*see Section 4.1.4.3*).

Table 4.35 Microbial Diversity (Known and Estimated Species)

Group	Estimated Total Species	Known Species[b]	Proportion known of total %
Algae	60,000	40,000	67
Archaea	?	<500	?
Bacteria	40,000[a]	4,800	12[c]
Fungi	1,50,000	69,000	5
Lichens	20,000	13,500	67
Viruses	1,30,000[a]	5,000	4[c]

? Unknown

Source: Cowan 2000

a) Values are substantially underestimated, possibly by 1 to 2 orders of magnitude

b) Values date from the mid-1990s and will have increased by 10-50%

c) Values are probably gross underestimates

d) (Note that the classification here includes fungi and algae (often also included in plants) and protozoa (often included in animals)

Table 4.36 Estimates of the Proportion of 'Uncultureable' Micro-Organisms in Various Terrestrial and Aquatic Biotopes (Worldwide)

Biotope	Proportion of Culturability (%)
Sea water	0.001-0.100
Freshwater	0.25
Mesotrophic lake	0.1-1.0
Unpolluted estuarine water	0.1-3.0
Activated sludge	1-15
Sediments	0.25
Soil	0.3

Source: Cowan, 2000

There has been no systematic exploration for microbial diversity in specific ecosystems. In view of the sporadic efforts, a limited number of microbes have reached the national collection centers, even though microbes are likely to be one of the major components of any particular region/ecosystem. To quote an example, a possible taxonomic picture presented by Gadgil (1996) based on the Western Ghats experience suggests that approximately 17% of a set of 2,500 species are likely to be microbial (*see Table 4.37*). The existing culture collections do not carry even a miniscule portion of this resource.

There are umpteen natural habitats which abound with micro-organism diversity – desert soils and sand; alpine and tropical soils; brackishwater and marshes; ice and glaciers, lakes and streams; acidic and alkaline soils; coastal lagoons and oceans, and thermal springs. Some of these unique extreme habitats are invaded only by micro-organisms and require exploration, since the so-called 'extremophiles' are a resource to reckon with in the context of emerging biotechnologies. (Johri, 2003)

Intertidal wood on the west coast of India provides a comprehensive example of this diversity. 88 fungal species in 47 genera could be recovered from 3327 wood samples collected from 13 locations representing beaches, harbours and islands. Of these, 22 species are new records for the Indian peninsula (Prasannarai and Sridhar 2001). The species diversity is higher in islands as compared to beaches and harbors. The islands near the west coast present a pristine habitat for marine fungal diversity.

Table 4.37 Possible Taxonomic Components of a Set of 2500 Species

Components	No. of species
Viruses	50
Bacteria	90
Algae	90
Fungi	200
Lichens	10
Angiosperms	700
Insects	700
Fishes	700
Birds	200
Mammals	25
Others	320
Microbes	*17.6%*

Source: Gadgil 1996

Extremely acidic soils (down to pH 2.8) of Kerala are home to cyanobacteria. As many as 42 species are recorded in acidic soils (pH 2.5 – 4.0), of which 19 are recorded for the first time in Kerala, with one new record for India (Dominic and Madhusoodanan 1999). Primitive forms of micro-organisms have been reported from iron formations in Orissa. Stramatolites have been reported from the Sandur Schist belt from the Kolar Schist. In a study of six caves around MKU and Tirunelveli, 35 species of sporulating mesophilous fungi and seven non-sporulating mesophilous fungi were recovered from entrance, twilight and dark zones (Koilraj *et. al.*, 1999).

With so little known about micro-organisms, especially in *in situ* conditions, nothing can be said about endemicity and threatened status.

Box 4.13 Estimates of Undiscovered Species in India

While the currently reported diversity of animal and plant species in India is roughly 134,000, most scientists agree that this would be only a portion of the total diversity. There is still much to be discovered, especially among the smaller fauna and non-flowering flora, among micro-organisms and in regions such as the deep seas, rainforests, and mountains. A range of botanists and zoologists who were asked about this in the mid-1990s, as part of a survey by the Indian Institute of Public Administration (IIPA), suggested that undiscovered species could be several times more than the currently known number.

An example of what may still be found comes from the Andaman and Nicobar Islands. Recent surveys have discovered globally significant information from here. An international team comprising scientists from India, Australia and Britain recorded 197 species of coral, of which an astonishing 111 were new finds for the Andaman and Nicobar Islands. One of the species of corals was a new one to science, and another one, found commonly during dives, had earlier been reported only from the Philippines. The study also reported that the reefs in the Andamans were more diverse than expected and less impacted than feared by other scientists working in the Indian Ocean (Sekhsaria 2002).

For example, several new species of freshwater fishes have been reported in the last decade. Systematic surveys in the Western Ghats and northeast India have reported several new species of amphibians, with one survey in the Western Ghats reporting the possibly of at least 110 new species (Biju 2001). Even among mammals, new records for India are likely in the north-east; e.g. the likely occurrence of two species of barking deer (Datta *et. al.*, 2003). The small mammals (murid rodents and shrews) and bats are taxa which have not been systematically surveyed for several decades and among which new species and records are likely.

4.1.3 Agricultural Ecosystems

4.1.3.1 Agroclimatic Zones of India

From the desert ecosystem of Rajasthan in the West to the flood plain systems of Bengal in the East, from the mountain agriculture of the Himalayas to the wetland ecosystems of Kerala, from the semi-arid rainfed ecosystems in the Deccan plateau to the highly developed terraces of Northeast, the wide-ranging agro-ecosystems in India offer a mind-boggling variety. They also represent a fascinating array of practices which embody a vast expanse of agriculture-related knowledge systems of local rural communities. And as the National Agricultural Policy 1999 put it, 'Agriculture is a way of life, a tradition, which, for centuries, has shaped the thought, the outlook, the culture and the economic life of the people of India. Agriculture, therefore, is and will continue to be central to all strategies for planned socio-economic development of the country' (MoA 1999).

The eight broad agricultural zones in India are (Murthy and Pandey 1998):

1. Humid Western Himalayan
2. Humid Bengal-Assam
3. Humid Eastern Himalayan Region and Bay Islands
4. Sub-Humid Satluj Ganga Alluvial Plains
5. Sub-Humid to Humid Eastern and South-Eastern Uplands
6. Arid Western Plains
7. Semi-Arid Lava Plateaus and Central Highlands
8. Humid to Semi-Arid Western Ghats and Karnataka Plateaus

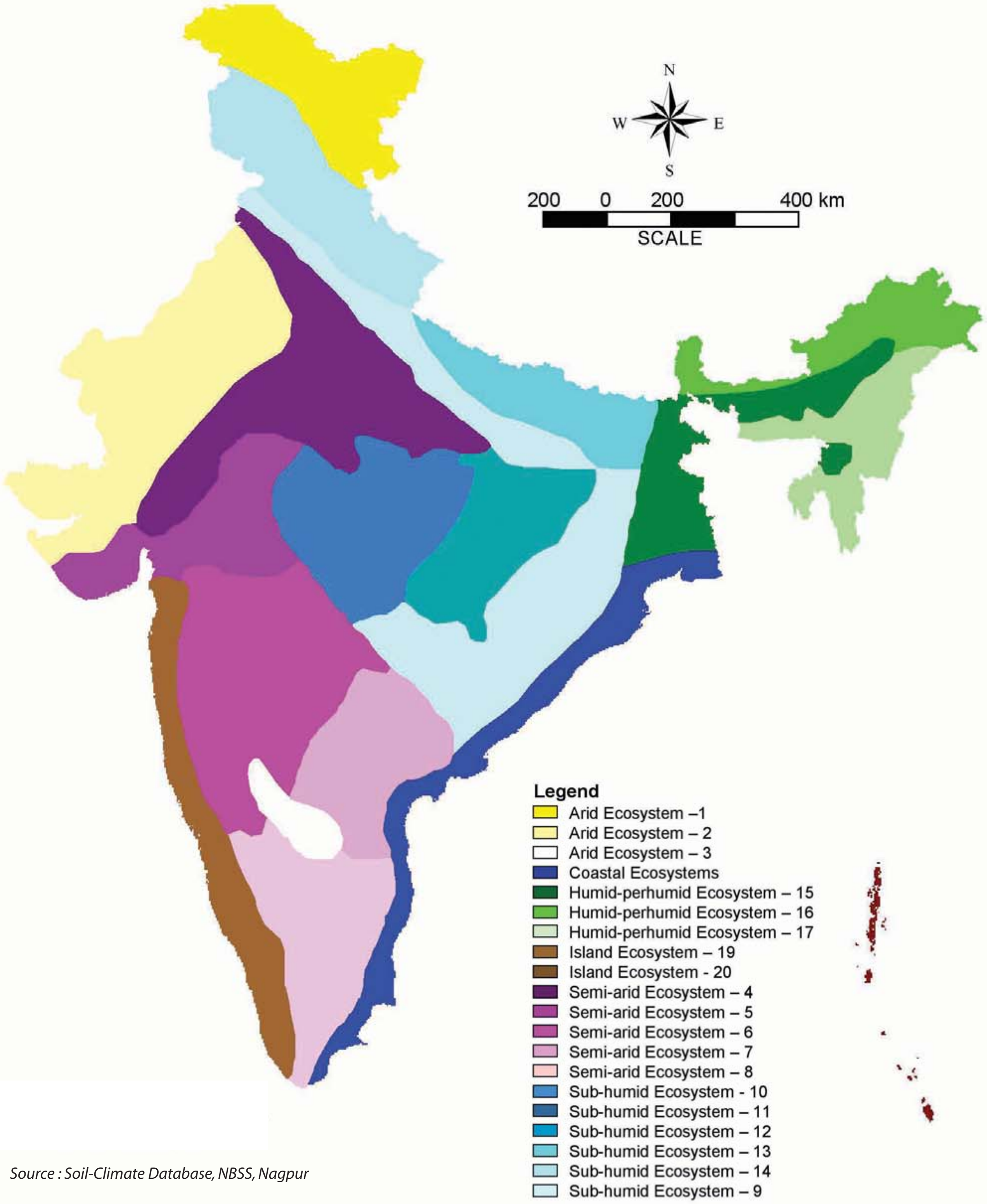
The Planning Commission of India, during a mid-term appraisal of the 7th Plan (1985-1990), delineated the following 15 broad agro-climatic zones, based on physiography and climate:

1. West Himalayan Region
2. East Himalayan Region
3. Lower Gangetic Plains Region
4. Middle Gangetic Plains Region
5. Upper Gangetic Plains Region
6. Trans-Gangetic Plains 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 Plains and Hill Region
12. West Coast Plains and Ghats Region
13. Gujarat Plains and Hill Region
14. Western Dry Region
15. The Island Region

The National Bureau of Soil Survey and Land Use Planning of the Indian Council for Agricultural Research took up a more sophisticated classification by bringing out an 'agro-ecological' map of the country, with each region distinguished on the basis of physiography, soil types, bioclimate, and length of crop-growing period (Sehgal *et. al.*, undated). A set of 21 agro-ecological regions has been delineated (see *Map 4.6 and Map 4.7*):

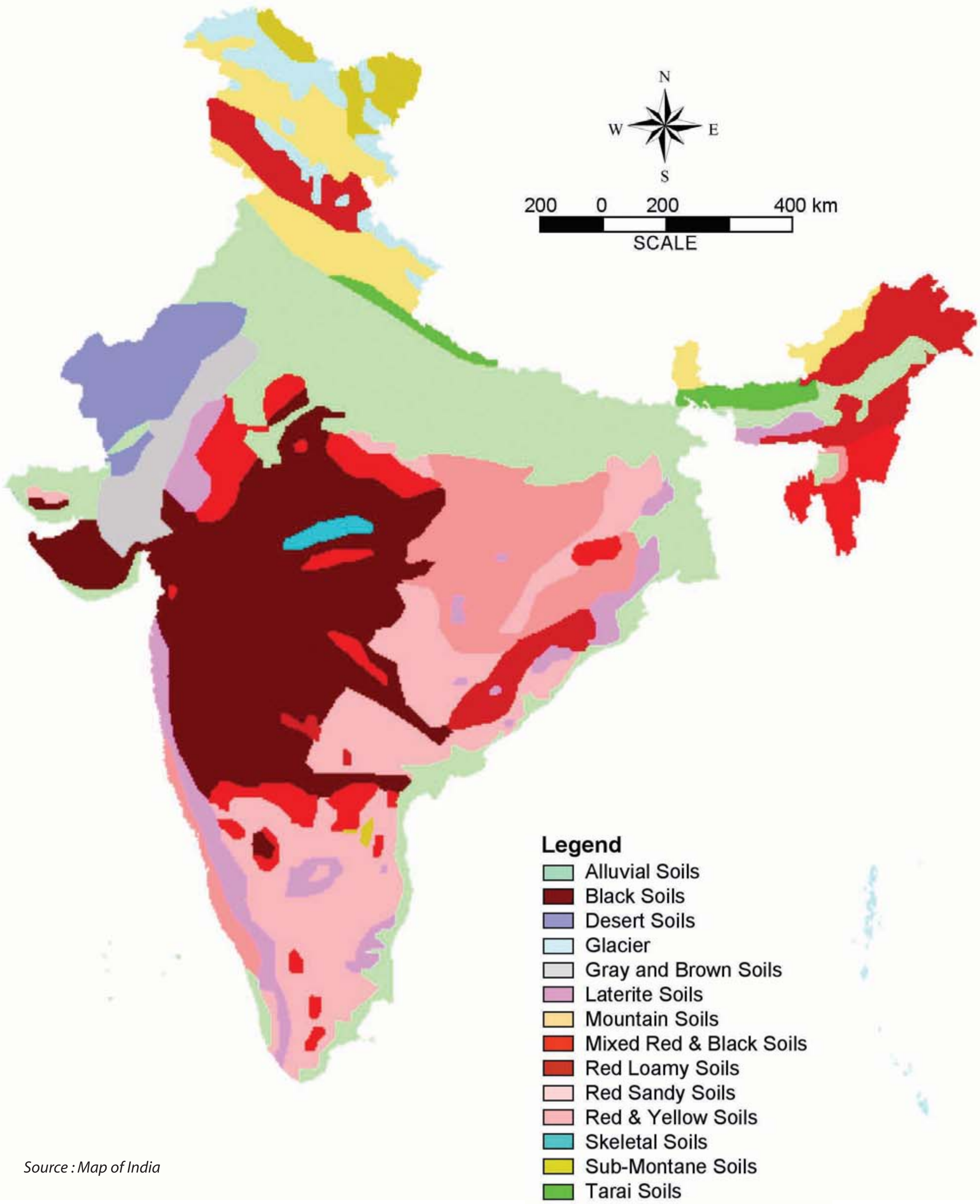
1. Western Himalayas: Cold arid ecoregion with shallow skeletal soils. Length of growing period (LGP) < 90 days
2. Western Plain and Kutch Peninsula: Hot arid ecoregion with desert and saline soils. LGP < 90 days.
3. Deccan Plateau: Hot arid ecoregion, with mixed red and black soils. LGP < 90 days.
4. Northern Plain and Central Highlands: Hot semi-arid ecoregion with alluvium derived soils. LGP 90-150 days.
5. Central (Malwa) Highlands and Kathiawar Peninsula: Hot semi-arid ecoregion with medium and deep black soils. LGP 90-150 days.

Map 4.6 Agro-ecological Regions India



Source : Soil-Climate Database, NBSS, Nagpur

Map 4.7 Soil Types India



Source : Map of India

6. Deccan Plateau: Hot semi-arid ecoregion with shallow and medium (inclusion of deep) black soils. LGP 90-150 days.
7. Deccan Plateau and Eastern Ghats: Hot semi-arid ecoregion with red and black soils. LGP 90-150 days.
8. Eastern Ghats (Tamil Nadu uplands and Deccan Plateau: Hot semi-arid ecoregion with red loamy soils. LGP 90-150 days.
9. Northern Plain: Hot sub-humid ecoregion with alluvium-derived soils. LGP 150-180 days.
10. Central Highlands (Malwa and Bundelkhand): Hot sub-humid ecoregion with medium and deep black soils. LGP 90-150 days.
11. Deccan Plateau and Central and Highlands (Bundelkhand): Hot sub-humid ecoregion with mixed red and black soils. LGP 150-180 days.
12. Eastern Plateau (Chhattisgarh): Hot sub-humid ecoregion with red and yellow soils. LGP 150-180 days.
13. Eastern (Chhota Nagpur) Plateau and Eastern Ghats: Hot sub-humid ecoregion with red loamy soils. LGP 150-180 days.
14. Eastern Plain: Hot sub-humid ecoregion with alluvium-derived soils. LGP 180-210 days.
15. Western Himalayas: Warm sub-humid (inclusion humid) ecoregion with brown forest and podzolic soils. LGP 180-210 days.
16. Assam and Bengal Plains: Hot humid ecoregion with alluvium-derived soils. LGP > 210 days.
17. Eastern Himalayas: Warm perhumid ecoregion with brown and red hill soils. LGP > 210 days.
18. Northern Eastern Hills (Purvanchal): Warm perhumid ecoregion with red and lateritic soil. LGP > 210 days.
19. Eastern Coastal Plains: Hot sub-humid ecoregion with alluvium-derived soils. LGP 150-210 days.
20. Western Ghats and Coastal Plains: Hot humid perhumid ecoregion with red, lateritic and alluvium soil. LGP > 210 days.
21. Islands of Andaman and Nicobar and Lakshadweep: Hot perhumid ecoregion with red loamy and sandy soils. LGP > 210 days.

The amazing diversity in agriculture in India extends from the fascinating farms under the *Baranaja* and others systems in the Himalayas, with the hundreds of varieties of rice, beans and millets, to the extraordinary spread of various varieties of rice in the coastal and flood plains of Orissa; from the diverse pearl millet varieties farmed in the desert ecosystems of Rajasthan to the diverse spice gardens in the wet ecosystems of Kerala; and from the millet-pulse-oilseed combinations of the semi-arid farms of the vast Deccan plateau to the brilliantly designed terrace-farms of the North-eastern hill region. The depth and range of crops (and the knowledge about them) cultivated in these dramatically different ecosystems and diverse farming communities bridges the past and the future of Indian agriculture.

Crop diversity is a result of complex agricultural practices followed by farmers for centuries (*see Box 4.14*). These practices included multiple cropping and intercropping by a mix of species, the simultaneous or staggered growing of intra-species varieties, tolerance or even encouragement of wild and weedy relatives of crops, deliberate seed selection and experimental breeding for a variety of traits, interspersing of trees and other non-crop species, and others. The domestication of wild plants has itself led to increase in genetic variety in many crops (Salick and Merrick 1990).

Detailed assessments of cropping systems as far apart as the paddy fields of south and south-east Asia, the potato farms of the Andes, the *chinampas* (wetland agriculture) of Mexico, and the swidden (shifting) cultivation of Africa have shown the following common characteristics (Norman 1979):

- They combine high species numbers and diversity in time and space (i.e. through use of both vertical and horizontal spaces).
- They use the full range of micro-habitats (defined by varying soils, water regimes, temperatures, altitudes, slopes, and fertility values) for growing a diversity of plants; they rely on the complex interplay of a number of biological factors, including prey-predator relationships, resulting in the maintenance of both cultivated and natural biodiversity, and in the natural suppression of pests.
- They rely on local crop varieties and on wild plants and animals to a great degree.

Box 4.14: Genetic Diversity in Traditional Agro-Ecosystems

The high diversity of cultural and ecological conditions in traditional farming systems gave rise to the large-scale genetic diversity of crops.

'Genetic diversity is maintained in traditional agro-ecosystems by cultural intervention as well as by natural selection. Cultural and socio-economic factors that influence evolutionary processes include terracing, fallowing, run-off channelling, soil moulding, mulching, use of fire, selective weeding, interplanting, trapping of particular crop predators, attention to individual plants, pollarding of selected wild trees in agricultural fields and management of secondary successional vegetation.

'Because traditional farm management strategies often integrate livestock and wildlife production with crop cultivation, the farmers use complex production schedules. They also place the crops to create a patchy distribution of cultivated fields, different human-modified vegetation zones and natural resource zones. Fallows, pastures, riverbanks, forests, grasslands, and rocky desert outcrops are included in traditional agroecosystems. This habitat diversity influences the organisms (e.g. insects and weeds) that enter the fields and interact with the crop plants.

'Traditional farmers' fields are spatially heterogeneous. Each field contains multiple microhabitats created by the varying slopes and soils and different patches of intercropped cultivars and wild vegetation. There is also temporal variation which may be cyclical as when crops are regularly planted 2 or 3 times during the year and therefore are subjected to different climatic regimes. Individual farmers are also likely to use slightly different farming methods or choice of seeds in one of the several field types in a given year.

'Heterogeneous environments created within traditional agroecosystems not only provide a variety of selection pressures but they also afford some crop plants protection from environmental stresses. Such protection is not provided by modern agroecosystems.'

Extract from: Oldfield and Alcorn 1991

It is precisely this emphasis on diversity, and on the use of local resources, which has given these systems the stability and sustainability that has ensured agricultural productivity for centuries (Altieri 1990). Farmers explicitly and implicitly recognised the enormous utility of diversity in their farming systems, in terms of stability (as insurance against the failure of one crop, for instance), pest and disease resistance, satisfying diverse human needs, and other values (*see also Section 4.2.2*).

Box 4.15 The Advanced Agriculture of 19th Century India

Various ecologically significant features of traditional Indian agriculture gained recognition from the formal scientific sector a century ago. In 1893, Dr. John A. Voelcker, Consulting Chemist to the Royal Agricultural Society of England, who had toured India studying its agriculture for over a year, wrote:

'I explain that I do not share the opinions which have been expressed as to Indian Agriculture being, as a whole, primitive and backward, but I believe that in many parts there is little or nothing that can be improved. I have remarked in earlier chapters about the general excellence of the cultivation; the crops grown here are numerous and varied, much more indeed than in England....To take the ordinary acts of husbandry, nowhere would one find better instances of keeping land scrupulously clean from weeds, of ingenuity in devices of water-raising appliances, of knowledge of soils and their capabilities as well as of the exact time to sow and to reap, as one would in Indian agriculture, and this not at its best alone, but at its ordinary level. It is wonderful too, how much is known of rotation, the system of mixed crops and of fallowing. Certain it is that I, at least, have never seen a more perfect picture of careful cultivation, combined with hard labour, perseverance and fertility of resource, than I have seen at many of the halting places in my tour. Such are the gardens of Mahi, the fields of Nadiad, and many others.'

Writing in more detail about the inter-cropping and crop rotation systems followed by Indian farmers, Voelcker said:

'It is quite a mistake to suppose that rotation is not understood or appreciated in India. Frequently more than one crop at a time may be seen occupying the same ground but one is very apt to forget that this is really an instance of rotation being followed. It is not an infrequent practice, when drilling a cereal crop, such as jowar (*Sorghum vulgare*) or some other millet, to put in at intervals a few drills of some leguminous crop, such as *arhar* (*Cajanus cajan*)...

'There are many systems in ordinary use which are far more complicated than the above. For instance, not only may there be rows of crops, side by side, as noticed above, but the alternating rows may themselves be made up of mixtures of different crops, some of them quick growing and reaped early, others of slower growth and requiring both sun and air, and thus being reaped after the former have been cleared off. Again, some are deep-rooted plants, others are surface feeders, some require the shelter of other plants and some will thrive alone. The whole system appears to be designed to cover the bareness and consequent loss to the soil, which would result from the sun beating down upon it, and from the loss of moisture which it would incur.'

(Quoted in Dogra 1983).

4.1.4 Domesticated Plant/Animal Taxa and Cultured Micro-Organisms

4.1.4.1 Crop Diversity

In 1951, Russian scientist N.I. Vavilov classified the world's crop-producing regions into 8 centres of plant origin. Of these areas of crop genetic diversity, India was central to what he called the Hindustan Centre of Origin of Crops and Plant Diversity.

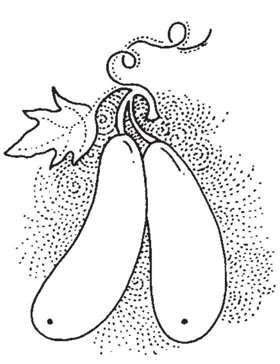
Vavilov's terminology for India was well justified, for this region has produced a significant share of the major crops used the world over. At least 166 species of crops (6.7% of total crop species in the world) and 320 species of wild relatives of cultivated crops are believed to have originated in India (Rana 1993). These are spread across the entire range of crops known to humans: cereals, millets, legumes, vegetables, fruits, oilseeds, forages, fibres, sugar-yielding plants, condiments, spices, medicinal and aromatic plants, and others.

India's endemic life forms have in the past been enriched by migrations both from the African region as also the Indo-Malayan region. Apart from natural dispersals, such movement has also taken place accidentally or deliberately as a result of the activities of travellers, invaders, missionaries, and other ancient visitors to India (Rana 1993).

Major crops with rich diversity in India include the following (Mehra and Arora 1982):

Cereals: Rice (*Oryza sativa*), Wheat (*Triticum aestivum* ssp. *sphaerococcum*), and Maize (*Zea mays*).

Millets: Millet-Adlay/Job's Tears (*Coix lacryma-jobi* – soft-shelled forms), Millet (*Digitaria compacta*), Millet or Large crab grass (*Digitaria sanguinalis*), Shama Millet (*Echinochloa colona*), Sumatran Millet (*Panicum sumatrense*), Kodo Millet or Ditch Millet (*Paspalum scrobiculatum*), Pearl millet or *bajra* (*Pennisetum americanum*), and Guinea corn (*Sorghum bicolor*).



Legumes: Pigeon Pea (*Cajanus cajan*), Jack Beans (*Canavalia cathartica*), Chickpea (*Cicer arietinum*), Cluster Beans or guar (*Cyamopsis tetragonoloba*), Horse gram (*Macrotyloma uniflorum*), Lablab Beans (*Lablab niger*), Bean (*Mucuna capitata*, *Mucuna utilis*), Indian Moth Bean (*Vigna aconitifolia*), Udad pulse (*Vigna mungo*), Green gram (*Vigna radiata*), Rice bean or *Moth* (*Vigna umbellata*), and Cowpea (*Vigna unguiculata*).

Oilseeds: Mustard (*Brassica rapa* ssp.), Turnip rape (*B. rapa* spp. *campestris*), Indian rape (*B. rapa* var. *toria*), Indian or brown mustard (*Brassica juncea*), Safflower (*Carthamus tinctorius*), Bitter Apple (*Citrullus colocynthis*), Rocket Cress (*Eruca vesicaria*), Niger seed (*Guizotia abyssinica*), Linseed (*Linum usitatissimum*), and Sesame (*Sesamum orientale*).

Fruits: Jackfruit (*Artocarpus heterophyllus*), Indian Wild Orange (*Citrus indica*), Khasi papeda (*Citrus latipes*), Wood Apple (*Limonia acidissima*), Indian Mangosteen or Kokum (*Garcinia indica*), *Khirni* or *Ryan* (*Manilkara hexandra*), Mango (*Mangifera indica*), Banana (*Musa* spp. AB, AAB group), Banana (*M. balbisiana*), Jamun (*Syzygium cumini*), Ber or Indian jujube (*Zizyphus mauritiana*).

Vegetables: Taro (*Alocasia cuculata*), Taro (*Alocasia macrorrhizos*), Yam (*Amorphophallus Paeoniifolius*), Capsicum (*Capsicum annuum*), Squash Melon (*Citrullus lanatus* var. *fistulosus*), Ivy fruited gourd (*Coccinea grandis*), Taro (*Colocasia esculenta*), Cucumber (*Cucumis sativus*), Pumpkin (*Cucurbita* spp.), Yams (*Dioscorea* spp.), Bottle Gourd (*Lagenaria siceraria*), Ridge gourd (*Luffa acutangula*), Loofah or Sponge gourd (*L. aegyptiaca*, *L. hermaphrodita*), Drum (*Moringa oleifera*), Radish (*Raphanus sativus*), Sukha Sak (*Rumex vesicarius*), Brinjal (*Solanum melongena*) and Snake Gourd – wild (*Trichosanthes cucumerina*)

Medicinal and Aromatic: Dill (*Anethum sowa*), *Ajawin* (*Trachyspermum ammi*), Croton or Purging Cotton (*Croton tiglium*), Malabar Lemon Grass (*Cymbopogon flexuosus*), *Dhatura* or Downy Thorn Apple (*Datura metel*, *Hydnocarpus laurifolius*), *Sarpgandha* or Snake root (*Rauwolfia serpentina*), *Nux vomica* (*Strychnos nux-vomica*, *Saussaurea lappa*), and Vetiver (*Vetiveria zizanioides*).

Spices: Bengal Cardamom (*Amomum aromaticum*), Tavoy Cardamom (*A. xanthioides*), Mango Ginger (*Curcuma amada*), East Indian Arrowroot (*Curcuma angustifolia*), Turmeric (*Curcuma longa*), Zedoary (*Curcuma zeodaria*), Cardamom (*Elettaria cardamomum*), Pepper (*Piper longum*), and Ginger (*Zingiber officinale*).

Misc: Bamboo (*Bambusa arundinacea*), Bamboo (*B. strictus*), Bamboo (*B. tulda*), Hemp (*Cannabis sativa*), Painted Bamboo (*Cephalostachyum capitatum*), Coconut (*Cocos nucifera*), Jute (*Corchorus capsularis*), Sunhemp (*Crotalaria juncea*), Bamboo (*Dendrocalamus hamiltoni*), Bamboo (*Dendrocalamus longispathus*), Ceylon Cotton (*Gossypium arboreum*), Kenaf (*Hibiscus cannabinus*, *Melocanna bacccifera*), Bamboo (*Neohouzeaua dullosa*), Elephant Bamboo (*Ochlandra travancorica*), Sugarcane (*Saccharum* spp.), and Giant Bamboo (*Sinocalamus giganteus*).

Specifically, plants with their primary centre of evolution in the Indian region include: Rice (*Oryza sativa*), pigeonpea (*Cajanus cajan*), turmeric (*Curcuma longa*), ginger (*Zingiber officinale*), black pepper (*Piper nigrum*), banana (*Musa* spp.), bitter gourd (*Momordica charantia*), okra (*Abelmoschus esculentus*), coconut (*Cocos nucifera*), cardamom (*Elettaria cardamomum*), cinnamon (*Cinnamomum zeylanicum*), jackfruit (*Artocarpus* spp.), sugarcane (*Saccharum* spp.), bamboo, taros (*Colocasia* and *Alocasia*), cucumber (*Cucumis sativus*), eggplant (*Solanum melongena*), rapeseed *(Brassica rapa* ssp. *Campestris*), sacred basil (*Ocimum sanctum*), indigo (*Indigofera tinctoria*), sunhemp (*Crotalaria* spp.), *Amaranthus* spp., and gooseberries (*Emblica* spp.) (NBRI 1993; Querol 1992).

The region is also considered a secondary centre of diversity for crops like amaranthus, maize (*Zea mays*), red pepper (*Capsicum annuum*), soybean (*Glycine max*), sweet potato (*Ipomoea batatas*), and rubber (*Ficus elastica*).

Crop genetic diversity in India is great not only at the species level, but also at the intra-species varietal level. Indeed, Indian farmers have been able to develop, through various deliberate and accidental processes, a crop varietal diversity which is truly astounding. One fact should be sufficient to illustrate this point: a minimum of 50,000 (S.D. Sharma, Central Rice Research Institute, personal communication 1992) varieties of rice have been grown in India until the very recent past. A botanical survey of the Jeypore tract of Koraput district in Orissa revealed the existence of over 1500 distinct rice varieties (Richaria and Govindaswami 1990). In the region between 1800 and 2700 metres in Meghalaya and Arunachal Pradesh, scientists of the Indian Agricultural Research Institute collected several thousand cultivars (Rao and Murti 1990). In a single year, farmers in Raigad district of Maharashtra collected 365 varieties of rice, of which only 35 to 40 were on the documented list. A simple extrapolation from this example would show that rice diversity in India may be over 2,00,000 varieties (Sampemane 1993).[13]

Other crops too show great internal diversity. Indian farmers, for instance, have developed over 1000 cultivars of *Colocasia esculenta* (Groombridge 1992). Other crops with high diversity include:

Mango: 1000 varieties
Sorghum: 5000 varieties
Pepper: 500 varieties

Though crop species and varietal diversity is found throughout India, certain regions have heavy concentrations. These include the Western and Eastern Ghats, north-east India, north-western Himalaya, central India and the Deccan plateau (Rana 1993). This amazing diversity is not a freak of nature, but a result of careful selection and even cross-breeding, over centuries, by India's farmers.

Certain types of traditional agriculture have been known for their exceptional diversity. This is true, for instance, of shifting cultivation, practiced in the tropics across the world, and in India in the north-east, central highlands, and the Western Ghats. Ramakrishnan (1989, 1992a) has shown how *jhum* cultivators in the north-east use a mixture of a minimum of 4-5 crops, and occasionally as many as 35 crop species. These include pulses, cucurbits, vegetables, legumes, cereals, tubers, and fruit crops, both annuals and perennials. Crop mixtures change from region to region, and even within a region, depending upon local ecological conditions and the socio-economic and cultural traits of the farming communities. Swidden farming by the Angamis in Nagaland, involving cultivation of 15 – 60 crop species, has been called a 'female farming system' as sowing, manuring, weeding, seed selection and storage are all done by women while men do the tree cutting, clearing and burning of the *jhum* plot (Raju and Sarin 2001). A study conducted by NEPED (Nagaland Environmental Protection and Economic Development Project) in Chetheba area of Phek district (Nagaland) revealed that at least 167 crops are cultivated in a typical *jhum* field (*Nagaland State BSAP*).

Ramakrishnan (1992a) describes a typical *jhum* system. After a plot of forest is burnt, seeds of pulses, cucurbits, vegetables and cereals are mixed with dry soil and then broadcast. Maize and rice seeds are dibbled in at regular intervals. Semi-perennial and perennial crops such as ginger, colocasia, tapioca, banana, and castor are sown intermittently throughout the growing season. Leaves of *Ricinus communis* are used to rear silkworms. Each crop harvested makes way for another. *Coix lacryma-jobi*, *Eleusine coracana*, *Ipomoea batatas*, and *Dioscorea alata* are other crops which may be grown.

Shifting cultivation systems are also known for their encouragement to intermixture of trees and crops. Indeed, agroforestry in many forms has also been prevalent in some parts of India, and has tended to use considerable diversity of species. It has been defined as a 'land use system in which woody perennials (tree and/or shrubs) are deliberately combined on the same land management unit as crops and/or animals, either in some form of spatial arrangement or in time sequence' (Gill and Deb Roy 1992).

The Warlis, an Adivasi community living in Thane district of Maharashtra, have a similar farming system, which is known for its strong knowledge base and robust diversity. It has been developing over several millenia by a close study of interactions between plants, animals and human beings. If it has survived for so long, it can only be because it is ecologically sound. They have evolved a complex method of multiple cropping which appears unique. Dependent as it is on a short, irregular, rainy season, it maximises food security, makes optimum use of the available resources of land, labour and animal power. Warlis mainly cultivate a few of more than 15 traditional varieties of paddy that are available to them. These have differing requirements of water and soil, mature at staggered times, have different susceptibility to pests and possess varied flavours. If the monsoon proceeds normally, their main varieties give a good yield; if it doesn't, the others, more hardy but with lower yields, still produce some food (Pereira and Seabrook 1990).

Over the generations, tribal communities – Irulas, Malayalis and Muthuvans – living in the state of Tamil Nadu have been cultivating traditional cultivars of paddy, millets, pulses and vegetables. The subsistence lifestyle, local diet habits as well as dependence on monsoon rain for irrigation have led them to cultivate traditional varieties and to conserve local seeds for consumption and for sowing the following season. The cropping practices of these subsistence farmers, particularly the mixed cropping system which result in intensive farming in a limited area, are unique. Their knowledge of seed selection, their traditional methods of conserving seeds and grains in eco-friendly traditional granaries, and their communities' participation in maintaining germplasm provide important insights to global efforts aimed at genetic conservation (Ravishankar and Selvam 2002, www.mssrf.org). This is not just the case of Tamil Nadu but also the situation in all the *adivasi* communities across the country, including the Chhattisgarh region of Madhya Pradesh, the Santhal areas of the central forest belt and the extensive *adivasi* habitats in Orissa, Andhra Pradesh, both the Eastern and Western Ghats, the North-eastern region and the Himalayas.

Box 4.16 Home Gardens

Home gardens are mixed farming systems comprising seasonal and perennial crops, as well as plants and trees, and with a variety of animals sustained in the land surrounding the house. Millat-e-Mustaffa (1998) defines home gardens as the land surrounding a house on which a mixture of annual and perennial plants are grown, with or without animals, and largely managed by the members for their own use or commercial purposes. Fernandez and Nair (1986) view home gardens as 'land-use practices involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and, invariably, live stock, within the compounds of individual houses, the whole crop-tree-animal unit being intensively managed by family labour'.

Home gardens have been developed and sustained by farmers in many regions in the past due to the fact that these were then the most beneficial forms of cultivation or land use, given the constraints and opportunities encountered by them. Such systems were mostly prevalent in humid or sub-humid tropical areas such as South-East Asia (Soemarwoto and Soemarwoto 1982; Wiersum 1982), Kerala (Nair and Krishnan Kutty 1984; Nair and Sreedharan 1986; Jose and Shanmugaratnam 1993) and North-Eastern states of India (Godbole 1998), Bangladesh (Millat-e-Mustafa 1996), Southern Mexico (Gleissman 1984) and Central American countries such as Guatemala (Rico-Gray *et. al.*, 1990; Anderson 1950), the Amazon basin (Padoch and Jong 1991), and wet-tropical Africa (Mergen 1987; Rugalema *et. al.*, 1994). The establishment and sustenance of this system could be attributed to the traditional farmer's realization that such a mixed tree-cum-crop plus animal system of agriculture was more rewarding than the mono-crop or mono-species cultivation, due to the conditions that prevailed in such regions. These conditions include the rainfall and other climatic features such as topography and natural diversity, with the farmer aiming at generation of the highest amount and variety of food and other materials for livelihood requirements such as house construction and health, and also for generating cash income through market transactions in the past.

Home gardens cater to the different requirements of the farm family in terms of food, building construction, health, energy and culture (i.e., religious and ritual needs). Home gardens also provide a major part of requirements like fuel-wood and other tree products for which many societies usually depend on non-agricultural lands and forests. In addition, generation of cash income through the marketing of products (and/or procurement of other household necessities through the bartering of products) from home gardens was also prevalent, at least during the last couple of centuries. For example, the pepper trade was prevalent for many centuries in Kerala without commercial cultivation in plantations. Similarly, the mid-land Keralites had been acquiring items such as salt, fish and clothes by bartering garden products, much before the circulation of money in that society.

According to Godbole (1998), chilli varieties with high capsaicin content are only cultivated in Lotha and Konyak Naga home gardens. Forest trees such as *Aguillaria agallocha* are domesticated in Konyak home gardens in North-East India. 154 plant products used in local diet have been recorded in Konyak home gardens. More than 120 plant and several animal species have been found in large spacious home gardens.

Common trees and plants in Kerala homesteads are Mango (*Manginfera indica*), Silanti (*Thespesia populnea*), *Erukku* (*Calotropis gigantea*), *Avarum* (*Cassia auriculata*), Laurel (*Calophyllum inophyllum*), Jack (*Artocarpus integrifolia*), Coconut (*Cocos nusifera*), Anjil (another *Artocarpus* species), Tamarind (*Tamarindus indica*), Tree cotton (*Gossypium arboreum*), Yam (*Dioscorea esculanta*), Chempu (*Colocasia antiquorum*), Elephant Yam (*Typhonium trilobatum*), Pepper (*Piper nigrum*), Ginger (*Zingiber officinale*), Turmeric (*Curcuma longa*) and Plantain (several varieties of *Musa sapientum*).

According to Sinha and Das (2000) studies on traditional home gardens in the Barak valley in Assam reported that some of the common species grown are *Bambusa polymorpha*, *Erythrina ovalifolia* and *Parkia roxburghii* which is a member of *Mimosuceae*, and is locally called '*Yongchak*'. *Yongchak* is a popular bean among the people of Manipur, Nagaland, Mizoram and other hill tribes of the Northeastern states.

From gender and equity perspectives home gardens are very important. In one study, woman spent 9.4% of their productive activity time in the home gardens while men spent only 2.3% of their productive activity time there (Ahmed *et. al.*, 1980). Women could name 29 plant products form home gardens, while men could name only 12 such products (Godbole 1998). Women are also leading the process of revitalization of home gardens and other healthy traditions, in about 100,000 households in Southern India, by raising Kitchen Health Gardens (KHG) promoted by FRLHT and its collaborating NGOs from 18 places in the states of Karnataka, Kerala and Tamil Nadu. This massive growth was achieved during the last 5 years as women could save much of their domestic primary health care expenditure by raising a package of 15-20 important herbs (www.undp.org/tcdc/bestproc/social/cases/05herbal.htm, *Home Gardens and Biodiversity Subthematic Review*).

Box 4.17 Diversity in Rainfed Agriculture

One of the prime centres of domesticated biodiversity, the rainfed agricultural region in India extends over 97 million hectares (67%) of the cultivated area. Rainfed agriculture is defined as crop and livestock production based on rainwater. It usually covers all areas under arid, semi-arid and sub-humid climatic zones. It has not been fully realised that even when the full irrigation potential of the country becomes operative, 50% of the net sown area will continue to remain rainfed. Rainfed agriculture supports 40% of the India's population and contributes 44% to the national food basket. It is in the rainfed belt that cultivation of 91% pulses, 80% oilseeds and 65% cotton occurs. This is the region where crops like rainfed rice, sorghum, pearl millet and a range of other millets are also grown; their cumulative diversity is enormous. The genes from the traditional varieties could be useful to implant drought resistance, especially in view of the impending climatic change scenario (Ghate 2002).

Current Status of Crop Diversity

Unfortunately, there is little information on the status of most crop species and varieties in India. Thus, for instance, no one seems to know how many rice varieties are still grown in India; indeed, there is considerable speculation about whether the recorded figure of 50,000 to 60,000 varieties represents only a part of actual diversity. In such a situation, it is not possible to assess the precise status of most crops. However, it is obvious that a severe decline in indigenous genetic diversity has taken place in a number of species, including rice, potato, cotton, sugarcane, small millets, etc. (IIPA 1996) One measure of this is the rapid increase in cropped area under a handful of so-called HYVs, at the cost of area under traditional varieties (*see Section 5.1.2.2*).

It is estimated that within a short period, just 10 varieties may cover 75% of total rice acreage in the country (Jain 1982), but some scientists refute this argument. Clearly though, the introduction of exotic and laboratory-hybridised varieties has pushed the earlier diversity out. Detailed case studies on the mechanisms of this loss are rare but indicative (IIPA 1996). In the case of West Godavari district of Andhra Pradesh, for instance, there appears to have been a 95% loss of diversity, while in the north-east and in south-east India, about 20% loss has taken place (S.D.Sharma pers.com. 1992), but in both cases there is little historical documentation of this process of erosion.

Box 4.18 Loss of Crop Diversity in West Bengal

A comparative analysis of the prevailing and pre-Independence crop and varietal diversity in West Bengal has shown that the number of crops and varieties grown during the pre-independence period was more than it is at present. The following information emerges from a crop survey conducted in all 18 districts of the state:

Crop diversity: In pre-Independence days, the number of crops that were cultivated, including both the *kharif* and *rabi* seasons was ascertained to be 38. After Independence, with the introduction of new and more economic crops, a few of the old economic crops fell out of favour with the farmers. By the process of deleting old and uneconomic crops and addition of new and more economic crops, the total number of crop species being cultivated after independence came down to 35. The change is marginal. While all the major crops in cultivation earlier retained their positions, changes affected some minor crops that were less important economically (*see Section 5.1.2.2*).

Varietal diversity: The most striking diversity existed in rice, the major crop of the state. During pre-independence days, there were as many as 252 indigenous varieties and 32 improved indigenous varieties being cultivated. With the availability of high-yielding varieties, the number of indigenous varieties and improved indigenous varieties came down to 36 and 10 respectively. However, this number is not absolute and final, as extensive survey in all districts could not be conducted within the scope of the survey.

Nevertheless, there is no doubt that the number of indigenous rice varieties, which were being cultivated in pre-independence days, came down substantially, yielding place to the HYVs. At present, nearly 70% of the cultivated rice area is covered by HYVs and in 30% area indigenous varieties are surviving.

Source: West Bengal State BSAP

4.1.4.2 Domesticated Livestock Diversity in India

(All information compiled in this section is from Ghotge 2002.)

India has the distinction of having some of the widest range of breeds within each species, representing a significant percentage of the world's domesticated livestock diversity (*see Table 4.38*).

Table 4.38 Domestic Animal Diversity

Species	World	India	Share of India in World (%)
Cattle	787	30	3.81
Buffalo	72	15	20.83
Sheep	920	42	4.56
Goat	351	20	5.7
Pig	353	3	0.85
Ass	77	3	3.9
Horse	384	6	1.56
Camel	56	8	14.28
Chicken	606	18	2.97

Source. Sahai and Vijh 2000

This rich diversity is accounted for by the diverse cultures, agro-ecological zones, and social and economic practices in the country. These breeds have developed and evolved over hundreds of years to suit the different production goals and requirements of different classes of livestock owners.

Livestock rearing has also been distinctly related to castes and communities, with specialized groups rearing distinct animal types and breeds. While many of these communities continue to rear these animals, others find their breeds threatened with extinction.

Given the large diversity of breeds in the country, there is little doubt that careful breeding has gone on for centuries to mould and shape a particular species from its wild state to a domesticated species which produces to satisfy different needs. There has also been a process of natural selection, whereby the strongest animals – those most resistant to a disease or most suited to a particular environment – have survived as breeding stock.

Selection for animals has always been in response to the production and cultural goals of the community raising these animals. Horses and camels in India have been bred both as riding animals and as pack animals. Breeds which are used for riding are of lighter build and slender, while those selected as pack animals are often of heavier build and more sturdy in structure. Cattle and buffaloes bred for draught do not have dairy qualities; their selection is based on their ability to perform different agricultural operations.

Animals which migrate are selected on the basis of their ability to withstand the pressures of migration and the stresses it imposes. This is true for many of the breeds of sheep found in the semi-arid regions of the country. Breeds selected in areas with heavy rainfall have a skin that can withstand heavy rains – like the Dangi and Siri breeds of cattle. Resistance to disease and parasites are some of the other factors which Indian farmers have carefully selected for. Amongst chickens, selection has largely been towards birds which produce quality meat, withstand disease, are good brooders and for their cock-fighting abilities.

Breeding strategies are very advanced for animals belonging to pastoral communities whose livelihood essentially depends on having quality stock. Although difficult to comprehend because careful pedigree records are not maintained, there is a great deal of thought which goes into the process of breeding.

Some male animals are carefully selected as breeding stock and these animals are retained in the herd while the rest of the male animals are sold. Care is also taken to prevent in-breeding by changing the stock periodically or bringing in animals from other herds.

Some of the crucial factors influencing selection are:

- Criteria related to production traits or assumed to be related to production traits, such as rate of growth of young ones, milk yield;
- Known genetic defects of the individual animal, its parents or offspring. Such animals are rejected; and;
- Economic and logistic constraints. Animals which demand heavy feed resources may not be welcome in resource-poor areas.

Even in animals that exist in a semi-domesticated state (like the *mithun* and the yak), a certain degree of selection has gone towards evolving suitable animals. In the case of the yak, bull calves showing larger body size and having attractive colours and horn patterns are selected as future sires for breeding. In some areas yak and *siri* cattle hybrids have also been produced for areas which are too low in altitude for the yak and too high for cattle. The Monpas, a Buddhist tribe of the West Kameng and Tawang areas of Arunachal Pradesh, have used *mithuns* for hybridisation with local *siri* cattle.

Breeding has also been a fairly specialized occupation and there are a number of communities throughout the country whose livelihood depends on the sale of breeding stock. They charge farmers for the services rendered by their animals. Often these are different pastoral communities like the Rabaris and Bhadawars who also provide this service. Owners of female animals are charged for a service, and if the animal does not conceive it can be taken back for servicing two more times. This system exists for buffaloes as well. These services were however too expensive for poorer communities, and they have had to be content with non-descript animals or animals which have been rejected by wealthier farmers.

Breeding is an expensive activity, and so is maintaining a quality animal both in terms of time and resources. Local rulers often developed many of the best breeds of horses and cattle. The *Amrit Mahal* cattle of Karnataka were developed during the reign of Tipu Sultan, the *Gaolao* of Vidarbha by the Maratha rulers and the now almost extinct *Punganur* by the rulers of Mysore.

Indian breeds of cattle have attracted international attention from as far back as the 19th century when breeds like the *Gir*, *Ongole* and *Sahiwal* were exported to the Americas and Australia under the name Brahman bulls. The special properties of these animals were perfectly suited for the grasslands of the Americas, as well as Australia and New Zealand. Excellent animals were taken to these countries by the colonizers. These breeds however have

Box 4.19 Yak Breeds and Distribution in India

Yaks are distributed in the four Himalayan states – the Ladakh region of Jammu and Kashmir; Kinnaur, Spiti and Chamba Districts in Himachal Pradesh, Sikkim; and Twang and West Kamang districts of Arunachal Pradesh in the north-eastern states. The total yak population in India is around 40,000, and it is one of the most important animals of the Himalayan region. Indian yaks can be described based on their regional distribution.

Ladakh yaks: These are found in the Ladakh plateau including Leh, Kargil and Hunza regions. There is wide variation in the phenotypes of yaks found in this region, but three distinct types have been reported by Gupta and Kumar (1994). The yaks in Hunza, Ashokman and other regions of Kashmir are similar to those found in Leh region of Ladakh.

Arunachal yaks: Yaks found in Arunachal Pradesh can be classified into four main types depending on the physical conformation and hair types. They are Common type, Bisonian type, Bareback type and Hairy forehead type (Pal *et. al.*, 1994). According to the 1998-99 census, the total population of yaks reported from Arunachal Pradesh was 8976 (*Arunachal Pradesh State BSAP*).

Sikkim yaks: Yaks in Sikkim occur in the Trans-Himalayan Highland in the east (Bhutan Border) and Khangchendzonga National Park in the west on Nepal border (Usha Lachungpa, personal communication 2002). Two main types of yaks are found in Sikkim and they are classified based mainly on the geographical distribution and the communities related to herding. The *bho* yaks are found in western Sikkim and are reared by the Bho community, whereas *aho* yaks are reared by the Aho community in the eastern districts.

Himachal yaks: The yaks of Himachal are hardy animals with elongated and compact bodies. The yaks of Spiti and Pangi valley are sturdy and big in size, similar to those of the upper mountains of Ladakh region. The yaks of Sangla valley of Kinnaur district are small and compact.

Source (except where otherwise stated): Gupta and Gupta, undated

seldom attracted as much attention in our own country. Livestock scientists have found that migratory pastoralists in Rajasthan had selected for, and helped develop, a new breed of sheep called *kheri*, in response to the increasing incidence of drought and declining pasture availability (Jain *et. al.*, 1993).

In many parts of the country, though, breeding animals are maintained as a community resource and the entire village treats these animals with a great deal of reverence. Buffalo and cattle bulls of good breeds are allowed to wander at will through different villages. They are also given extra nourishment and care and allowed to stay wherever they wish.

In the case of livestock breeds, there is a 'critical' stage/number; if population falls below this, restoration is impossible. A species-wise list of breeds deserving attention for conservation initiatives in this respect is given in *Table 4.39*.

Box 4.20 Indigenous Breeds of Indian Dogs

A number of indigenous breeds of dogs have also been identified. Somani (1963) distinguished 34 breeds, but no recent work establishing an all-India estimate appears to have been done (Baskaran 1985). No information is available on indigenous house cats of India (*see also Section 5.1.2.2*).

Some of the common Indian breeds are *Combai*, *Chippiparai*, *Rajapalayam*, *Caravan Hound, Kanni*, and *Mudhol Hound*. *Rampur Hound* is powerfully built with strong jaws and broad skulls. The hound also hunts vermin, deer and jackals. *Alangu* is a breed from the Thanjavur and Tiruchi districts in South India. This is a tall breed with a noble carriage and short coat. The dogs may be red, fawn and black with white markings on their chest. The *Kuchi* is also a native of Thanjavur, and is a small dog with a long coat. The *Kaikadi* is named after a nomadic tribe in Maharashtra. It may be white, tan, and black. The dogs are small (about 40 cms or less) with thin long legs, but powerful thighs and hocks. They make excellent watchdogs (*see Section 5.1.2.2*) (Baskaran 1985, Somani 1963, http://www.dogsindia.com/indian_breeds.htm).

The *Santal Hound* seems to be close to the original dogs domesticated by humankind well over 15,000 years ago. Archaeological evidence has shown this type to be the same in India, the Middle East and other sites. Rural communities in India, particularly *adivasi* societies, are one of the last repositories of this breed, which has all the natural abilities and mental characteristics of the first wild ancestors that were domesticated (Gautam Das, personal communication 2002).

Table 4.39 List of Threatened Livestock Breeds

Species	Name of the Breed
Cattle	Bachaur, Dangi, Kenkatha, Siri, Kherigarh, Rathi, Krishna Valley, Red Sindhi, Sahiwal, Tharparkar, Punganur,* Vechur,* Malnad Gidda, Amrithmahal, Umbalacherry, Kangeyam, Nar
Buffalo	Toda, Nili ravi, Bhadawari, Jaffarabadi, Pandharpuri,
Sheep	Nilgiri, Bhakarwal, Poonchi, Karnah, Gurez, Changthangi, Muzafarnagari, Chokal, Munjal, Jaisalmeri, Kheri, Bonpalo, Hassan, Bannur (Mandya), Changthangi, Vembur, Kachakatty black
Goat	Jamna pari, Barbari, Surti, Beetal, chegu, Changthangi, Jhakrana, Sangamneri, Tellicheri (Malabari), Gohelwadi, Kanchu Mekha
Camel	Double humped camel, Jaisalmeri, Sindhi
Poultry	All indigenous breeds especially Aseel, Kadakanath, Chittagang and Maly
Cultured fish	*Schistira sijuensis* and *Horaglanis krishnispecies*
Pet dogs	Kombai,** Banjara,** Himalayan breed, Rampur and Mudhol

**Species count below 5000, **Almost extinct*

Source: Jiang 1992; Domesticated Biodiversity Thematic BSAP

4.1.4.3 Cultured Micro-Organisms

As mentioned in *Section 4.1.2.3*, a small fraction of India's micro-organisms have been cultured. *Table 4.40* gives estimates of key culture collections.

In addition to the above, several other culture collections are available (*see Section 6.1.2.3*), whose collection figures are not available.

Table 4.40 Microbial Cultures held at Different Centers in India

Centers	Actinomycetes	Algae	Bacteria	Fungi	Yeast
MTCC, IMTECH, Chandigarh	900	–	1500	1800	700
NCIM, Pune	500	600	1000	200	–
HMR/QIL, Mumbai	15,027	–	937	9,050	–
ARI, Pune	4	–	251	8	1
IARI, New Delhi	–	500	1200	2779	–
NCMCB, Tirchuirapalli	–	268	–	–	–
Christ Church, College Kanpur	–	–	–	250	–

Source: Micro-organic Diversity Thematic BSAP

4.2 Importance and Uses of Biodiversity in India

4.2.1 Ethical Values

The vast diversity of species and ecosystems contribute to the richness and beauty of life on Earth. Human beings constitute only one of the millions of species that inhabit the earth. Each species is unique and was created as a consequence of evolutionary processes without human intervention. In traditional literature, it is pointed out that every *dravya* (natural substance) has distinct qualities (*guna*) and it has a definite role (*karma*) to play. Each species thus has value in its own place and is worthy of respect regardless of its worth to human beings. It is this understanding and appreciation of the inherent value of each and every life form that constitutes the 'ethical' value of biodiversity.

Whereas the utility of a large number of species was 'discovered' by human communities for varied economic, social and cultural needs, the ethical values of biodiversity are independent of all these, and highlight the intrinsic value of biodiversity for its own sake (*see section 4.2.7*). All religions practiced in India promote the conservation of biodiversity in their own way. Jainism, for example through its perception of 'livingness' of the world, follows the ideals of the environmental movement. Further, the practice of non-violence in the religion fosters an attitude of respect for all life-forms. In deference to that, many Jains wear masks to prevent invisible creatures from getting killed while breathing and speaking. The advanced monks and nuns sweep their path to avoid trampling on insects. Buddhism has long advocated reverence and compassion for all life. This religion is also more direct in encouraging individuals to limit their resource consumption to the optimal satisfaction of the four basic needs of food, clothing, shelter, and medicine. Sikhism focuses on natural phenomena, animals and birds, seasons, flora and fauna and above all the creation of the world. Islamic teachings state that 'All living creatures are worthy of our respect and we were entrusted with the Earth to God: thus it is our duty to care for our planet. We have a duty of care and respect for all people and other forms of life.' Judeo-Christian ethics also fostered an attitude of stewardship towards nature (*Culture and Biodiversity Thematic BSAP*).

4.2.2 Ecosystem Benefits and Values of Biodiversity

There is growing awareness about the importance of maintaining a high level of bio-diversity in terrestrial and aquatic habitats in the context of what is referred to as 'ecosystem benefits or services'.

Ecosystem benefits are generated as a result of interaction and exchange between biotic and abiotic components of ecosystems. The ecosystem benefits include numerous invisible but essential services, viz., soil formation and fertility generation, reduction of soil salinity, decomposition and waste dissipation, productivity, carbon sequestration and balance of atmospheric gases, stabilization of climate and mitigation of climatic change, nutrient cycling, maintenance and raising of the water table, enhancement of water and air quality, flood and drought control, and many more.

Such functions can be seen in the context of agriculture also. It is a significant fact that the energy consumption balance sheet weighs very heavily in favour of the more traditional biodiverse farming systems as opposed to modern mono-cropping systems. While the energy requirements for modern agriculture are derived from fossil fuels and consumption levels are very high, biodiverse farming systems usually produce the energy needed for the system on the farm itself and regularly recycle the biomass produced on the farm to meet its energy requirements. This may be understood to be an ecosystem benefit provided by a biodiverse agricultural system.

It is also important to make a distinction between biodiversity and biological resources and between natural ecosystems, diverse agro-biodiversity and homogenised agro-systems. The presence of *Eucalyptus* spp. or *Rauvolfia* spp. in a garden, or hybrid rice in a field, may not necessarily carry a positive biodiversity value, although these species are undoubtedly valuable biological resources because of their usefulness.

Biodiversity values, in the form of multi-dimensional ecosystem benefits of the kind outlined above, are expressed in a natural ecosystem because, in such a system, the presence of diverse taxa, plant, animal, micro-organism, including their interactions, is not due to chance or engineered by some external designer, but as a result of the changing equilibrium in ecological and evolutionary processes guided by edaphic, symbiotic, synergistic, genetic, antagonistic and several other insufficiently understood principles of evolution. It is less clear how biodiversity values could be systematically assessed in a diversified agricultural system, which is a product of human intervention with a natural ecosystem. One could perhaps discern the biodiversity values in such a system design, if it has demonstrated ecological stability over a sufficiently long period of time, is self-sufficient and also meets with the social, cultural and spiritual needs of the communities that depend on it and retains evolutionary potential. The credit for the design of such integrated system must be given to native farmer-ecologists, pastoralists and fisherfolk of yore (and to their present-day descendants) for initiating, evolving, adapting and sustaining the system over generations and successfully transmitting essential information about their design principles to their successors.

Over the last century modernization seems to have overlooked biodiversity values and their resulting services. Although there has been a recent awakening to the perils associated with the loss of biodiversity, there is still a huge gap between mental awareness and practical social actions.

From the way we manage the forest and wetlands systems to the way we deal with the coastal and agro-diversity, there is serious neglect of ecosystems and consequently of their potential services, due to ignorance of the value of the ecosystem functions. Eutrophication of the lakes of Kashmir, Nainital and other such waterbodies and loss of their hydrological and ecological value; receding glaciers and depleted water flow to rivers; increase in the intensity of flood peaks; landslides and erosion in mountains; widespread gully formation in the Chambal ravines; salinisation and depletion of groundwater; widespread expansion of exotic invasive species in natural ecosystems, both terrestrial and aquatic; increasingly erratic nature of the waterflows and possibly even of the climate; decline in marine and freshwater fisheries; degradation of recharge zones and drying-up of springs; soil

Table 4.41 Comparison of the Ecosystem Services of Three Himalayan Forests

Forest	Ecosystem Characters	Ecosystem Services
Banj oak (*Quercus leucotrichophora*)	Large biomass (400-500 t ha-1); deep roots and deep carbon storage in soil; high amount of investment of photosynthesis in ectomycorrhizae, massive annual return of nutrients to soil	Rapid soil formation, high soil fertility, effective carbon sequestration; effective nutrient and water retention
Chir pine (*Pinus roxburghii*)	Small biomass (200-250 t ha-1); high productivity on degraded slopes, high nutrient use efficiency; high stress tolerance, effective coloniser, more fire proneness, depletion of flow in water springs	Supply of ecosystem services in inhospitable conditions; retention of nutrients on steep and rocky slopes; moderate nitrogen enrichment
Alder (*Alnus nepalensis*)	Very small biomass (<100-150 t ha-1), very high productivity (up to 30 t ha-1 yr-1); rapid coloniser of fresh landslip; very high rate of N-fixation (up to 200 kg N ha-1 yr-1)	Facilitation of more useful species, high carbon fixation, nutrient supply to other ecosystems.
Lantana camara (an invasive species)	Very small biomass (<30 t ha-1), productivity similar to oak and pine; carbon shortage in shallow soils, low biodiversity, cool but frequent fires	Low soil carbon storage, persistent fire regime, low nutrient and water retention

Source: Western Himalayas Ecoregional BSAP and water degradation in intense monoculture areas are some examples to indicate how loss of biodiversity has impacted our ecosystems and the flow of their services.

People of every region depend on the daily flow of local ecosystem services from terrestrial as well as aquatic habitats for managing their lives; therefore, there is a need to value and conserve the natural ecosystems of all regions and not focus only on hotspots or flagship species. Identification and recognition of ecosystem services is therefore required at various scales from local to regional, national and global levels. Unfortunately, in India very little has been done to evaluate ecosystem services in the context of both natural as well as human-impacted ecosystems in an integrated and systematic way (for some limited examples, see *Section 4.2.5* and *Table 4.46*). There is also inadequate appreciation of the enormous value and critical nature of such services to the most disprivileged sections of Indian society, including women and those without the ability to buy fuel, fodder, water, medicines etc.

Box 4.21 Mountain Forest Ecosystem and Water

Mountains and their forest ecosystems are regarded as the water towers of the world. The extraordinarily massive Himalayan ranges, for example, have shaped the climate of the Indian subcontinent and provided water and soil to the Gangetic plains. Among the contributions of the Himalayas are the monsoon pattern of rain, high round-the-year humidity, mild winters and slow lapse rate of temperature with increasing altitude.

The ecosystem services provided by the Western Himalayan forests to the people in the Gangetic plains include:

- Maintaining water flow in rivers and lakes which contributes to pollution control and helps maintain aquatic diversity and soil and water storage;
- Controlling flood peaks and erosion;
- Rapid soil formation, particularly in oak forests, thus nursing crop-fields, both in the hills and plains, by providing soil and nutrients;
- Carbon sequestration and climate stabilization; and;
- Restoration of landslide sites through the process of succession in which nitrogen-fixing woody species like alder (*Alnus nepalensis*) and *Coriaria* (a bush) play an important facilitating role. In fact, succession is a composite ecosystem service, generating soil, nutrients and control over destabilising physical forces of nature.

The hill ranges of peninsular India provide critical water services to the plains below them, since they are the source of springs and streams that form the rivers flowing through these plains. Natural vegetation on these hills plays the essential catchment and 'sponge' role so necessary for the stability of these hydrological systems.

Source: Western Himalayas Ecoregional BSAP, Aravalli Ecoregional BSAP, Western Ghats Ecoregional BSAP, Eastern Ghats Ecoregional BSAP

It is important to emphasise that when we are talking of ecosystem services we need to consider the services arising not only from the more familiar terrestrial habitats but also those services that are provided by aquatic habitats. Mangroves and coral reefs are good examples. Apart from their normal ecosystem benefit role in preventing erosion, they play a critical role in the context of the tremendous protection they provide to offshore life during hurricanes and storms.

4.2.3 Livelihoods

In India biodiversity supports the livelihoods of millions of ecosystem people. Around 70% of the Indian population depends on land-based occupations, forests, wetlands and marine habitats and are thus directly dependent on local ecosystems for their basic subsistence requirements with regard to water, food, fuel, housing, fodder and medicine. Around 10,000 species of plants and a few hundred animal species are involved in this direct relationship of biodiversity and livelihood.

Apart from this livelihood dependence for subsistence needs, there is livelihood dependence for seasonal or annual income derived from a wide range of terrestrial and aquatic wild resources. For example, there are estimated to be around 20 million persondays per year involved in medicinal herb collection from the wild, for a net collection of around Rs 112 crores per year (FRLHT 2001). 275 million people depend on non-timber forest products (NTFP) for their livelihood (Bajaj 2001). NTFP collection generates about 1063 million persondays of employment in India (Khare 1998) and about 60-70% of NTFP gatherers are women (Gera 2001). There are estimated to be 22 million fisherfolk who depend on aquatic habitats for their livelihood (Kocherry 2001). Over 200 castes, as much as 6% of the total Indian population, are engaged in pastoral nomadism (Agarwal *et. al.*, 1982). The small and marginal farmers, who account for over 80% of the farming community in India, are directly dependent on agro-biodiversity for their livelihood.

Table 4.42 gives an idea of livelihood dependence on wild plants which occur in common property resources (CPRs). It is significant that the highest livelihood dependence on CPRs is that of the rural poor.

Table 4.42 Livelihood Linkages with Common Property Resources[a]

No. of Districts and villages By state	Household by income Categories[b]	Fuel[c] (%)	Animal grazing	Employ-ment[e] Days	Annual income[f] (Rs)	% income from CPRs	Gini coefficient on income from[g] all Sources	All sources except CPRs (%)
Andhra Pradesh (1,2)	Poor	84	–	139	534	17	0.41	0.5
	Others	13	–	35	62	1	0.41	0.5
Gujarat (2.4)	Poor	66	82	196	774	18	0.33	0.45
	Others	8	14	80	185	1	0.33	0.45
Karnataka (1,2)	Poor	–	83	185	649	20	–	–
	Others	–	29	34	170	3	–	–
Madhya Pradesh (2,4)	Poor	74	79	183	733	22	0.34	0.44
	Others	32	34	52	386	2	0.34	0.44
Maharashtra (3,6)	Poor	75	69	128	557	14	0.4	0.48
	Others	12	27	43	177	1	0.4	0.48
Rajasthan (2,4)	Poor	71	84	165	770	23	–	–
	Others	23	38	61	413	2	–	–
Tamil Nadu (1,2)	Poor	–	–	137	738	22	–	–
	Others	–	–	31	164	2	–	–

Source: Jodha 1986; IIPA report 1996

a. CPRs include community pasture, village forests, wasteland, watershed drainage, river and stream banks, and other common lands. Data indicate average area per village.

b. The number of sample households from each village varied from 20 to 36 in different districts. 'Poor' households are defined as agricultural labourers and small farmers (< 2 ha dryland equivalent). 'Others' includes large farm households only.

c. Fuel gathered from CPRs as proportion of total fuel used during three seasons covering the whole year.

d. Grazing days per animal unit on CPRs as a percentage of total grazing days per animal unit.

e. Total employment from CPR product collection.

f. Income derived mainly from CPR product collection. The estimation procedure underestimated the actual income derived form CPRs.

g. A higher Gini coefficient indicates a higher degree of income inequalities. Calculations are based on income data for 1983–84 from a panel of households covered under ICRISAT's village level studies

The panel of 40 households from each village included 10 households from each of the categories, namely large, medium, and small farm households and labourer households.

The extent of livelihood dependence on biological resources and their host ecosystems is thus very substantial and there is an enormous challenge in finding ways and means to make this dependence sustainable and equitable.

Despite the erosion of community rights, CPRs continue to play an important role in sustaining diverse livelihood systems. A recent National Sample Survey Organisation (NSSO 1999) survey has for the first time provided a comprehensive database on the size, utilization and contribution of common pool resources in the country. The survey's main focus was to assess the role of common pool resources in providing biomass, fuel, irrigation water, fodder for livestock and other forms of economic sustenance to rural households. The NSSO defined common property resources as resources that are accessible to and collectively owned/held/managed by an identifiable community, and on which no individual has exclusive property rights. The study distinguished between the '*de jure*' (legally defined) and the '*de facto*' (actual) resource ownership and use. Only those common pool resources were treated as *de jure* which were within village boundaries and formally held (by legal sanction or official assignment) by the village panchayat or a village community. *De facto* common pool resources included all resources which were by convention in use by the community, irrespective of ownership and even if they were located outside the village boundary. The average value of collections from common pool resources was found to be highest for rural labour households. Grazing of livestock, and collection of fuelwood and fodder continue to be two important contributions of common pool resources to the rural economy (NSSO 1999, quoted in Chopra and Dasgupta, 2002).

Box 4.22 Economic Values of Arid Grasslands in Kachchh

Grasslands are of particular ecological and economic significance to arid regions like Kachchh in Gujarat, due to their high biodiversity values and the dependence on them of a significantly large population of pastoral and agro-pastoral communities to sustain their livelihoods based on free-grazing livestock. Banni and Naliya are two large grassland tracts in Kachchh, Banni being considered as one of the largest remaining grassland tracts in the sub-continent. Nearly 80% of the grassland area of Banni has been lost through invasion by *Prosopis juliflora*, an exotic mesquite native to South America that was introduced into the region as part of forestry programmes. An ecological-economic analysis of these grasslands highlights the contributions of grasslands to the overall rural economy of the two regions.

The dominant occupation in Banni is livestock rearing (65% of total families), followed by wage labour, most of which is linked to illegal wood-charcoal making from *Prosopis juliflora*. Livestock and non-livestock based incomes are the two major income sources in Banni. The wood-charcoal from *P. juliflora* forms the major share of non-livestock based income, although this is illegal under the current policy regime. Mean annual gross income per household is about Rs 57,000 from livestock, while that from other income sources is nearly Rs 23,500. Total extrapolated gross income per year for the 2500 families in Banni works out to be about Rs 170 million, of which 70% is from livestock with milk sales alone accounting for 64%.

In Naliya village, most of the households are agro-pastoral. A substantial part of the farm and livestock outputs are for subsistence. Of the total average annual income (including imputed incomes from subsistence agro-pastoral outputs), 37% comes from livestock. In the poorest group, the largest share of income is derived from the grassland dependent livestock sector (43%). Mean gross annual farm-based income per household is about Rs 39,500, while that from livestock is about Rs 29,000. Total extrapolated gross income per year for 750 families in the 9 villages studied is about Rs 48 million. There are definite patterns of dependency on the grasslands, across seasons and income groups. There is marked variation in such dependency across different income groups, which points to differentials in the benefits derived from open pastures by different income groups. The mean imputed cost of the resources used per year by the poorest and richest quintiles are about Rs 38,800 and Rs 360,700 respectively. The total annual unpaid cost of grass resources for the nine villages studied works out to be approximately Rs 4.75 million, based on a nominal cost of 50 Paise per kg of grass consumed. *Prima facie*, in the absence of an analysis of such differentials in the unpaid costs, it would appear that the richer agro-pastoralists with large land holdings are less dependent on the open grasslands. However, about 38% of annual unpaid benefits are accounted for by the richest quintile, while the poorest quintile benefits by a mere 4%. While the unpaid costs of grassland resources helps the poor in subsistence, the huge benefits enjoyed by the richer agro-pastoralists could be a major input for the profitability of the relatively larger agro-pastoral enterprise.

Source: Geevan et. al., 2003

4.2.4 Health and Food Security Values

Empirical evidence reveals that the largest use of ecosystem resources (8000 species of plants and a few hundred species of animals) by local communities is for maintaining the 'health security' of human, livestock and plants (bio-pesticides and bio-fertilizers). *Table 4.43* gives some data on the large number of medicinal plant species used in health care of humans and livestock across the different biogeographic zones of the country.

Table 4.43 Medicinal Plants Species Diversity Used by Local Communities in Different Biogeographic Zones of India

S. No.	Biogeographic Region	Estimated Number of Medicinal Plants Used	Examples of Some Typical Medicinal Species
1.	Trans-Himalayan	700	*Ephedra gerardiana*, *Hippophae rhamnoides*, *Arnebia euchroma*
2.	Himalayan	2500	*Aconitum heterophyllum*, *Ferula jaeschkeana*, *Saussurea costus*, *Nardostachys grandiflora*, *Taxus wallichian*, *Rhododendron anthopogon* and *Panax pseudoginseng*
3.	Desert	500	*Convolvulus microphyllus*, *C. pluricaulis*, *Tecomella undulata*, *Citrullus colocynthis*, *Cressa cretica*
4.	Semi-Arid	1000	*Commiphora wightii*, *Caesalpinia bonduc*, *Balanites aegyptiaca*, and *Tribulus rajasthanensis*
5.	Western Ghats	2000	*Myristica malabarica*, *Garcinia indica*, *Utleria salicifolia*, and *Vateria indica*
6.	Deccan Peninsula	3000	*Pterocarpus santalinus*, *Decalepis hamiltoni*, *Terminalia pallida*, *Shorea tumbuggaia*, *Pterocarpus santalinus*
7.	Gangetic Plain	1000	*Holarrhena pubescens*, *Mallotus philippensis*, *Pluchea lanceolata*, *Peganum harmala*
8.	North-East India	2000	*Aquilaria malaccensis*, *Smilax glabra*, *Abroma augusta*, *Hydnocarpus kurzii*, *Coptis teeta* (*Mishmi teeta*)
9.	Islands	1000	*Calophyllum inophyllum*, *Adenanthera pavonina*, *Barringtonia asiatica*, *Aisandra butyracea*.
10.	Coasts	500	*Rhizophora mucronata*, *Acanthus ilicifolius*, *Avicennia marina* and *Sonneratia caseolaris*

Source: Adapted from FRLHT 2002

Box 4.23 The Value of Weeds

To a lay person the term 'weed' stands for a useless, unproductive plant, which competes with crops for water and nutrients and needs to be removed. However, there are many who differ. Local communities use many of the 'weeds' to cure common physical ailments. Practitioners of traditional systems of medicine know for a fact that many of the plants commonly termed as weeds have significant medicinal value. These plants have been extensively documented in *Ayurveda*. According to one study, more than 50 'weed' species are found in the rice fields of Chhattisgarh, which local drug retailers are exporting to other countries for medicinal and industrial purposes. It is important then that documentation of these so-called weeds is carried out. Depending on their value, these could be promoted in villages. If there is an organized supply of the same to retailers, then this will not only reduce the weed 'menace', but will also recover the cost of weeding manually. Also, the processed form of the weed will get a better price in the market. This provides a wonderful opportunity for local communities to develop an enterprise.

Source: A, Kumar, Undated

The species used by local communities include a vast diversity of ecosystem-specific food and fodder plants, including species that are used by them in times of scarcity.

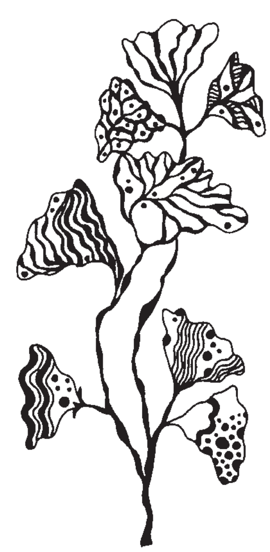
With the development of modern high-yielding varieties of crops and growing homogenization of food habits across the world, an increasing reliance has been placed on a few edible species. This was not always the case, and is still not so in many rural parts of the world. Approximately 80,000 edible plants have been used at one time or another in human history, of which at least 3,000 have been used somewhat consistently (Ayensu 1983). However only about 150 have ever been cultivated on a large scale and a mere 10 to 20 provide 80-90% of the world's calories today (Soule *et. al*., 1990)

A considerable part of the daily food intake of rural (especially tribal) communities comes from the wild. In an extensive study of wild foods by Singh and Arora (1978), information was collected from all over the country which revealed that a wide variety of tubers, edible grasses, flowers, fruits and seeds are eaten. Some examples are cited below:

Edible greens include leaves of *Ardisia* spp., *Meliosma pinnata* from the north-east; *Eremurus himalaicus*, *Sedum* spp., *Origanum vulgare L.*, *Arenaria holosteoides* and *Urtica hyperborea* in Lahaul and Ladakh. In coastal areas, *Sesuvium portulacastrum* is eaten as spinach. Examples of edible seeds include those of *Nymphaea* and *Nelumbo* species, *Buchanania lanzan*, *Euryale ferox*, *Cleome icosandra* and *Alpinia galanga*.

Tribal populations in Madhya Pradesh, Andhra Pradesh and Santhal Parganas of West Bengal (central and eastern India) use lichen species such as *Heterodermia tremulans*, *Everniastrum cirrhatum*, *Ramalina* spp., *Usnea longissima* and *Roccella montagnei* as spice and flavouring agents (Singh and Sinha 1993). In coastal areas of the southern state of Tamil Nadu, seaweeds such as *Gracilaria edulis* Silva are used for making gruel (Chennubhotia *et. al.*, 1993).

Some examples of wild floral species utilized primarily as famine foods, in Sikkim are the flowers of *Urtica dioica* and *U. parviflora*; rhizomes of *Dioscorea* spp.; fruits of *Aisandra butyracea*, *Calamus erectus*, *Elaeagnus conferta*, *Heracleum lanatum*, *Podophyllum hexandrum*, *Machilus edulis*, *Melia dubia*, *Morus australis*, *Terminalia chebula*, *Zanthoxylum acanthopodium*; and shoots of *Rheum nobile*, *Diplazium esculentum*, *Polygonum molle* and *Ficus virens*. Similarly, in the Rajasthan desert, famine foods include *Prosopis cineraria*, *Cenchrus biflorus*, *Calligonum polygonoides*, *Citrullus colocynthis*, *C. lanatus*, *Dactyloctenium aegyptium*, *Acacia jacquemontii*, *A. leucophloea*, *Ziziphus nummularia*, *Z. mauritiana*, *Indigofera cordifolia*, *Tamarindus indica*, *Capparis decidua*, *Salvadora oleoides*, *Achyranthes aspera*, *Eleusine coracana*, *Sesamum indicum* and *Cyperus rotundus*. It is also interesting that the desert locust (*Schistocera gregaria*) is relished (both fresh and preserved) and used during periods of scarcity. In the Bhimashankar Wildlife Sanctuary in Maharashtra, dried unripe fruits of *Bombax ceiba* are stored and eaten during food shortages; unripe and ripe fruits of *Jasminum malabaricum* are also boiled, dried and stored as cereal for times of food scarcity. It appears that earlier each household would store 5-6 kgs of this species for periods of shortages (Borges and Rane 1992). The Padhars of Gujarat in western India dig for tubers of *Scirpus kysoor* in times of famine (MoEF 1989). Grain amaranths were similarly used as reserve foods in the Himalayas (Joshi and Rana 1991).



Wild edible seeds are also used as famine foods. Examples are *Indigofera glandulosa*, *I. linifolia*, and *I. cordifolia*, out of the flour of which bread was baked. Seeds of grasses such as *Echinochloa*, *Panicum* and *Eleusine* species were made into bread or roasted. Grains of *Bambusa* are cooked as rice. Grains of legumes like *Vigna capensis* and *Phaseolus sublobatus* are cooked as pulses (Singh and Arora 1978).

Several plant species are used for their insecticidal properties. *Ipomea* species are used against aphids and larvae of insect pests; *Fagonia indica* var. *schweinfurthii* for insects like blister beetle in *bajra* crop; castor for termite aphid; *Calotropis gigantea* for aphids; *Leucas indica* and chilli for pests of storage; *Euphorbia* species for larvae and pigeon pea; *Clerodendrum multiflorum* for aphids; *Eleusine coracana* for termites; *Bidens biternata* for insect pests of paddy (Gupta *et. al.*, Undated). Recently, much emphasis is being placed on *neem* (*Azadirachta indica*) as a biopesticide. Krishnan has given an account of how *jowar* grains were stored for more than 30 years, sealed in between layers of *neem* leaves in bins and buried in a 12 ft. deep pit (*The Statesman*, 22.3.92). Storing of wheat and barley grains with cow dung ashes was a practice to prevent insect attacks (Atkinson 1973). Besides the leaves, seeds and the oil from the seeds are used also as pesticides (Dastur 1964). The crushed fruit of *Catunaregam spinosa* Tiruvengadum is used to protect stored grains; the oil cake of *Madhuca longifolia* and the oil and leaves of *Derris indica* are used for their insecticidal properties (*ibid*). Apart from *neem*, the oil from the seed of the marking-nut called *bibba* (*Semecarpus anacardium*) is smeared and mixed with grain and is believed to be the most effective protection against insects and pests. This is a practice in the Marathwada region of Maharashtra, to which this species is indigenous (Darshan Shankar, personal communication 2002).

Box 4.24 Uncultivated Greens

The severe agro-climatic constraints of the dryland regions of Medak District in Andhra Pradesh have led farmers to develop various adaptive strategies. The enormous crop diversity employed in their farms helps them to overcome the unfavorable climatic conditions and still get good yields. Farmers treat this huge diversity, especially the diversity of uncultivated greens, in their fields with a great reverence. Uncultivated greens broadly denote:

- The greens from land that are not cultivated, such as forest plants;
- The greens that are not cultivated but are available as partner crops in a cultivated field; and;
- The greens that are available from cultivated plants, which are not cultivated explicitly for their greens.

For the people in the rural areas, especially the poor, uncultivated greens are a major source of vegetables. They not only form a significant quantum of the food they consume, but are also a major source of different minerals and vitamins, including calcium, iron, beta-carotene, vitamin C, riboflavin and folic acid.

Greens like *Doggali Koora*, *Gangavayeli*, *Sannavayeli* and *Pundi* are consumed throughout the year. *Pundi* and *Doggali Koora* are eaten more than 20 times in a year by some families. Some of the greens like *Gunugu* are sold as green fodder in or near by towns. Uncultivated foods like *Chennangi*, *Soyikoora*, *Adonda* and *Adivikakarakaya* are also sold in towns, as there is a demand for these greens. Greens like *Talaili* and *Kashapandla chettu* are never uprooted, as their availability is low and they have high medicinal value. Even the landlords ask the labourers not to weed these two plants, which shows their importance in the lives of people and their concern to protect them. *Kasapandla chettu* is called '*Davakhalnaleni Mandu*'.[14]

Uncultivated greens are present mostly where farmyard manure is applied or in fields where chemical fertilizers are not used. Very few greens are seen in fields where chemical fertilizer is used, as they die when they are young due to 'burning' effect. Greens are not collected from fields in which pesticides have been used.

Uncultivated greens play a key role in the health care of poor people. They utilize these greens in different forms like curry, leaf extracts, tablets etc. to cure common ailments like headaches, swellings, wounds, scabies, improper digestion and major diseases like jaundice and diabetes. *Atteli koora* when fed to postnatal mothers improves breastmilk availability to infants. When lactating mothers eat *pundi*, it is good for infants as it keeps their stomach clean. *Kashapandla chettu* is called '*Davakhana leni Mandu*' (medicine available without the existence of hospital) by people.

Source: Satheesh 2001

Cultivated diversity is also a critical part of health and food security. Traditionally, local communities have preferred a diverse range of foods from their fields and pastures, to the extent possible. In particular, many traditional crops like millets, which have been increasingly replaced by wheat and rice, have been favoured.

All food grains do not contain the same nutrients (*see Table 4.44*). Almost all the millets possess medicinal properties, both preventive and curative. Foxtail millet has sulphur, which is good for high blood pressure. *Ragi* is very helpful to diabetics. Because of their high fiber content, millets also help in prevention of heart disease. Many of the dryland crops (foxtail millet, ragi, little millet, pearl millet, sorghum) which are purely rainfed are relatively free of chemicals and safe for consumption

Table 4.44 Nutritive Values Per 100 g of Food Grains

Food	Protein G	Fat G	Minerals G	Fiber G	Carbohydrate G	Energy Kcal	Calcium Mg	Phosphorous Mg	Iron Mg	Caroteine M	Thamine Mg	Riboflavin Mg	Niacin Mg	Folic Mg
Rice	6.8	0.5	0.6	0.2	78.2	345	10	160	0.7	0	0.06	0.06	1.9	8
Pearl millet	11.6	5	2.3	1.2	67.5	361	42	296	8	132	0.33	0.25	2.3	45.5
Foxtail millet	12.3	4.3	3.3	8	60.9	331	31	290	2.8	32	0.59	0.11	3.2	15
Sorghum	10.4	1.9	1.6	1.6	72.6	349	25	222	4.1	47	0.37	0.13	3.1	20
Finger millet	7.3	1.3	2.7	3.6	72	328	344	283	3.9	42	0.42	0.15	1.1	18.3
Little Millet (samalu)	7.7	4.7	1.5	7.6	67	341	17	220	9.3	0	0.3	0.09	3.2	9
Kodo Millet (argulu)	6.2	2.2	4.4	9.8	65.5	307	20	280	5	0	0.33	0.1	4.2	0

G = Grams
K. Cal. = Kilo Calories
Mg = Milligrams
Source. Gopalan et al. 1984.

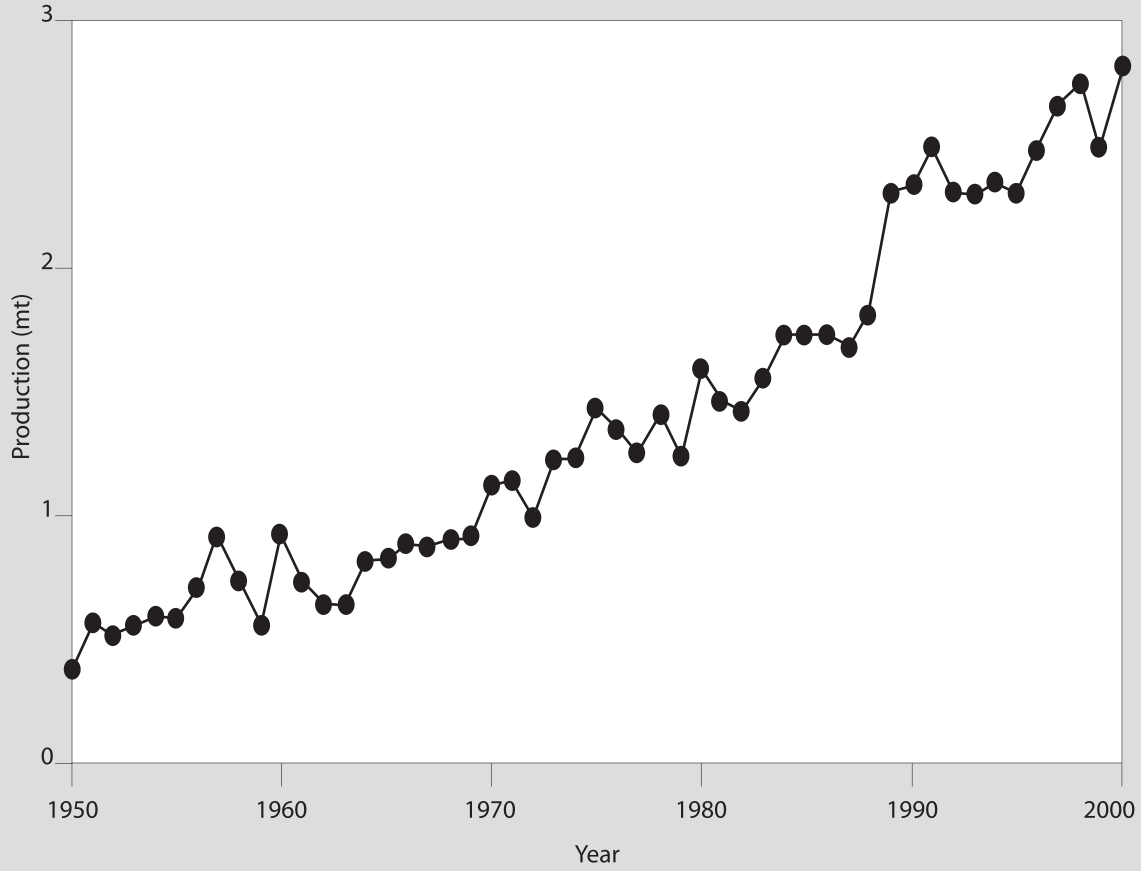
4.2.5 Economic Values

The global economic value of ecosystem services and components of biodiversity as estimated by Constanza *et. al.* (1997) amounts to US $33 billion, which is around 1.8 times the world's GNP. Whereas these estimates give a macro-picture of the economic value of biodiversity, it should be possible to disaggregate it and form estimates of the economic worth of biodiversity in the context of specific sectors. However, systematic research in this field has only been recently initiated and the methodologies for valuation are still being evolved. Therefore information on the economic values of biodiversity is only indicative, particularly in countries like India. The inadequacy of economic data reflects the limited efforts put into generating the data, but the indicative estimates are adequate to highlight the immense economic values of biodiversity.

The most important biological components harvested from the sea are the fish. From an annual yield of less than 50,000 tonnes a few decades ago, marine fish production in India has risen to 2.7 million tonnes in 2000 (Figure 1). The pelagic[15] fish groups form more than half (53%) of the total landings, with the remaining constituted by demarsal[16] finfish, crustaceans and molluscs. Among the crustaceans, penaeid[17] prawns rank first in importance (42%), followed by non-penaeids (39%), stomatopods (12%), crabs (7%) and lobsters (<1%). About 65% of the marine fish catch was made by mechanized modern units and the remainder by traditional craft. The harvest is, however, uneven, and the major fisheries groups are in different stages of exploitation. There is scope for substantially increasing the catches of clupeids, crangids and silverbellies and for marginally increasing the catches of elasmobranchs, lizardfishes, perches, ribbonfishes, seerfishes, flatfishes, penaeid shrimps and non-penaeid shrimps. There is, however, no scope for increasing the catches of eels, catfishes, Bombay duck, sciaenids, pomfrets, Indian mackerel and cephalopods.

Chemicals like prostaglandins, medically useful for birth control, prevention of peptic ulcer, asthma treatment, blood pressure regulation, etc. are obtained from marine species like *Gorgonids* (Thomas and George 1987).

Fig 4.1 Marine Fish Production in India



Box 4.25 Economic Value of Wild Medicinal Plants

The pharmaceutical industry still depends to a great extent on wild resources, estimated at around Rs 1200 million rupees/year. Around 660 wild species are involved in all-India trade. (FRLHT, Trade database, 2001) Of the annual turnover of the herbal industry of Rs 42 billion, 30%, i.e. Rs 120 billion, would be the production cost, of which just 10%, i.e. Rs 1200 million p.a. would represent the value of the raw material, 90% of it coming from the wild. (Shankar 2002). The export value of medicinal plants is also high (*see Table 4.46*).

Box 4.26 Medicinal Value of Marine Bioresources

Parulekar (1990) screened 283 species of marine flora and fauna for bioactivity potential and found 100% anti-fertility/anti-implantation activity displayed by 4 species of seaweeds, 6 species of sponges and 5 species of soft and hard corals. Characterizations of other bioactivity potentials were diuretic (16 species), Central Nervous System (CNS)-stimulant (14 species), toxic and antiviral (9 species each), hypotensive (lowers blood pressure) (7 species), spasmolytic (controls spasms) (3 species) and hypoglycemic (lowers blood sugar) (3 species each) and spasmogenic (generates spasms) (2 species). Antimicrobial (prevents infection), antihistamine (anti-allergic), analgesic (pain reliever) and CNS-depressant activity was displayed by one species each.

Biomedical properties are also present in sponges – the compounds *Aerothionin* and *Aeraphysinin*, halogen compounds like bromine and iodine, spongouroidine and spongothymidine have anti-tumour and anti-viral activities (Thomas and George 1987). The blue-coloured blood of the horseshoe crab contains a chemical called 'amoebocyte lysate', which is used to test the magnitude of adulteration of food and medicines (http//www.horseshoecrab.org/med/med/html).

Table 4.45 Exports of Medicinal Plants in 2000-01

S. No	Item Description	Quantity (Kg.)	Value (Rs)
1.	Liquorice Roots	54897	7053388
2.	Belladona Roots	2304566	33118392
3.	Ipecac Dried Rhizome & Roots	14550	500390
4.	Zedovary Roots	19400	570795
5.	Other Ginseng Roots	3271038	134562913
6.	Belladona Leaves	16532	8463996
7.	Chirata	9139	916381
8.	Nux Vomica Dried Ripe Seeds	18000	1797180
9.	Poppy, Flowers & Unripe Head of Dried Poppy	9400	1844321
10.	Psyllium Husk (Isabgol Husk)	19277667	1999380763
11.	Psyllium Seeds (Isabgol)	1001451	74682167
12.	Sarasaparilla	13500	364434
13.	Senna Leaves & Pods	7430254	183996774
14.	Tukmaria	97701	4960053
15.	Ayurvedic & Unani Herbs (Not Elsewhere Specified)	9367120	225025548
16.	Vinca Rosea Herbs	522912	18931333
17.	Neem Seeds	106457	3864426
18.	Neem Leaves/Powder	13125	681440
19.	Gymnema Powder	19996	11090361
20.	Saps & Extracts of Opium	22812	84091525
21.	Extracts of Neem	29283	10999995
22.	Red Sandalwood Powder	47647	11010604
23.	Betal Leaves	1246178	36731351
24.	Others	2563839	303102348
	Total	**47,477,464**	**3,157,740, 878**

Source: Rawal 2003

Box 4.27 Values of Micro-Organisms in Medicines

Micro-organisms (fungi, actinomycetes and bacteria) are used to transform chemically synthesized steroid hormones in such a way as to make them resemble naturally occurring hormones. These can be used clinically. Thus, antibiotics formed by fungi are penicillins from *Penicillium* species; Cephalosporins from *Cephalosporium* species; and Griseofulvin from *Penicillium griseofulvum*. Unicellular bacteria such as *Bacillus brevis*, *B. polymyxa*, *B. subtilis* produce the antibiotics Gramicidine, Olymyxin B and Bacitracin respectively. Antibiotics formed by actinomycetes are Chloramphenicol from *Streptomyces venezuelae*, Tetracyclines from *S. rimosus* and *S. aureofaciens*; Neomycin from *S. fruidiae*, Erythromycin from *S. erythreus*, Nystatin from *S. noursei* and Amphotericin B from *S. nodusus* (Guru 1990).

One of the greatest values of biodiversity is the various ecological functions or ecosystem benefits provided to humans, including aesthetic and recreational values. Some examples are given in *Table 4.46*.

Table 4.46 Economic Value of Ecosystem Benefits: Selected Indian Studies

Goods and services valued	Annual Value	Location	Methodology Applied	Source
Recreation/ Ecotourism	Rs 16197 per ha (Rs 427.04 per Indian visitor Rs 432.04 per foreign visitor)	Keoladeo National Park, Bharatpur	TCM	Chopra 1998
Recreation/ Ecotourism	Rs 20944 per ha (Rs 519 per Indian visitor and Rs 495 per foreign visitor)	Keoladeo National Park	CVM	Murthy and Menkhuas 1994
Recreation/ Ecotourism and other benefits	Rs 23300 per ha (Rs 90 per household. (Rs 7.5/month/household); Rs 240 million/year	Borivali National Park, Mumbai	CVM	Hadker *et. al.*, 1995
Ecotourism	Rs 676 per ha (for locals); (Rs 3.2 million total per year)	Periyar Tiger Reserve	CVM/TCM	Manoharan 1996
Ecotourism	Rs 2.95 million total; (Rs 34.68 per visitor)	Kalakadu Mundanthurai Tiger Reserve, Tamil Nadu	CVM	Manoharan and Dutt 1999
Ecotourism/ recreational/ pilgrimage/ sacred grove	WTP (Willingness to Pay) for maintenance and preservation of the lake by: Local community= US $ 0.88 (Rs 36.08) Local pilgrims = US$ 2.2 (Rs 90.2) Resident visitors=US$ 2.5 (Rs 102.5) Non-resident visitors=US$7.2 (Rs 295.2) (Aggregate WTP = US $46940 based on total visits per year (Rs 1.92 million) Per hectare value = Rs 1604	Sacred lake in Sikkim Himalaya (Khecheopalri lake)	TCM/CVM	Maharana *et. al.*, 2000
Ecotourism	WTP for the management of the park: By foreign tourists: $8.84; by domestic tourists: $1.91; by local community: $6.20 per year. WTP total for annual maintenance works out to $87,777.	Khangchendzong National Park, Sikkim	CVM	Maharana *et. al.*, 2000
Water supply	Rs 4745 per hectare	Almora Forests	Indirect Methods	Chaturvedi 1992
Water supply	Annual willingness to pay for water: Rs 109-410 for irrigation purposes; Rs 27-53 for drinking purposes	From glacier to Terai mountain region of Kumaon valley	CVM	Kadekodi *et. al.*, 2000
Carbon store	Rs 1,292 billion for total Indian forests & Rs 20125 per hectare	Indian Forests	Species-wise forest inventory data	Haripriya 1999

Goods and services valued	Annual Value	Location	Methodology Applied	Source
Carbon Store	Rs 120,000 per hectare	All-India forests	Biomass estimation	Kadekodi and Ravindranath 1997
Fishery resources	Willingness to pay for conservation: Rs 859 per year on average	Coastal Karnataka	Stakeholder Analysis and CVM	Bhatta 2001
Watershed Values	Rs 200,000 per hectare meter of soil	Yamuna Basin	Indirect method (Reduced cost of alternate technology)	Chopra and Kadekodi 1997
Forests in Himachal Pradesh	The total economic value of forests in HP is estimated as Rs 1066640 million , which is 2.61 times the value of the growing stock.The percentage of forestry as a percentage of corrected GSDP (Gross State Domestic Product) is 92.40% instead of recorded 5.26%	Himachal Pradesh State	TEV (Total Economic Value) approach	Verma 2000
Forests in Maharashtra	Contribution of forests is estimated as Rs 35,245.65 million as against Rs 14,080 million	Maharashtra State	Physical accounting (tools employed: net price method, present value method, etc)	Parikh and Haripriya 1998
Forests in Yamuna Basin	Use Value of timber: Rs 8,279 to Rs 18,540 per cubic meter of extracted timber Annual Value of main non-timber forest products (NTFPs): Rs 7509 per sq km in Hills and Rs 558 per sq km in Plains Use value of ecological functions and unrecorded production: Rs 176 per hectare in Himachal Pradesh Rs 3509 per hectare in Haryana Average: Rs 624 per hectare	Yamuna Basin	CVM; Direct market valuation; Multi-criteria analysis & Travel cost	Chopra and Kadekodi 1997
Waste assimilation capacity	Rs 90,000 million	Coastal Marine ecosystem	At a processing cost of Rs 1/- per litre of sewage/ industrial effluent	M.V.M. Wafar, personal communication May 2003

CVM: Contingent Valuation Method

TCM: Travel Cost Method

Source: Economics and Valuation of Biodiversity Thematic BSAP

Box 4.28 Valuing Ecotourism at a Sacred Lake of the Sikkim Himalaya, India

Sacred lakes of the Himalayan region attract visitors and pilgrims from all over the world for their aesthetic, cultural and spiritual importance. The Sikkim Himalaya has more than 150 lakes at different altitudes and most are considered sacred. The recreational, biodiversity and spiritual values of Khecheopalri, a lake situated in the West of Sikkim, are presented here.

The number of visitors to Sikkim began to increase in 1990 as a result of a relaxation of regulations; this opened a number of new areas to both domestic and foreign tourists. The number of visitors to Khecheopalri lake was 18713 in 1998. In 1998, 7800 visitors were from Sikkim and the remaining 10913 were from outside the State. About 78% of the pilgrims visited the lake for religious purposes, while the majority (85%) of the domestic visitors came for recreation. Most (65%) of the foreign visitors came to the lake for recreation, but 19% came for religious purposes and 16% cited the rich biodiversity of the area as their purpose in visiting. Approximately 56% of foreign visitors, 43% domestic visitors, 35% of local community members and 28% of pilgrims showed some interest in conservation and maintenance of the lake and its surrounding watersheds. The aggregate annual recreational/sacredness value amounted to US$ 430186 for pilgrims.

In the Hindu-Kush Himalayan region there are a large number of similar lakes which might bring economic benefits with simultaneous conservation links, if they are properly managed and marketed.

Source: Maharana et. al., 2000

The use of species from various kinds of ecosystems also has high economic value. An indication of this can be gained from the figures of exported and marketed produce from marine and forest areas (*Tables 4.47* and *4.48*).

Table 4.47 Production and Export of Marine Products of India

Products	1992		1995		1999	
	Production (Tonnes)	% age of Exports	Production (Tonnes)	% age of Exports	Production (Tonnes)	% age of Exports
Shrimp	278191	27.42	253142	39.88	320023	31.64
Lobster	2011	81.15	1923	65.05	2093	68.22
Fish	1830271	2.71	1790063	7.14	1925569	6.33
Crabs	26940	4.34	30610	9.14	27547	12.89
Molluscs	89493	44.96	116764	58.98	93374	74.81
Others	50102	4.03	66381	8.39	41897	10.05
Total	2299594	7.47	2258883	13.61	2417503	12.53

Source: Economics and Valuation of Biodiversity Thematic BSAP

It should be noted that these values do not indicate whether the exploitation of these biodiversity elements is sustainable or not. Indeed, given that there are concerns of general over-exploitation of marine fisheries (*see Sections 5.1.1* and *5.2.8*), it is possible that these figures are an over-valuation. They do, however, provide an indication of the economic value of India's marine ecosystems, especially since this over-valuation may be offset by the lack of valuation of several under-utilised marine species.

Table 4.48 Revenues Obtained from Non-Wood Forest Produce (in Rs '000)

States	Bamboo & Cane	Fodder & Grass	Gums & Resins	Drug & Spices	Tannin & Dyes	Others*	Total
Andhra Pradesh	34,976	–	–	–	–	54,213	89,189
Arunachal Pradesh	729	–	–	–	–	1,896	2,625
Assam	1880	59	–	3	–	12311	14,253
Bihar	13033	433	60	–	–	73203	86,729
Gujarat	3509	4607	269	1	43	1728	10157
Haryana	232	516	567	–	–	279	1,594
Himachal Pradesh	485	1,601	22,938	2,342	–	28	27,394
Jammu and Kashmir	640	–	180,000	–	–	21,050	201,690
Karnataka	20,427	385	24	425	1,078	61,510	83,849
Kerala	–	–	–	–	–	5,904	5,904
Madhya Pradesh	92,200	–	–	–	–	350,800	443,000
Maharashtra	10,979	3,885	2,866	16 7	895	42,840	61,488
Manipur	46	–	–	–	–	872	918
Meghalaya	32	Below 500	44	50		1,031	1,157
Nagaland	4	–	–	–	–	1,316	1,320
Punjab	101	3,477	649	–	–	1,269	5,496
Rajasthan	14,574	892	2,583	–	137	23,319	41,505
Sikkim	5	20	–	391	–	2,197	2,613
Tamil Nadu	1,721	1,337	–	–	8,147	60,218	71,423
Tripura	483	152	–	–	–	1093	1728
Uttar Pradesh	4904	6829	50252	–	200	53826	116011
West Bengal	–	–	–	–	–	–	3417
Andaman and Nicobar	282	–	57	–	–	1087	1426
Goa, Daman & Diu	80	–	–	–	–	–	80
Mizoram	19	–	–	–	–	57	76

**The category 'Others' includes fibres and flosses, vegetable oils and oilseeds, bidi leaves and other non-wood produce.*

Source: CSO 1990: 69

The overall economic (not just financial) value of biologically diverse, organic farming is also vividly brought out when comparing it with chemical-intensive or homogenous conventional agriculture.

A study[18] undertaken by the Deccan Development Society, a NGO in the Deccan region of South India, between the *rabi* season of 1999 to the *kharif* season of 1999, tried to trace the links between biodiversity-based small farms and their economic viability (Murali Vuyyur et. al., 2002). The study differentiated, on the basis of the guidelines set by FAO 2000, three distinct farming systems in operation. They are: *ecological*, *conventional* and *chemical*. The distinction between these three types is based on the inputs used for raising the crops (*see Table 4.49*).

- The ecological farmers use their own seed, inputs and labour, and stay away from machines and chemicals.
- The conventional farmers use seeds purchased from the seed outlets, and employ tractors and other machines if needed. Their choice of crops depends on the market rather than home needs.
- The chemical farmers use high-yielding varieties, hybrids, chemical fertilisers and pesticides for crop production.

Table 4.49 Traits of Farms in the Deccan Region, Andhra Pradesh

Traits	Ecological	Conventional	Chemical
Seeds	Purely local and land races. A part of farm produce is used as seed for next season.	Use of improved and sometimes l local. Often purchased from seed outlets.	New varieties, hybrids. Purchased from seed outlets.
Livestock integration	Followed	Often followed	May or may not be followed
Energy	All farming operation are carried out by animal power	Partly animal power and partly mechanized with tractor.	Mostly mechanized
No. of crops/ varieties	Often more than 6 crops, with at least 2-3 varieties per crop	Monocrop or intercropping	Monocrop or intercropping
Agriculture diversity	More	No	No
Manures	Used	Often used	May or may not be used
Fertilizers	Never used	Often used	Used
Plant protection	Use of traditional practices	Used pesticides in the past	Complete dependence on pesticides
Use of own inputs	Mostly	Low	Very low
Role of women	Traditional importance is maintained	Usually undermined	Completely undermined
Economy of the farms	Combines own consumption with marketing of surplus	Market-oriented	Market-oriented
Element of Risk	Very less	High	Very High
Type of farm	Purely organic farms	Organic farms by default	Chemical farms

Source: Murali Vuyyur et al. 2002

In several case studies done on each of the three categories, farmers express very clearly the reasons behind adopting this type of agriculture. This enables us to understand how the ecological farmers strive to minimise the risk factor inherent to arid regions through mixed farming and livestock diversification, and derive multiple benefits of crop diversity, milk, meat and draught power in comparison with conventional and chemical farmers.

One of the most important indicators of viability of a farm is reflected in its sustainability. Much of the key to sustainability lies in the properties of the soil and the maintenance of key soil elements. On the basis of laboratory tests of the soils on different farms, the study analysed the soil conditions of different kinds of farms (see Table 4.50). It is clear that organic carbon content, one of the most crucial soil-building elements, was significantly higher in ecological farms than in conventional and chemical farms. The P and K content were also very high in ecological farms.

Studies have also shown that, if gross yields and their values are quantified, ecological agriculture could be more beneficial even from an economic point of view than conventional or chemical-intensive farming (*see Table 4.51*).

Table 4.50 Chemical Properties of Different Farms

Property	Ecological	Conventional	Chemical
Soil PH range	6.7-7.8	6.6-7.2	6.4-7.4
Electrical conductivity Dsm-1 (range)	0.20-0.33	0.24-0.32	0.26-0.37
Organic Carbon Status	• High in 42% samples	• High in 0 samples	• High in 0 samples
	• Medium in 58% samples	• Medium in 4% samples	• Medium in 46% samples
	• No samples with low status	• Low in 96% samples	• Low in 53% samples
Available Phosphorous (kg/ha)	3.6-5.76	1.44-4.32	0.72-2.88
Available Potassium (kg/ha)	240-289	277-308	141-243

Source: Murali Vuyyur et al. 2002

Table 4.51 Comparison of Crop Yields and Returns Between Ecological, Conventional and Chemical Farming in Dryland Agriculture[19]

Crops	Ecological Agriculture		Conventional Agriculture		Chemical Agriculture	
	Yield (Kg)	Value (Rs)	Yield (Kg)	Value(Rs)	Yield (Kg)	Value (Rs)
White sorghum	400	1600	500	2000	400*	1000
Yellow sorghum	10	40	–	–	–	–
Foxtail Millet	3	15	–	–	–	–
Little millet [white]	7	35	–	–	–	–
Little millet [black]	3	15	–	–	–	–
Kodo Millet	3	15	–	–	–	–
Niger	1	18	–	–	–	–
Sesame	4	80	–	–	–	–
Cowpea	5	50	–	–	–	–
Pearl millet	15	40	–	–	–	–
Finger millet	5	25	–	–	–	–
Creeper mung beans	4	60	–	–	–	–
Pigeonpea	25	375	–		20	300
Field beans	4	40	–	–	–	–
Uncultivated products		300	–	–	–	–
Weed fodder (Bundles)	10	50	10	50	5	25
Sorghum straw (Bundles)	400	400	400	400	400	200
Pigeonpea husk (Baskets)	10	20	–	–	5	10
Pigeonpea stems (Bundles)	10	10	–	–	8	8
Total returns (Rupees)		3263	–	2450	–	1543

Source: Murali Vuyyur et. al., 2002

The balance sheet of different production systems is presented below (*see Table 4.52*). The benefit-cost ratio was high in ecological agriculture, standing at 4.4 when the farmers' own resource use was deducted from the cost of cultivation. (Any value above 2.0 is considered good, as the farmer gets Rs 2 for every rupee invested.) Therefore one can say ecological agriculture is more remunerative and economically sustainable.

Table 4.52 Balance Sheet Between Ecological, Conventional and Chemical Agriculture

Item (Rupees)	Ecological Agriculture	Conventional Agriculture	Chemical Agriculture
Cost of cultivation	2191	2690	3475
Cost of cultivation after deduction of own resources	655	1320	3385
Crop returns	2443	2000	1300
By-products value	520 + uncultivated foods	450	243
Gross Returns	3263	2450	1543
Net returns (Profit/loss)	2880	-240	-1842
Net returns (Profit/loss)*	2880	1130	-1842
Cost Benefit Ratio*	4.4	1.85	0.35

**After deducting own resources*

Source: Murali Vuyyur et. al., 2002

Commercial varieties are advocated for their high potential under optimum conditions which in turn are replacing the landraces. Unlike commercial varieties which have high productivity and hence has an appeal for the growers; characters of land races are more of hidden nature. A comparative list of land race and commercial variety is provided for appreciating the value of both.

Table 4.53 Comparative Values of a Land Race and a Commercial Variety

	Land Race	Commercial Variety
Uses	Hidden /unexpressed and unrealized	More visible and market-oriented
Cultural need	For religious ceremonies and social functions land races with particular characters are needed	Nil
Taste factor	Tasty	Less
Culinary factor	Positive attributes	Less
Weather changes	Easily Adaptable	Becomes vulnerable
Suitability	Well suited for agro-ecological niche	Well suited for uniform and optimum conditions
Marketability	Least considered	Very high
Productivity under optimum conditions	Less	High
Demand of external inputs	Low	High

Source: Agricultural Research sub-thematic paper 2002

4.2.6 Scientific Values

It is well known that nature is a major source, inspiration and subject of scientific thought. The mainstream sciences as well as the several non-mainstream indigenous sciences are all centrally concerned with understanding nature. Thus, biodiversity, which constitutes the whole of 'living' nature, has a profound and intrinsic 'scientific value' in all cultures. Modern western sciences confine themselves to the study of the physical, chemical and biological aspects of biodiversity whereas in many non-western cultures the spiritual aspects of biodiversity, are also considered. The entire body of fundamental knowledge contained in the so called 'life-sciences', including their numerous applications in conservation and many scientific insights and discoveries based on observation of nature (in fields like consumer goods, medicine, agriculture and bio-technology) are examples of the scientific values of biodiversity. In the Indian context indigenous sciences like *Krishi-shastra*, *Ayurveda*, *Vriksh-Ayurveda* etc. provide examples. Today the modern scientific values of biodiversity are also influencing developments at the frontiers of seemingly unrelated fields like information technology, in the context of themes like artificial intelligence, where biological chips may one day replace silicon chips.

4.2.7 Cultural Values

In several Indian languages, the two key words, which point to the central relationship between nature and culture, are the words '*Pra-kriti* and *Sams-kriti*'. Whereas nature (*Prakriti*) is seen as an unmodified (*pra*) life process (*kriti*), culture (*samskriti*) is described as modified (*samskar*) nature (*kriti*). There is a great deal of anthropological literature showing how interaction with a diversity of life forms and ecosystems has been the source of cultural evolution and technological innovation (McNeely 1992). It would be appropriate to assert that the incredible extent of human creativity manifested throughout history is substantially founded on the ecosystems and natural diversity found on earth.

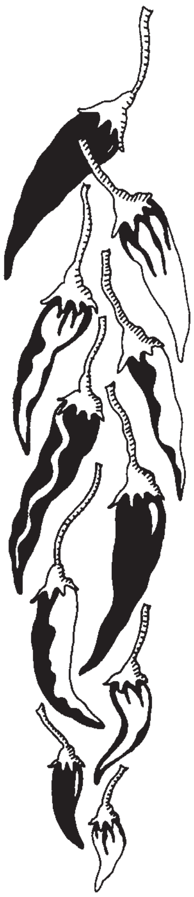
Cultural values in human societies are often expressed in the form of respect for symbols of biodiversity. Some species such as the peafowl are key icons of cultural heritages, while others (e.g. tiger, lion, lizard, turtles and bison) are integral to religious and spiritual beliefs. In local cultures the behaviour of several species is indicative of various material and non-material events. In the Thakur tribal community of coastal Maharashtra the sighting of red ants before monsoon indicates an early onset of rains (R.P. Palekar, personal communication, 1998). The repeated chattering of a house lizard is believed to be a sign of the presence of the God Shiva. Species inspire songs, stories, dances, poetry, myths, crafts, regional cuisines, decorations, rituals, festivals, holidays and even names of sports teams.

A great diversity of plants and animals have been used for cultural purposes, outside the sphere of basic subsistence needs of food, shelter, and clothing, but yet considered to be equally important.

Rituals in all parts of India are occasions for the use of many plants and animals. Among auspicious plants and flowers offered in temples are Hibiscus offered to the goddess Kali, Datura flowers to Shiva and flowers of *Euphorbia ligularia* to Manasa. The leaves of *Aegle marmelos* are ritually offered to Shiva; green bamboos are considered sacred; mango tree parts are used in sacrificial rites; palas or dhak wood (*Butea monosperma*) is used to produce the sacrificial fire. Sandalwood and banana are considered sacred, and used in ceremonies during auspicious occasions like marriage. *Kusa* grass (*Eragrostis cynasuroides Beauv*) is necessary for most religious ceremonies. In Gujarat, *sami* (*Prosopis cineraria* Druce) twigs are used in sacrificial fires (Desai 1965).

Similarly, rice and til (*Sesamum orientale*) are used as offerings in religious ceremonies. Almost as if in celebration of diversity, the *Visnu Purana* enjoins the offering of 14 kinds of grain in ceremonies, among which are rice, barley, kidney bean, wheat, millet, sesamum, horse gram, a wild rice called *nivara* (possibly *Oryza nivara*), wild sesamum called *jarttila*, and a wild panicum called *markata* (Wilson 1979). Certain types of rice (called *sawa* and *khaia*) are grown specifically for use on religious occasions (Paroda and Joshi 1990). In Orissa, in the temple of Puri, fresh paddy is supposed to be harvested daily as an offering to the Lord. In the Himalayan region of Jammu, *Chenopods* also have a religious significance among the Hindu Dogras. The grain is considered sacred and is eaten on days of fast, along with amaranths and buckwheat (Partap 1990). The odorous roots of *Dolomaea macrocephala* (*dhup*) are used as incense and the flowers offered at shrines. In Ladakh, twigs of *Juniperus communis* are used as incense; other plant species used as incense are *Potentilla argyrophylla* and *Waldheimia tomentosa* (Buth and Navchoo 1989).

The sacred nature of various plant and animal species has evolved on account of their association with different deities. Some animal species are termed as vahanas or vehicles (freshwater crocodile and turtles) of deities and



are hence venerated. Important among these are the bull for Shiva, the rat for Ganesa, the lion for Durga, the tiger for Iyyappa and the peacock for Muruga.

Other ritual and sacred values are attached to plant/animal species. *Mallotus philippensis* is used as a *sindhur* or *kumkum* by women to signify their marital status (CSIR 1962). In Ladakh, the roots of *Arnebia guttata* yield a red dye which is used to decorate Buddha idols. Charms and sacred songs are written on the outer bark of the *Betula utilis* tree (Dastur 1964). Certain plants are grown so as to keep evil spirits away, such as *Descurainia sophia* in Ladakh (Buth and Navchoo 1989) and coconuts in the Nicobar Islands (Dagar and Dagar 1986). The sacred *chank Xancus pyrum* is utilized to make bangles which are a symbol of matrimony for women in Bengal. Among the Ho tribals of Singhbhum, parts of the *sal* (*Shorea robusta*) tree are used on occasions when religious rites are performed. Offerings of food and rice beer are made on leaves of the giant climber *Bauhinia vahlii* (Deeney and Fernandes 1992).

In northeast Indian tribes like Dimasa, a specific variety of bamboo is needed to perform rituals in the sacred grove called '*Madaico*'. The Dimasa also maintain a separate banana plant in their homestead garden, and the leaves, flowers and fruits of that plant are used only for performing rituals whenever required. Many communities in the country observe restrictions on the use of certain resources during specified seasons. For instance, the Santhal and Munda tribes do not harvest any part of the sal (*Shorea robusta*) tree until their *Salui/Sarhul* festival is over in March-April. No part of *karam* (*Adina cordifolia*) tree in harvested by the Kora, Santal, Munda, and Bhumij until the *Karam* festival is performed in August- September. A wide diversity of plant resources is also needed in ceremonies associated with rites of passage in tribal and other cultures. Most of the plants required for these ceremonies and rituals are found in the forest. For example, flowers, fruits and twigs of *Madhuca indica* and fruit of *Terminalia chebula* are required during wedding ceremonies among the Bhumij and Kora of West Bengal. Several communities who derive livelihood or sustenance from hunting wild animals do not kill pregnant females. For example, Hamars, Harangkha Debbarma and Akuras in Assam do not kill deer in the mating season, and also do not kill a pregnant female, or a leader of a group of deer and wild boar. Some of the tribes in Bastar do not kill birds during their breeding season (*Culture and Biodiversity Thematic BSAP*).

Out of 3000 tribal and religious communities in India, about 1000 groups practice totemism. The different clans of the Meitei community of Manipur have a number of totems, touching or eating which is forbidden. For example, the taboo object for the Ningthouja clan is reed, for the Khuman clan a *simul* (Silk Cotton *Bombax Ceiba*), of the Moirang clan a buffalo and of the Angom clan a white goat. Killing a snake is forbidden for the members of the Khuman clan. As parts of the clan, the various lineages also have certain taboo regulations to

Box 4.29 Diverse Values of Agro-Biodiversity

A study on farmers' perception of biodiversity in the Deccan region of Andhra Pradesh, shows that farmers across caste, gender and class define the need for biodiversity on their farms in dozens of ways (Satheesh 2002). Farmers related their agrobiodiversity to soils, farming practices, moisture requirements, special qualities of the crops, household needs, diet; nutrition, seed selection, culture, gender.

In a much more detailed analysis, the farmers discussed what prompts them to make particular decisions to grow a certain crop on their fields and listed out 16 points which they take into consideration before they plant a crop:

Need to raise two or more crops during a year; Crop durations; Need for cash; Ensuring food security; Need for fodder;
Need for fuel wood; Need for thatching/fencing material; Need for fibre; Need for vegetables; Need for oil; Special foods for specific festivals; Rejuvenating soil fertility and 'strength'; Storability; Need to prepare land for the next crop; Medicinal properties; To ward off/reduce pest incidence;

Source: Satheesh 2002

validate their blood affinity. For example, if a lineage member meets his death in an extraordinary way, the elders of the lineage assemble together and declare the object, tree, plant or animal causing the death a taboo for the lineage. Thus the pumpkin (*Cucurbita moschata*) is a taboo for all the members of the Salam lineage. A lineage member has to observe the clan taboo as well as the lineage taboo (*Culture and Biodiversity Thematic BSAP*)

Culture is an often forgotten and neglected part of cropping practices. But for farmers, especially women farmers, culture has been an inalienable part of the decision to raise diverse crops on their lands. In the BSAP reports from different states, the way crops are intricately related with people's cultural and rituals uses has been documented in detail. The use of nine grains (*Navdhanya*) to propitiate the nine planets is a Hindu practice that spreads across the country. Muslims consider certain crops like bajra sacred for their rituals. In Buddhist and Christian traditions in India, one finds a large number of examples of sacred crops. The innumerable adivasi cultural traditions spread across the country are a testimony to the deep spiritual relationship between the people and the diversity on their farms (*see Box 4.30*).

Box 4.30 Festivals: Celebrations of Diversity

Each festival in the Deccan region of Andhra Pradesh in southern India, as is the case elsewhere in India, is the cultural manifestation of a particular season and a particular social and psychological condition. Some festivals are celebratory. Some are austere. Some are ostentatious, while some are reflective. According to the character of each festival, specific grains assume importance for use in that particular festival. The following list gives us a brief glimpse of the character of various grains, as perceived by various communities in relation to their culture.

- *Pyalala jonna* (popped sorghum) for *Nagula Panchami*, a day on which snakes are worshipped as symbols of fertility, and probably for their role in farming as controllers of rats and other pests.
- *Korralu* (foxtail millet) is cooked as *Paayasam*, a sweet pudding, on the day of *Peddala Amavasya*, the day on which the dead are remembered and worshipped. Chickpea is used for making *Bajji*, a fried snack for many festivals
- Finger millet, peanut, and chickpea are used for making a sweet pancake – *Polelu* – for a number of festivals

Two festivals in the Deccan are pure celebrations of diversity. The *Soonyam Pandugu* in December is heralded with a visit to the farm by the entire family of the farmer. They go singing around their farm. Several versions of the songs are available: *Olega Sagam Olega* and *Beliyo Jolave*, a song which urges the sorghum to grow well. Such songs are sung to propitiate *Bhootalli* (the Mother Earth), 'who is pregnant at that time', and bears a host of crops: sorghum, pigeonpea, a variety of pulses, and a host of vegetables (*sabbanda kooragayalu*). It is that time of pregnancy when the Mother Earth craves to taste different things. To satisfy her craving people cook *Bajjikoora*, a fascinating dish in which all the available vegetables (leafy and otherwise) and tender grains (including the green pods of pigeonpea, *Dolichos lablab*, chickpea, chillies, green peas, *lathyrus*, *amaranthas* and other leafy greens) are cooked together and offered to the Mother. The singing also is to please the Mother. The expected result of all this is to persuade the Mother to think: 'These people are making such an effort to keep me happy. Therefore I also should keep them happy by making the harvest bountiful.' Though this is the expected result, it is not negotiated as a crude business act. It is an act of love, an act of gratitude, an act of worship, and an act of celebration.

The second festival which joyously celebrates diversity is *Endlagatte Punnam*, a festival which precedes the harvesting of winter crops. On this day, men and women collect ears of various crops from their farm. These and special sweets and cooked rice are offered to the village goddess. It is an act of gratitude towards the goddess who has showered her blessings on the farms and made a diverse produce possible.

Source: Satheesh 2002

Some community management practices have religious influences, displaying sensitivity towards the rights of other non-human living beings, even in a drought year. Voluntary donations sustained the conservation efforts. Some examples are discussed below.

An indigenous institution for community care of cows – the *Gauchara* system – exists in Gujarat. According to certain elders of the Ahir community, the essentials of the form in which the *Gauchara* is practised today date back at least three hundred years. The institution of *Gauchara* has played an important role in ensuring maintenance of cows in many parts of Saurashtra in a harsh environment with low and uncertain rainfall. The system is believed to have been created in response to the frequent droughts in the area and the shortages of fodder during the dry season.

Chabutara (a platform) is an institution that focuses on feeding birds, particularly during food-scarce seasons. The *chabutara* is a small, 10-12 ft high platform constructed of bricks, with an open pan on the top where grains are kept. This practice is managed in some villages by nature-loving individuals, while in others an entire community is involved. The frequency of visits of birds increases during the late summer and monsoon (May to August) when an alternative source of grains in the fields becomes scarce. This helps farmers in controlling pests through their natural predators, the birds (*Community Conserved Areas of Gujarat Sub-thematic Review*).

One traditional example of respect towards domestic biodiversity among villagers in Gujarat is the practice of celebrating a livestock fair on *Kartik Poornima* (around October-November). On this particular day cows, bullocks and calves horn will have painted horns, necks garlanded with bells and have embroidered jackets placed on their backs. Later these bejeweled animals take part in a race. This is very common in south Gujarat (*ibid*).

The names of many places in the Kullu valley in Himachal Pradesh commemorate saints who came there to meditate in the sanctuary of the Himalayas. Many of the places in the valley are still preserved as sacred groves. The same is true for many remote and inaccessible areas in this country. Direct relationship between spirituality and biodiversity can be seen among the people who live close to the natural areas where biodiversity occurs; many such people still live within their needs, and they still follow a lifestyle which is far removed from the crass consumerism seen in cities (Pandey 2002).

4.2.8 Aesthetic Value

Nature has an aesthetic value that is 'experienced' by human beings when they are in natural surroundings. Growing up in degraded environments can result in the implantation of negative attitudes in human populations. A study of the impact of environment on the psyche was undertaken by Kaplan and Kaplan (1989), in which they found that being near nature relieved stress of work, while people who worked in closed environments or with views of only human-made structures experienced much more job stress and illness.

The value people put on the aesthetic function of nature is reflected in the millions of small home gardens, hundreds of community gardens and several dozen botanical gardens, zoos, aquariums and so on that communities, NGOs and government agencies have established in different states. It is also reflected in the number of tourists flocking to areas of natural beauty.

The travel and tourism industry in India accounts for 5.6% of the GDP. According to the Confederation of Indian Industry (CII) statistics, travel and tourism supports 5.8% of the total employment and generates 10.8% of the total exports of the country. Of course, much of this is not to biodiversity-related areas, but a substantial amount is. One indication is the tourism to protected wildlife areas.

In a survey of 101 national parks and sanctuaries conducted in 1983-84, tourist numbers were found to be over 50,000 annually in nine of the protected areas (Kothari *et. al.*, 1989). In a majority of these protected areas, it seemed that tourism was low, due either to their being unknown to all but the most avid of wildlife lovers, or because of a complete absence of facilities for tourists. The function of a natural area near or within a dense human settlement is clearly seen in the case of the Sanjay Gandhi National Park on the outskirts of Mumbai, which receives a colossal traffic of 15 lakhs (1.5 million) tourists every year. The sustainability of such mass tourism is questionable, but it does indicate the importance attached by people to the aesthetic values of biodiversity.

Notes

1. The Exclusive Economic Zone is a sea area extending up to 200 nautical miles from the shore, within which India enjoys sovereign rights over living and non-living resources.
2. Continental shelf break is the point from where the sea floor falls off rapidly towards the sea bottom.
3. An estuary is a semi-enclosed coastal body of water, which has a free connection with the open sea, and within which seawater is measurably diluted with freshwater derived from land drainage.
4. A coral reef is a ridge or mound of limestone, the upper surface of which lies (or lay at the time of its foundation) near the level of the sea. It is predominantly composed of calcium carbonate secreted by organisms, of which the most important are corals.
5. The term mangrove refers to an assemblage of angiosperms or flowering plants (and associated fauna and flora) adapted for survival in a range of saline waters along tropical and subtropical coasts.
6. Corals expel their symbiotic algae when environmental conditions become unfavourable, thus losing their colour and eventually dying off. The seawater temperature in 1998 rose by 2ºC higher than the seasonal maximum and this persisted for several weeks. This stress killed corals worldwide.
7. The Convention on Wetlands was signed in Ramsar, Iran, in 1971. This is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. At present there are 136 Contracting Parties to the Convention, with 1284 wetland sites, totaling 108.9 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance (http://www.ramsar.org).
8. Lentic habitats are those with still waters; they range from large deep reservoirs to small village ponds.
9. Lotic habitats are those with flowing waters; they range from large semi-perennial and ephemeral rivers to the small streams and nullahs.
10. This section is based on the Wild Plant Diversity Thematic BSAP, 2002.
11. The information here is compiled from Daniels 1993; Inger & Dutta 1986; Whitaker & Whitaker 1990; Alfred et. al., 1998.
12. Table 4.34 presents the recent inventory of the number of freshwater and marine fauna species in India.
13. Figures such as these are cited by several rice scientists in India. Some experts dispute these figures, saying that since rice is a self-pollinating crop, what may appear to be two distinct varieties may actually not retain their distinction on successive growing.
14. Mydkur Narasamma of Metlakunta lives only by selling these uncultivated greens in Bidar a nearby town. She is very old and with a fracture in her hand cannot work as a labourer, and hence collects these plants and sells them in the town.
15. Refers to the marine environment.
16. Refers to sea bottom-living.
17. A group of prawns, a popular one among which is the tiger prawn.
18. The particular study presented was conducted in the dryland areas and may not be applicable to other parts of India.
19. The study was conducted in a dryland area where rice and wheat are not traditionally grown, so values for rice and wheat are not built into Table 4.5.