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PHYTOGEOGRAPHICAL REGIONS OF INDIA , CHATTERJEE 1960

DOMINANT FLORA OF EASTERN AND WESTERN HIMALAYA AND SUNDERBAN

Contributor : DR. AMITAVA GHOSH

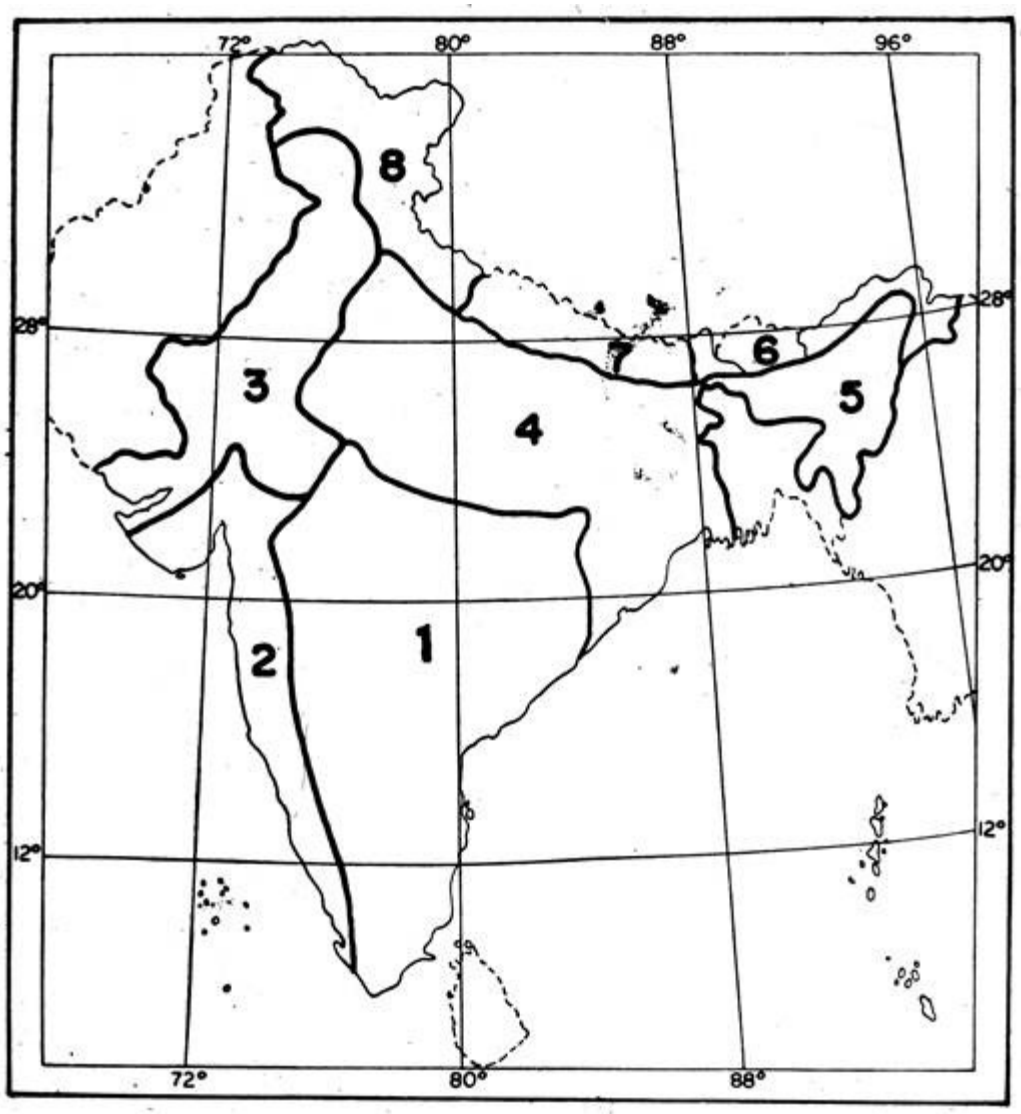
Plant geography is one of the branches of Botany which deals with the spatial relationship of the plants both in the present and the past. The main aim and object of plant geography is to record and then to explain the distribution of pl ants over the surface of the world. *This* branch of botany *is* intimately connect ed with plant ecology to constitute a new and much more wider subject known as "geo-botany" , which comprehends all aspects of the relation between plants and the surface of the earth that is the substratum of their lives (Good, 1964). Plant ecology is particularly concerned with the way in which plants are mutually related to one another and to the conditions of their habitat. Plant geography on the other hand, is concerned primarily with the correlation between plants and the distribution of external conditions (Good, 1964). The study of nativity, distribution, adaptation, association of plants are some of the important aspects in the comprehensive field of plant geography.

As the climatic condition and the edaphic factors are the chief criteria for plant migration, the study on phytogeography of the region under study may throw some light on the present day ecological condition of the region. From the literature, it appears that some of the authors (Clarke, 1898; Hooker, 1907; Calder, 1937; Chatterjee, 1939 & 1960) studied the phyto geographical regions of India. Among them , Chatterjee (1939, 1960) introduced the region of Central Himalaya covering Nepal in addition to Eastern Himalaya and

Western Himalaya as proposed by most of the authors during separation of phytogeographical regions of India..

Chatterjee (1939) in the "Studies on Endemic Flora of India and Burma" divided the then British India into 10 phytogeographical regions. After the political partition of the sub- continent of British India into Indian Dominian and Pakistan in 1947, Chatterjee (1960) suggested a revised scheme of the phytogeographical regions of Indian Dominian. In his scheme, he showed only 8 distinct botanical regions of India proper excluding Burma with Upper and Lower) and the regions under both western and eastern Pakistan (now Bangladesh). In both the schemes proposed by Chatterjee (1939, 1960), the most characteristic feature was the establishment of Central Himalaya (covering Nepal) along with Eastern and Western Himalaya. According to him , the region under study fell under Eastern Himalaya like all other previous authors.

In view of the rapid change in physical conditions from one region to the other too much reliance on sample surveys and statistical method would not help much in solving India's land problems (Chatterjee, 1964) and suggested for undertaking land use surveys by geographers and completing within a reasonably short period of time. This would help the planning agencies to take up right measures for the infrastructural development of the regions. This survey would include among other topics the types of soil, drainage conditions, erosional features etc. He further pointed out that for a rapid coverage aerial photographs would be an invaluable aid for the study. A number of land use maps on various scales ranging from 16 inches to a mile to one to two million have been prepared by the National Atlas & Thematic Mapping Organisation, Govt, of India under his able guidance. A scheme on the classification of land use for the whole of the country was also put forward by him, following more or less the World Land Use Classification recommended by the World Land Use Survey.



MAP II

(i) West Himalaya

(ii) East Himalaya

(iii) Arid zone

(iv) Gangetic Plain

(v) Assam

(vi) Malabar

(vii) Deccan

The recent classified phytogeographical regions of India done by D. Chatterjee ,1960.

The 2 Himalayan divisions are divided into 3 distinct zones according to altitude, viz.:

(a) Tropical zone,

(b) Temperate zone and

(c) Alpine zone.

The Tropical zone stretches up to 1800 m. from the foot of the hills. The Temperate zone occupies a belt from 1800 m. to 3500 m. and above this is the Alpine zone. In the Western Himalaya Temperate zone starts from 1000 m.

West Himalaya stretches from western part of Nepal westwards to Chitral and East Himalaya includes the rest of Nepal, Darjeeling district, Sikkim, Bhutan, northern part of Assam and Arunachal Pradesh. The arid zone is the division designated as the Indus Plain by the previous authors.

The gangetic plain is the area as described by D. Chatterjee and is divisible into:

(i) A drier tract including a portion of drier Punjab, Delhi and Uttar Pradesh up to Allahabad,

(ii) A comparatively humid tract including the rest of Uttar Pradesh, Bihar, West Bengal and Bangladesh, and

(iii) The littoral forests of the Sunderbans.

Assam division is also the same as that of Chatterjee including the Brahmaputra valley the Naga, Khasia and Jaintea hills. Malabar division is the same as that of Hooker, Calder and Chatterjee a narrow stretch of land south of Gujarat running to the southern-most point of the country and including the Western Ghat hills.

The seventh division Deccan includes a vast area east of the Western Ghats and south of the Gangetic plain. Vegetation of any place is modified by the environmental factors; climate, geology and biotic factors. The great area of Indian subcontinent has wide range of climate and corresponding diversity in the vegetation.

India has been divided into the following botanical zones by D. Chatterjee (1962) Fig. 11.4:

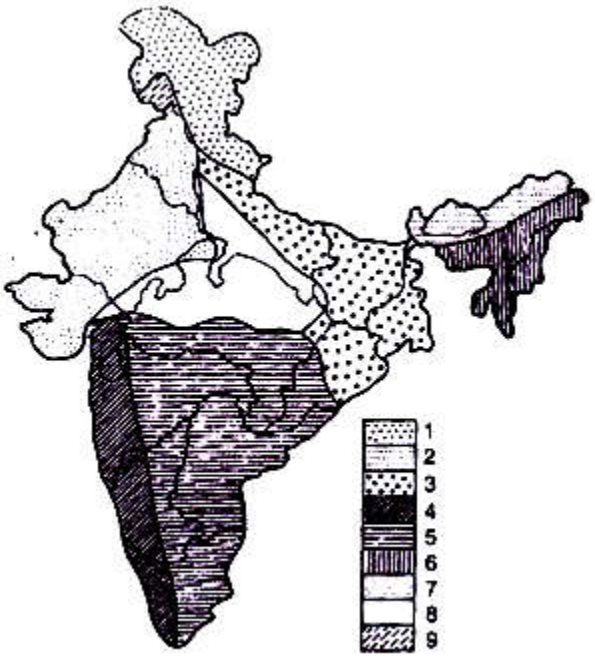


Fig. 11.4. Botanical zones of India.

(1) Western Himalayas,

(2) Eastern Himalayas,

(3) Indus plain,

(4) Gangetic plain,

(5) Central India,

(6) Deccan,

(7) Western coasts of Malabar,

(8) Assam, and

(9) Bay Islands of Andaman and Nicobar.

1. Western Himalayas:

The northern part of our country is bounded by highest ranges of Himalayas and is one of the important botanical regions of the world with climate and vegetation ranging from truly tropical near the low altitudes to temperate arctic types at the high altitudes. The northern mountain division can phytogeographically be divided into western, central and eastern zones.

Western Himalayas consist of north Kashmir, south Kashmir, a part of Punjab, H.P., Garhwal and Kumaon. This zone is wet in outer southern ranges and slightly dry in inner northern zone. The average annual rainfall in this region is from 100 to 200 cm. Snowfall occurs in this region during winter season. The region may be divided into three subzones.

(i) Submontane zone or lower region or tropical and subtropical belts (up to about 1500 metres altitude from the sea level).

(ii) Temperate zone (from 1500 metres to 3500 metres altitude),

(iii) Alpine zone (above 3500 metres and up to the line of perpetual snow).

(i) Submontane or lower region or tropical and subtropical belts:

It includes outer Himalayas, particularly region of Siwaliks and adjoining areas where annual average rainfall is over 100 cm. This zone ranges between 300 and 1500 metres above sea level. In this zone, forests dominated by timber trees of *Shorea robusta* are common. Other important tree species are ***Salmalia malabaricum***, ***Butea monosperma***. ***Acacia catachu*** and ***Zizyphus*** **species**

In the swampy areas, ***Dalbergia sisso (Shisham), Ficus glomerata, Eugenia jambolana*** are of common occurrence. In west dry regions sal trees are replaced by xeric plants particularly ***Zizyphus, Carissa, Acacia***, and thorny ***Euphorbias.*** At higher elevation, around 1000 to 1500 metre altitude, cheer (pine) forests are also found at certain places. The common species of pine are ***Pinus longifolia*** **and** ***Pinus roxburghii***. Ground vegetation is scanty. **(ii) Temperate zone:**
It commonly ranges at the altitudes from 1500 to 3500 metres above the sea level. Oaks are dominant along with ***Populus, Rhododendron, Betula*** **and** ***Pyrus***. ***Pinus excelsa, Cedrus deodara, Picea, Abies, Cupressus*** **and** ***Taxus baccata*** are found in the heavy rainfall region (between 1600 and 1800 m). Herbs are also common in this region. Common herbs are ***Ranunculus hirtila, Polygonum, Pedicularia, Potentilla argyrophylla. Primula, Delphinium, Clematis,*** Crucifers and many members of Asteraceae.

In cultivated drylands of Punjab, wheat and barley are main crops. In Kashmir, ***Betula*** (birch), ***Salix*** (cane), ***Populus*** (poplar) are of common occurrence. Besides these, ***Quercus semicarpifolia, Q. dilatata, Aesculus indica*** (chestnut) and many conifers are commonly met within this region. In west Kashmir rice cultivation is common Sar or S**affron** (***Crocus sativus***), apples, peaches, walnut, almonds and other fruits are important economic plants of Kashmir region.

Populations of ***Draba, Braya, Cortia, Leontopodium*** go on increasing with the increase in altitude. Species of ***Ephedra, Juniperus, Berberis*** are also found scattered. ***Poa***, ***Stipa*** and ***Fectuca*** are common grasses of alpine zone.

Eastern Himalayas :

This region extends from Sikkim to **upper Assam, Darjeeling and NEFA**. Vegetation of this region differs from that of western Himalayas. The chief differences are due to changed environmental factors as heavy monsoon rainfall, less snowfall and high temperature and humidity.

This region can also be divided into:

(i) Tropical submontane zone

(ii) Temperate or Montane zone, and

(iii) Alpine zone

. **(i) Tropical or Submontane Zone:**

The tropical subzone characterized by warm and humid conditions extends from plain up to the altitude of about 1800 m. In this zone mostly sal forests, and mixed deciduous forests consisting of important plants, such as ***Sterculia, Terminalia Anthocephalus cadamba*** and ***Bauhinia*** are common. In the savannah forests, common plants are ***Albezzia procera***, ***Bischofia, Salmelia***, ***Dendrocalamus.*** Evergreen forests of ***Dillenia indica, Michelia champaca***, ***Echinocarpus,*** **Cinnamon**, etc. are common.

(ii) Temperate or Montane Zone:

It may be further divided into upper and lower zones Lower temperate zone is the region between 1800 and 3000 metre altitudes. In the lower temperate zone, Oaks (***Quercus***). ***Michelia, Pyrus, Cedrela, Eugenia, Echinocarpus*** are common plants. In upper temperate zone (3000-

4000 metre altitude), **Conifers and Rhododendrons** are common. Important conifers of this region are ***Picea spinulosa***, ***Abies, Larix, Juniperus, Tsuga griffithi, Tsuga brunoniana***, etc.

(iii) Alpine Zone (from 4000 metres up to snow line):

Climate is humid and extremely cold. The vegetation in the alpine zone is characterised by complete absence of trees and predominance of shrubs and meadows. Important plants of this zone are ***Rhododendron*** and ***Juniperus***. Eastern Himalayan vegetation is considered to be one of the richest vegetational units in the world and consists of several species of plants which are native of foreign countries, such as, China, Japan, Burma, Malaya and European countries.

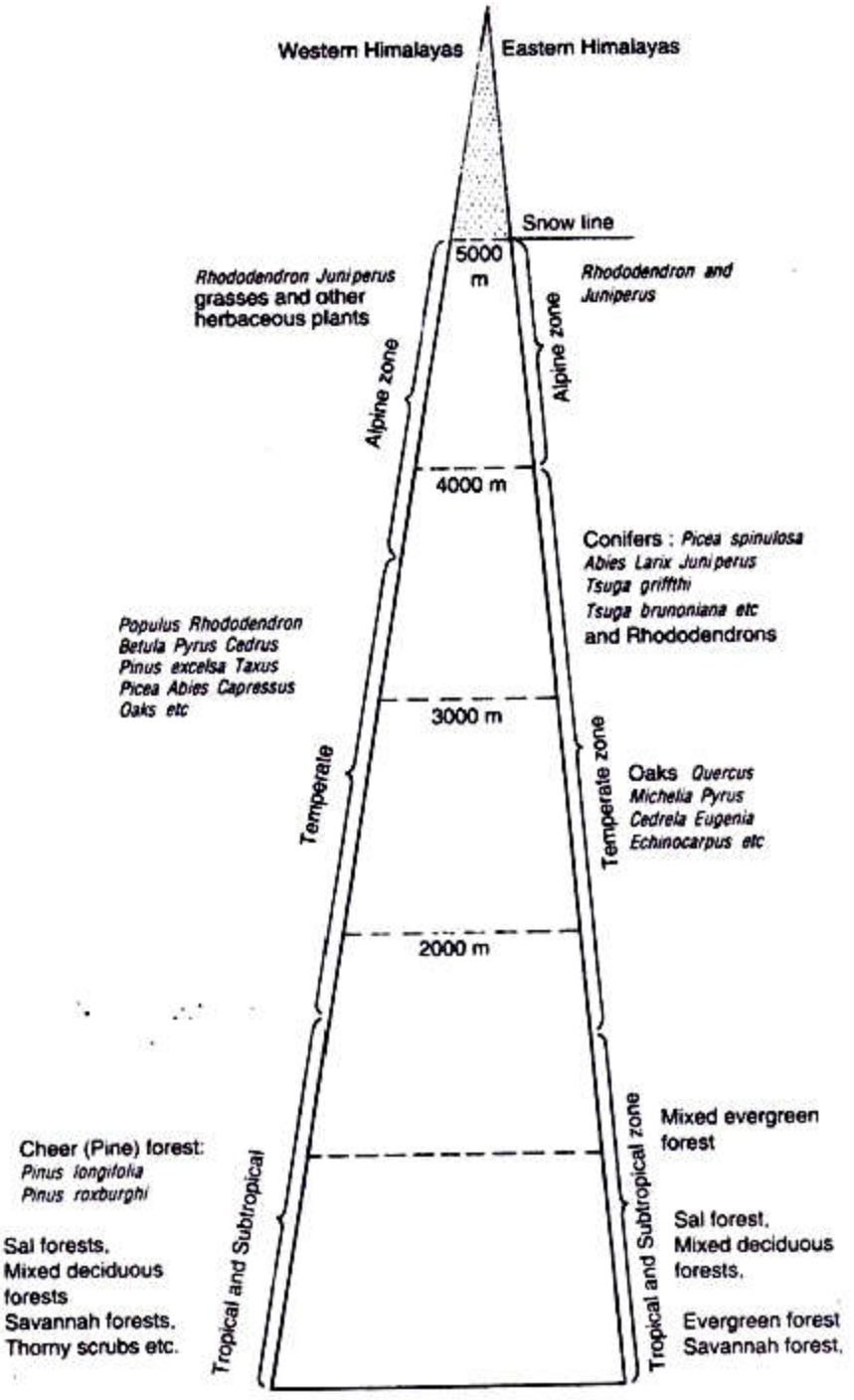


Fig. 11.5. Main types of vegetation at different altitudes in the Western and Eastern Himalayas.

Phytogeographically, the eastern Himalaya forms a distinct floristic region. Thearea comprises Nepal, Bhutan, and neighboring states of northern India along a continuous sector of the Yunnan province in south-west China. In the neighboring stateof Sikkim (geographical area 7298 km2), of the 4250 plant species, 2550 (60%)are endemic (Myers 1988). In Nepal, there are around 7000 plant species, many of which overlap those of India, Bhutan, and even Yunnan. Of these species, atleast 500 (almost 8%) are believed to be endemic to Nepal. Bhutan possesses anestimated 5000 species, of which as many as 750 (15%) are considered to be endemic to the eastern Himalaya (Anon. 1992). This region is the meeting ground ofthe Indo-Malayan, Afro-tropic and Indo-Chinese biogeographical realms as well asthe Himalayan and Peninsular Indian elements, formed when the peninsular platestruck against the Asian landmass, after it broke off from Gondwana land. The regionis recognized as refugium of flowering plants and center of active speciation (Rao1994). The numerous primitive angiosperm families found in this region include Magnoliaceae, Degeneriaceae, Himantandraceae, Eupomatiaceae, Winteraceae, Trochodendraceae, Tetracentraceae, and Lardizalbalaceae.. The primitive genera are ***Alnus, Aspidocarya, Betula, Decaisnea, Euptelea, Exbucklandia, Haematocarpus, Holboellia, Houttuynia,Magnolia,Mangelietia, Pycnarrhena , and Tetracentro***l (Malhotra and Hajra 1977). Studies have shown that northeastern India along with the contiguous region of the Chinese provinces of Yunnan and Schezwan is an active center of organic evolution and is the cradle of flowering plants (Takhtajan1969).Endemic plant species in India has been estimated at 33% withca. 140 endemicgenera but no endemic families (Anon. 1983). Hooker (1904) attributed thefloristic diversity of the Indian subcontinent to the immigration of plants from differ-ent bordering countries, notably Chinese and Malayan on the east and south, of oriental,european and African on the west and of Tibetan

and Siberian on the north. Out of 150important botanical sites identified for conservation action by the World ConservationMonitoring Center (WCMC), five locations are in India, of which the easternHimalaya is one (IUCN 1987). Of the 17 000 estimated flowering plants in India 7025–7872 or 2.8–3.2% are endemics in terms of global diversity. The flora ofArunachal Himalaya comprises well over 6000 species of flowering plants, 500species of pteridophytes and numerous other lower cryptograms. Nearly 30–40% ofthese are endemic (Baishya 1999). Besides representing a high degree of diversity in or-chids, Rhododendrons, Hedychiums, grasses, canes and bamboos, Arunachal Himala-ya also harbors numerous plant species of medicinal and ethono-botanical values(Rao 1994). The humid conditions have resulted in speciation in several genera, thus adding to the high endemicity of the flora (Chatterjee 1939). Satellite remote sensing imagery has permitted eight-broad habitat types of natural and semi-natural vegetation cover in the area (Behera 2000). Present approach of plant survey and endemics is based on proportional stratified random sampling derived from satellite-based classification.This method has an advantage of quantitative assessment over the conventional methodof plant survey along certain floristic tracts, since it takes variance into consideration.

The Sundarban:

The Sundarban, covering about one million ha in the delta of the rivers Ganga, Brahmaputra and Megh-na is shared between Bangladesh (~60 %) and India (~40 %), and is the world's largest coastal wetland. The area experiences a subtropical monsoonal climate with an annual rainfall of 1,600–1,800 mm and severe cy-clonic storms. Enormous amounts of

sediments carried by the rivers contribute to its expansion and dynamics. Salinity gradients change over a wide range of spatial and temporal scales. The biodiversity includes about 350 spe-cies of vascular plants, 250 fi shes and 300 birds, besides numerous species of phytoplankton, fungi, bacteria, zoo-plankton, benthic invertebrates, molluscs, reptiles, am-phibians and mammals. Species composition and com-munity structure vary east to west, and along the hydrological and salinity gradients. ***Heritiera fomes*** (locally called Sundari, from which Sundarban derives its name***), Nypa fruticans and Phoenix paludosa*** are declining rapidly. During the past three decades, large parts of the remaining Sundarban have been protected for wildlife, particularly tiger, through the creation of several sanctuaries and a biosphere reserve. Parts of the Sundar-ban in both India and Bangladesh have been declared World Heritage sites. However, its biodiversity continues to be threatened by a growing human population that not only places pressure on its biological resources, but also impacts on the freshwater infl ows from upstream areas. Oil exploration in coastal areas is also emerging as a new threat. Further threats arise from global climate change, especially sea level rise. The future of the Sundarban will depend upon the management of freshwater resources as much as on the conservation of its biological resources

Mangroves are intertidal forested wetlands confined to the tropical and subtropical regions (Tomlinson, 1986). The total global area of the mangroves is estimated at only 18.1 million ha (Spalding et al., 1997), against over 570 million ha of freshwater wetlands including peat-lands globally (but excluding paddy fields; Spiers, 1999). Although mangroves have been exploited for many cen-turies, our scientifi c understanding of these wetland for-ests remained poor until the 1970s (Lugo and Snedaker, 1974; Blasco, 1975; Chapman, 1976). During the past three decades or so, these wetland forests have received increasingly greater

attention which is reflected in an exponential increase in the number of publications (Ellison, 2002). Several recent publications have examined issues concerning ecology, management and conserva-tion of mangroves (Robertson and Alongi, 1992; Ricklefs and Latham, 1993; Ellison et al., 1999; Kathiresan and Bingham, 2001; Macintosh and Ashton, 2002; Ellison, 2002; Linneweber and de Lacerda, 2002; Vannucci, 2003; Saenger, 2003).The biodiversity of mangroves has also been of increasingly greater interest, firstly because of the Convention on Biological Diversity, and secondly, because the mangrove ecosystems are among the most threatened by the global climate changes, particularly the sea level rise (Macintosh and Ashton, 2002, 2004). Mangroves are relatively well known for their floral diversity which is comprised of only 65–69 species of vascular plants which have several specific adaptations to the dynamic coastal environment (see Kathiresan and Bingham, 2001) and among the fauna, their fisheries (both fishes and crustaceans) resources are better understood. The global pat-terns of biodiversity in mangroves also present an interesting picture. Whereas the latitudinal pattern of mangrove fl ora is normal in as much as the highest species richness of plants occurs around the Equator and declines at higher latitudes – both north and south (Duke et al., 1998; Ellison et al., 1999), the longitudinal distri-bution is quite 'anomalous' with high concentrations in the Eastern Hemisphere between 90º E and 135º E (Rick-lefs and Latham, 1993; Ellison and Farnsworth, 2001). Interestingly, the mangrove-inhabiting molluscs follow a similar pattern (Ellison et al., 1999). More than 41 % of the world's mangroves occur in South and Southeast Asia of which Indonesia alone accounts for 23 %. A further 20 % of the total mangrove area lies in Brazil, Australia and Nigeria (Spalding et al., 1997). While practically all mangroves occur in small patches that develop in deltaic habitats, the mangroves in the Ganga-Brahmaputra-Meghna Delta, shared

between India and Bangladesh, are the only contiguous and larg-est coastal wetland system in the world. Popularly known as Sundarban2, they currently cover about one million ha area, greater than the combined area of Wadden Sea wet-lands that are shared between Denmark, Germany and the Netherlands. Exploration of the Sundarban mangroves dates back to the 16th century (Rollet, 1981). A large bulk of pub-lished literature exists on the Sundarbans of both India (Naskar and Guha Bakshi, 1987; Chaudhuri and Choudhury, 1994; Guha Bakshi et al., 1999) and Bangladesh (Seidensticker et al., 1991; Hussain and Acharya, 1994; IUCN-BD 2002, Islam and Wahab, 2005) covering many aspects of their habitat characteristics, fl ora, fauna (par-ticularly fi sheries), utilization and management, yet very little is known about the functional aspects of this ecosys-tem. It may be noted here that since 1947 the Sundarban mangroves are di-vided between India and Bangladesh (formerly East Pakistan), and the two parts differ considerably in the nature and extent of investigations, conservation and management. They also differ substantially in the level of human exploitation over more than a century. This makes it dificult to integrate the information of the entire Sundarban. Therefore, we frequently refer to the Indian and Bangladesh parts of the Sundarban separately. The Sundarban (21º 30′ to 22º 40′ N, 88º 05′ to 89º 55′ E) comprises essentially of numerous islands formed by the sediments deposited by three major rivers, the Ganga, Brahmaputra and the Meghna, and a dense network of smaller rivers, channels and creeks. The maximum eleva-tion within the Sundarban is only 10 m above the mean sea level. The western and eastern limits of the Sundarban are defi ned by the course of the River Hooghly (a distributary of River Ganga) and River Baleshwar respectively (Fig. 1). The River Harinbhanga (known as Ichamati or Raimongal in Bangladesh) demarcates the border between India and Bangladesh. About 60 % of the mangrove forests lie in the Khulna

District of Bangladesh and the rest in the 24-Paragnas District of West Bengal (India). The estimates of the total area of Sundarban in the two countries often differ considerably. According to recent estimates, the area of the Sundarban in Bangladesh is 599,330 ha (1978 Landsat data; Rahman et al., 1979) and in India it is 426,300 ha. Species diversity Floristic diversity. Mangrove plants are usually divided into 'true mangrove' and 'mangrove associate' species. Globally, Duke (1992) recognised 69 species (belonging to 26 genera and 20 families) of true mangroves (major and minor, sensu Tomlinson, 1986) though recently Kathiresan and Bingham (2001) recognized only 65 species (22 genera and 16 families). Of these, at least 30 true mangroves occur in the Indian Sundarban. Debnath and Naskar (1999) identified 36 species as true mangroves. The Bangladesh part of the Sundarban differs mainly in the relative abundance of various species. Whereas members of the Rhizophoraceae and Avicenniaceae generally dominate most other mangrove areas, the Bangladesh part of the Sundarban has the greatest abundance of Sterculiaceae (Heritiera) and Euphorbiaceae (Excoecaria). Rhizophoraceae is the largest family with 11 species; four genera (***Rhizophora, Bruguiera, Avicennia and Sonneratia***) are represented by four species each and 5 genera (***Xylocarpus, Excoecaria***, ***Thespesia, Derris and Tamarix***) have three species each. In Bangladesh there is only one species of ***Bruguiera*** (***B. parviflora***), whereas Lumnitzera racemosa and Barringtonia sp. are quite restricted in occurrence. Interestingly, the Sundarban supports fewer species than other mangrove areas in India and Southeast Asia. For example, there are 45 mangrove species recorded from the Andaman and Nicobar Islands in the Bay of Bengal (Deshmukh et al., 1991a) and 55 species from Bhitarkanika in the delta of the Brahmani and Baitarni rivers in Orissa on the east coast of India (WWF-I, 2001). The total flora of the Sundarban has also been estimated differently in India and Bangladesh. In India, the total vascular flora (including mangrove

associates) is estimated at 100 species representing 34 families and 57 genera. comprises of 30 species of trees, 32 shrubs, and the rest are herbs, grasses, sedges and two ferns. Many terrestrial upland plants within the Sundarban area have apparently not been included because Seidensticker and Hai (1983) recorded 334 plant species representing 245 genera from the Bangladesh Sundarban. This record lists numerous epiphytes and climbers, which include 13 orchids and several ferns. Several species in the Indian Sundarban do not occur in Bangladesh part, whereas many other species have been reported from Bangladesh alone (Choudhury, 1968; Ismail, 1990). Interestingly, some species listed earlier from Bangladesh by Prain (1903) and Choudhury (1968), such as Bruguiera sexangula, Rhizophora apiculata and Sonneratia alba, were not recorded by Chaffey et al. (1985) and it is feared that these species may have disappeared from the eastern part of the Sundarban. Heritiera fomes (locally known as Sundari, the most important timber species from which Sundarban derives its name),which is abundant on the Bangladesh side, is not common on the Indian side where it is considered endangered. Nypa fruticans also has a limited occurrence within the Indian Sundarban; it is rapidly disappearing because of extensive exploitation. Based on their present status, Aegiceras corniculatum, Kandelia candel, Rhizophora sp., Sonneratia acida, Sonneratia apetala and Sonneratia caseolaris also require conservation measures (Table 2).

Table 2. Rare, threatened and endangered flora of the Indian Sundarbans.

Family	SPECIES	Status
Rhizophoraceae	***Rhizophora apiculata***	. Occasional
	Bruguiera parviflora	Occasional
	Ceriops decandra	Occasional
	.Kandelia candel	Occasional
Meliaceae	***Aglaia cucullata***	Rare
	Xylocarpus mekongensis	Threatened
	Xylocarpus granatum	Threatened
Sterculiace	***Heritiera fomes***	Threatened
Rubiaceae	***Scyphiphora hydrphyllacea***	Very Rare
	Hydrophyllax maritime	Very Rare
Tiliaceae	***Brownlowia lanceolata***	Occasional
Arecaceae	***Nypa fruticans***	Occasional
Acanthaceae	***Acanthus volubilis***	Very Rare
Papilionaceae	***Cynometra ramiflora***	Rare
	Dalbergia spinosa	Rare
Sapotaceae	Manilkara hexandra	Very Rare
Rutaceae	Atalantia correa	Rare


INDIA
BANGLADESH
Mongla
Kalabogi
Karamjal
Shibsa River
SUNDARBAN NATIONAL PARK
Koikhali
Pasur River
Kholpetua River
Bay of Bengal
Sundarbans protected areas
10 km