Pandit Govind Ballabh Pant Memorial Lecture: II

Plant Diversity in the Himalaya: Conservation and Utilization

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About Dr. T.N. Khoshoo, FNA

Padma Bhushan Dr. Triloki Nath Khoshoo, born on April 7, 1927 at Srinagar, Kashmir (India) is currently Jawaharlal Nehru Fellow and associated with Tata Energy Research Institute, New Delhi. He had his education at Punjab University. Dr. Khoshoo is a honoured Fellow of INSA, IAS Banglore, NAS Allahabad, Institution of Engineers, ISGPE New Delhi, IBS and IAAS. He had to his credit 209 original publication in National and International journals of repute, has authored 3 books and edited 8 books on environmental subjects. As a recognition of his significient contribution to science and academics, the President of India conferred on him the prestigious Padam Bhusan in 1992.

Dr. Khoshoo held various distinguished positions including Director, NBRI Lucknow, Secretary to the G.O.I. Deptt. Of Environment, and Distinguished Scientist CSIR. Some of the other Honours and Awards earned by him are:

Prince of Wales Gold Medal of Punjab University, Lahore (1942); Rafi Ahmad Kidwai Medal and Prize of the Indian Council of Agriculture Research, New Delhi for outstanding work on non- agricultural economic plants (1977); Birbal Sahni Gold Medal of the Indian Botanical Society for outstanding work in plant sciences (1982); Seth Memorial Medal of the Indian Society of Tree Scientists for outstanding work on forest trees, in particular conifers (1983); Ramdeo Misra Medal of the Indian Environmental Society for the valuable contributions relating to environmental sciences (1984); Dayawati Vira Medal of agri- horticulture Society for outstanding work in beautifying the environment (1985); Sanjay Gandhi Award for outstanding work in Environment and Ecology, and services rendered to the country in these areas (1986); Distinguished Service award of the Indian Science Congress (1988); Distinguished Service Award of the Indian Genetics and Plant Breeding (1991); Guru Prashad Chatterjee Lecture Award, Indian National Science Academy (1985); Om Prakash Bhasin Foundation Award in Agiculture (Biomass Production, Proceeding and Utilization) (1989); Guru Prashad Chatterjee Lecture Award in Agriculture (Biomass Production, Processing and Utilization) (1989); National Lectuer of the University Grants Commission, New Delhi (1981); Past President, Botany Section, Indian Science Congress Association, Calcutta (1982); Past General President Indian Science Congress Association – 73rd Session (1985-86); Past president, Bio-energy Society of India (1985-86); Past President, National Academy of Sciences India; Past President, Indian Society of Genetics and Plant Breeding. (1986); Past President, Indian Society of Tree Scientists (1988-1991); Past Co- Editor, *Silvae Genetica*, International Journal of Forest Genetics and Tree Breeding, West Germany (1960-84); Member, Editorial Board, *Plant Systematics and Evolution*. Springer verlag, Vienna and New York; Past Deputy Chairman, Working Group on Cytogenetics, International Union of Forestry Research Organization, Washington; Vice Chairman, Governing Council, United Nations Environment Programme, Nairobi (1982); Past National Chairman, International Union of Biological Sciences (1981-84); Member Scientific Advisory Committee to the Cabinet, Government of India (1982-85); Member, International Task Force on Tropical Forestry, World Resources Institute, Washington 91984); Member, Council of the World Resources Institute, Washington (1998-); Member, Advisory Board of World Resources Report (1989); Member, Plant Advisory Group of International Union for Conservation of Nature and Natural Resources, Switzerland; Member, Scientific Committee of the International Lake Environment Committee, Tokyo (1988-); National Chairman of Scientific Committee on problems of Environment (SCOPE), New Delhi; Member, National Committee on International Biosphere –Geosphere Programme, INSA, New Delhi.

Content

1

Tribute

I am indeed very happy to have been chosen to deliver the Second Pandit Gobind Ballabh Pant Lecture of the G.B. Pant Institute of Himalayan Environment and Development (GBPIHED). According to Pt. Jawaharlal Nehru, Pt. Pant, like the Himalaya itself, was a colossus in every sense of the word. He was among the greatest men that the country has produced. All his life, Pantji, shone on the Indian scene like the Himalaya peaks. Another reason for me to be happy is that it gives me great satisfaction that the GBP-IHED, after having been conceptualized and formulated during my tenure as the Secretary to the Government of India, is now taking shape.

2

Prelude

Looking at the continent of Asia from space, one of the most striking features is the 2500-km long Himalayan belt occupying an area of about 236,000 sq km in India. The Himalaya alongwith Hindukush is like a battlement (Fig. 1). The long middle portion extends from north- westerly (longitude East 73^o and Latitude North 37^o) to south-easterly (longitude East 97^o and latitude North 27^o) direction. The middle portion is not straight but has a bulge in the Nepal- Bhutan area. The flank on the western side extends into Afganistan in a south-westerly direction. The eastern flank extends into Myanmar in a south- easterly direction. The eastern flank extends into Myanmar in a south- easterly direction. The whole range when viewed from space gives the impression of being protective to Pakistan, India, Nepal, Bhutan, Bangladesh and Myanmar. The Himalayan ranges are between 240 to 340 km wide and rise from low-lying Indian plains to over 8000 m. Himalaya is a complex system and separate the northern part of the Asian continent (Tibet, China, Siberia and contiguous countries) from the southern part (Afganistan, Pakistan, India, Nepal, Bhutan, Bangladesh and Myanmar). The latter, in common parlance, is known as the Indian subcontinent, which, due to Himalaya, is a discreet geographic and ecological entity with its own climate(s).

Fig. 1.

The birth of Himalaya is related to a cataclysmic event of the breakup, some 140 million years ago, of the peninsular part of today's India (Deccan Plateau) from a super- continent Gondwanaland. The peninsular Indian Plate was located somewhere near the present day Madagascar and South Africa. The plate started drifting about 15cm per year northwards, across, what is now known as, the Indian ocean. Finally, it crashed about 15 million year ago into what was an northern Asian continent, at a place where the present Assam region is. Such a collision of the peninsular plate under the southern edge of the Asian continental plate, resulted in the rise of Himalaya. The peninsular plate continues to move north about 8 cm per year resulting in continued rise of the Himalaya (Audley Charles et al, 1981). Continued northward movement of the peninsular plate gives this mountain system an inherent instability. It is, therefore, not unexpected that there have been series of devasting earthquakes, the last being on October 20, 1991 in the Uttarkashi- Tehri region of Garhwal (Valdiya, 1991).

The tectonic breakup of Gondwanaland and subsequent drift and collision of peninsular plate at Assam, resulted in the creation and continuous rise of the Himalaya. This mountain system is the youngest, the tallest, and the most fragile mountain systems in the world. The erosion of the young Himalaya resulted in production of alluvia that led to filling and drying up of the Tethys Sea in the North-West India. With this, were born the Indus and the Gangetic alluvial plains. Other geological details have been discussed by Wadia (1975).

From the times immemorial, Himalaya has attracted spiritual leaders, devotees, expeditionists, mountaineers, venture trekkers, tourists and scientists of all specialties. The mountain system has been a source of tremendous inspiration. There are many trusts, foundations, societies, in non-governmental sector in India and abroad which are concerned about Hiamalaya. This mountain system has also seen battles which have left their imprint: the well known among there is the Rupkund tragedy. The alpine Rupkund Lake (4850m altitude) is situated at the base of Trishul massif on the southern fringes of Nanda Devi Sanctury. The mystery deepened with the discovery of many human skeletons and even undecomposed human flesh buried under scree and bolders on the north western slopes. Considerable myth is woven round this.

The Himalaya has been called variously: Abode of Snow, Abode of Gods, Weather –maker of the Indian Subcontinent, The Third Pole- a feature on earth no where else to be seen. The mountain system has inspired awe, respect and reverence. The Himalaya has been fountain head of yogic wisdom and spirituality of millions of Indians, not withstanding their differing religious beliefs. One only needs a mind, an eye and an ear to understand, see and hear the spiritual glory of Himalaya. Those of us who were born, bred up and educated in the company of the awe-inspiring mountain peaks have been told by their parents and other elders, the story of sages, religious leaders, artists, poets and philosophers who have been attracted from far and wide to this abode of snow. The mountain chain has influenced the life, culture and history of India.

The clouds rise in the Indian ocean and the Bay of Bengal, and are trapped on south side of the Himalaya and shower their "blessings" in the form of monsoon year after year. The mountain system not only traps monsoon winds, but also obstructs the cold dry Tibetan and Siberian winds. The Himalaya is thus the guardian of the Indian subcontinent. However, the monsoon is a mixed blessing. The young Himalaya with very steep slopes and unconsolidated soil is indeed fragile. The situation is compounded by increased human & livestock population pressure and deforestation. The mountain system is thus prone to high rate of erosion which results in floods year after year bringing untold misery to the poor people both in the mountains and in the plains (see also Agarwal and Chak, 1991). On the other hand, monsoon also makes

Indian plains verdant and washes the country clean, reducing the danger of acid rain to our forests.

The epics like Ramayana and Mahabharata carry beautiful descriptions of the Himalaya. Praise for the Himalaya has been so beautifully sung by the poet Kalidas. In one of his epic poems, *Meghdoot* (Messenger of Clouds), he describes the pilgrimage of clouds to the Himalaya peaks.

There is deep concern about the health of the Himalaya. On the one side of the spectrum, is the concern of the elitists like the Himalaya expeditionists: it is they, who in the first instance, have been spreading litter and rubbish all along the route to the Himalayan peaks. Now, they are concerned about collecting the disposing the same. They thus intend to stop spoilage of the landscape. On the other end of the spectrum, are the concerns of the poor residents of the Himalaya at the very grassroots, who are steeped, in utter penury. For them, it is a question of survival and a prospect of a very grim existence. Although mountain folk and highlanders throughout the world are poor, those in the Himalaya are the poorest. Their very existence is threatened and have to face grim realities of life. They have not only been consistently left out of the main stream of development of the country but also most of so called development in the mountains (be it dams, orchards, tea gardens etc.) has benefited the people in plains for more than the highlanders. To add injury to the insult, the highlanders have also bear the brunt of environmental degradation as a result of such development. Thus, much of the benefit goes to the rich plains people, but the long term costs are born by highlanders. There is a constant fear of existence, which is epitomised by a real life story of an ex- serviceman, C.S. Rana, who wrote in his letter dated May 1, 1984: " I was in the West Bengal Rifles for over 27 years and I fought in three wars. I have now returned to my village. My enemy is no longer Pakistan and China: it is now landslides. We have live in fear of landslides. I have put my gun away. My weapon is now trees to prevent landslides. We need trees to provide fuel for cooking, fodder for our cattle, fertilizer for our lands, fruit for our children, agricultural implements for our farmers, and some furniture for our small homes. We need trees to give us a healthy environment so that we can survive" (Khoshoo 1986).

Inspite of such grim realities, to a dweller in Himalaya, there mountains are his. her "spiritual parents" and living in their abode is indeed "living in the lap of one's mother".

The mountain system exerts a definite influence on the climate of the subcontinent. It has given a definite geologic and a geographic identity to the Indian subcontinent and its countries: Afghanistan, Pakistan, India, Nepal, Bhutan, Bangladesh and Myanmar. The earlier this group of countries realizes their common geological, geographical, ecological and economic destiny, the better it is for the people of the region. This is the central message that comes to us through the echoes of our sages down the corridors of time. Himalaya is intricately interwoven with our history, culture, religion and philosophy.

The unity stressed above is accompanied by the diversity. Himalaya is the abode of a number of ethnic and cultural groups of people: Indian, Nepalese, Bhutanese and Tibetan and all shades in between. People in the Himalayan Region speak different languages from Pusthu to Kashmiri, Himachali, Kumaoni, Garhwali, Napalese and Tibetan and mixtures in between. All people from the Himalaya, irrespective of their caste, creed and religion, believe that the mountain system is a living, dynamic and continuing system with which is irrevocably intertwined the destiny of Indian subcontinent and its people.

3

Climatic Diversity

Climatically Himalaya is very diverse on account of variation in topography, elevation and overall monsoon pattern. Basically, the monsoons are the result of temperature differential created by incoming solar radiation between land and sea. The land mass is heated up during summer, as compared to sea, both in the east and south. This results in low pressure areas and moist air moves towards land. The monsoon starts in first week of June in the Eastern Himalaya and then moves westward and showers rain almost on the whole range upto September every year. The high Western Himalaya and the valley in that region do not receive adequate monsoon. The post-monsoon period is rather dry, followed by western disturbance in winter months is the source of precipitation in the Eastern Himalaya, while the western disturbances are the source of snow in winter months in the Western Himalaya. This being the overall climatic pattern of the Himalaya which has its own local variation, resulting in varied climatic patterns. Based on geographic physiographic factors, there are five climatic zones in the Himalaya as affected by altitude. These are : Warm Tropical (8000m); Warm subtropical (800-1200m); Cool Temperate (1200-2400m); Alpine (2400-3600m); and Arctic (3600m and above).

While these are only broad zonations, there are many local variations as a result of variable precipitation, temperature, wind patterns, humidity, radiation etc.

4

Rock and Soil Diversity

The rock profiles of Himalaya are very varied in different zones, namely Siwaliks, outer and Greater Himalaya and the Trans- Himalayan zone. Rock formulation has been discussed in detail by Wadia (1975) and Krishnan (1974). In contrast to this, soils of Himalaya have not received any worthwhile attention. There are fragmentary reports, and only Brown Hill soils of Siwaliks have been studied to some extent. There is need to start a systematic study on the soils o f the Himalaya in order to close the gap in knowledge in this important area.

5

River Systems

Outside polar regions, Himalaya is a reservoir of over 5000 glaciers with permanent ice and snow. It is, therefore, understandable that Himalaya is the source of several large rivers together with their tributaries which flow southwards in the Indus- Gangetic Plains and finally discharge in the sea. There is a tremendous water potential estimated in 1972 at 16,725 milliard m^3 by the Second Irrigation Commission. On this water potential depends the well being of millions of people in the entire belt in Indus-Gangetic plains and North East India.

According to Wadia (1975), the main rivers of Himalaya are older than the uplift of Himalaya. Therefore, the mountain system is unique with highest peaks and passes and deepest gorges. The whole drainage system in Himalaya can be traced to three main river systems together with their tributaries, The Indus, Ganges and Brahmaputra systems. Out of these, Indus and Brahmaputra arise in Tibetan Highlands and are joined by many other rivers. The former goes west , while the latter goes east. Both enter Indus-Gangetic basin. However, Ganges arises in the Himalaya itself.

6

Biogeography

Following the classification of Rodgers (1985), India can be divided into two Biogeographical Zones. The Himalaya falls in the Boreal zone, which has two subzones: Sino-Siberian and Sino- Himalaya. Table 1 and Fig. 2 give the important feature of the classification.

The Western and the Eastern flanks of the Himalaya are different. The Western Himalaya ranges are much wider and colder with drier climate. In contrast, the eastern ranges are among the wettest regions of the world with high biodiversity. The western ranges have a vegetation which is cold-loving and drought resistant. There are large gregarious populations of conifers like the chir and blue pines, deodar, fir and spruce. On the other hand, in the eastern counterparts, conifers, through present, are not a dominant element. Rhododendrons dominate the plant life of this region. Unfortunately, after independence, particularly after the Chinese invasion, the rhododendron wealth has diminished substantially on account of defense activities where large chunks of mountain slopes had to be cleared. Today if one has to have an idea about diversity of East- Himalayan species of *Rhododendron*, one has to go the Royal Botanic Gardens at Kew and Edinburgh, Botanic Garden at Berlin Dahlem and the Royal Horticultural Garden at Wisley.

Fig. 2.

Table 1. Biogeography of Himalaya

Biogeographical Zone	Biotic province	Bioms
A. BOREAL		
1. Sino- Siberian	1a Ladakh	Tundra zone
2. Sino- Himalayan	2a N.W.Himalaya	Alpine zone temperate zone Sub-tropical zone
	2b W. Himalaya	Alpine Zone Temperate
2c C. Himalaya	Alpine Zone	Temperate zone Sub tropical zone
	2d E. Himalaya	Alpine zone Temperate zone Sub-tropical zone
B. PALAEOTROPICAL:INDO MALAYAN		
8. North-East India	8a Brahmaputra Valley	Tropical Evergreen Forest Very moist Sal Forest
	8b Assam Hills	Tropical Evergreen Forest Tropical Moist Deciduous Forest Sub-tropical Forest Montane Temperate Forest Wetlands

Source: Rodgers, 1985

The difference between the two flanks is the result of several factors. The western ranges lie at 36^0 North latitude and are an area of low rain fall. These ranges descend as low as 2135m in Kashmir. This affects the tree line which is at 3600m altitude. On the other hand, eastern ranges lie at 27^0 North latitude and are among the wettest regions of the world. This area receives full thrust of monsoon from the Bay of Bengal which are trapped in Arunachal Pradesh at the corner where Himalayan trapped ranges bend southward. The monsoon is very intense here leading to erosion of much of the Siwaliks in the East from Kosi to Manas in Bhutan. Eastern ranges descend to 3960m in Kanchenjunga. Tree line is higher (4570m).

The vegetation of western ranges is drought resistant and cold-loving and conifers, legumes, grasses, composites, pomegranate, etc dominate. In the cold dry valleys in higher altitutdes, chilgosa pine is dominant. The Eastern Himalaya is indeed very rich in plant wealth. There is a very large number of epiphytes, and a profusion of orchids, fern, especially tree ferns, terminalias, oaks, laurels, rhododendrons, magnolias and lot of other species. There are a number of gymnosperms not found in Western Himalaya like *Larix*, hemlock, chinese spruce, fir, *Cephalotaxus*, *Podocarpus* and *Gnetum*. There are over 26 species of bamboos in this region and very few in Western Himalaya but none in Kashmir. While the eastern part has its distinctive flora, it does have elements of the original Gondwanaland flora, which came with peninsular plate when it struck against the Assam region. The plate carried with it the well developed *Podocarpus* flora. However, there is no worthwhile palaenotological evidence of its fauna. One would assume, it did have faunal elements of the Gondwanaland, having affinities with Madagascar and African continent. The drifting continent was partly submerged and perhaps had some original elements, particularly invertebrates and amphibians, which were lost after its collision with the Asian mainland.

With the rise of Himalaya, exchange of biodiversity (faunal and floral) with the northern Asia (Palaeoarctic Realm) was separated from the southern flora and fauna which was essentially African. There has been far more spread of the biodiversity of the Indo- Chinese affiliation from the east through the forested foot hills of the Himalaya. These elements were of recent origin and were dynamic and radiating. On the other hand, the original Indian biodiversity was indeed ancient and rather stable. Therefore, it is not surprising to find many of the dominant species in the Indian subcontinent being of Indo- Chinese origin.

In India, Himalaya start in the West from Naga Parbhat (8126m at present in the Pakistan Occupied Kashmir) to its eastern limit in the Arunachal Pradesh. The mountain ranges runs through Jammu and Kashmir, Himachal Pradesh, Hills of Uttar Pradesh and West Bengal, Sikkim and Arunachal Pradesh. In wider sense, also include other North-Eastern states of India, Assam, Nagaland, Manipur, Meghalaya, Triura and Mizoram. In vertical cross-section, Himalaya extend from Indian plains to Tibetan Highlands in four almost parallel ranges from South to North (Fig. 3). These are:

Fig.3

A generalized north-south cross section of Himalaya source: Wadia, 1975

- Outer Himalaya or Siwalik ranges which are low lying foot hills, with a width ranging from 10 to 60 km and an altitude not more than 1000m
- Middle or lesser Himalaya about 60 to 80 km in width and an altitude averaging 3500m. These fall in Jammu- Kashmir, Himachal Pradesh, Uttar Pradesh and Nepal.
- Inner or Great Himalayan range. This is high mountain range, about 120 to 140 km in width.
- Trans-Himalayan Region. This is about 40 km wide. This region is located beyond Great Himalaya and covers Ladakh and the Tibetan Plateau covers. The whole area is a big river basin and is not less than 4000m high.

The Himalayan ranges as a whole virtually enclose Indus- Gangetic Plains. As a result of alluvium from the mountains. The river systems drain the Himalayan catchments in the sea. From the point of view of physiography and vegetation the Himalaya has two major contrasting regions: Western and Eastern (see also MacKinnon and MacKinnon, 1986).

Western Himalaya: The region extends from Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh upto the eastern borders of Nepal. The Jammu and Kashmir region has five divisions. These are: South-West plains between rivers Ravi and Chenab; Pir Panjal range; Valley of Kashmir with Jehlum river basin; Great Himalaya; Karakoram and Ladakh.

In Himachal Pradesh, Himalaya can be delineated into Siwaliks, Middle and Inner Ranges. Major river basins are Chenab, Sutlej, Beas, Ravi and Ghagar.

Uttar Pradesh Himalaya is the eastern most part of the Western Himalaya. This region is separated by Tons River from Himachal Pradesh in the West and Kali River in east from Nepal. In this sector, Great Himalaya range from 4800 to 6000 m. these areas are with a permanent snow cover. The Siwalik ranges go upto 3500m.

Nepal Himalaya: This is about 800 km long. From south to north there are the usual four ranges. The Siwaliks or sub- Himalayan zone consists of low-lying hills about 5 to 50km in width. The Middle- Himalaya is about 85 kms wide and nearly 3500 m in altitude. The inner or the Great Himalaya is about 25 to 30 km wide. Many of the tallest peaks fall into this region. Some of the important ones are Mount Everest (8814 m), Kanchanjunga (8598 m), Dhaulagiri (8167 m), Gauri Shanker (7145m)etc. there are at least 240 peaks in Nepal Himalaya which are above 6500 m.

Eastern Himalaya: This extends from North Bengal Hills, Sikkim, Bhutan and Arunachal Pradesh. The Sikkim Himalaya is bounded on the West by Nepal, on the north by Tibet and on the east by Bhutan. The width is 80km. In Sikkim the altitude ranges from 330 to 8579m. Teesta is the main river in upper region and this river drains Eastern Himalaya. There are many peaks above 5000m. Bhutan in the west is rather low lying, but the northern portion is high with the higher peak Chomolhari (7314m).

The Arunachal Pradesh portion of the eastern Himalaya extends in north-easterly direction. The lower ranges are about 3500m but there are high peaks like Gorichen (6530) and Kangto (7090m).

7

Vegetational Patterns

As seen above, Himalaya is a large mountain system with diverse geology, rock and soil formation. Added to it is latitudinal, longitudinal and altitudinal zonations giving varied climates. There have been many attempts at classification of the vegetational types. Schweinfurth (1957) has made an excellent analysis of the flora of the Himalaya particularly regarding the horizontal and vertical distribution of vegetation in the mountain system. Unfortunately, Indian botanists have not taken advantage of his analytical approach. However, comprehensive and more popular attempt has been made by Champion and Seth (1968). In the recent years, Singh and Singh (1987) have also written about the forest vegetation of the Himalaya. Broadly speaking there is a major differentiation between the western and eastern Himalayan regions. The following account is largely based on Champion and Seth (1968) and Kawosa (1985).

Western Himalaya

This zone has lower monsoon rainfall but experiences heavy snowfall in winters. Here, all areas east of Kashmir upto the eastern boundary of Nepal are included. The vegetation can be distinguished in six different types.

Tropical deciduous Forests: These occur in the foothills of Western Himalaya in the monsoon belt and are found up to an altitude of 1300m. *Shorea robusta* is the dominant species. Associated species are *Anogeissus latifolia*, *Terminalaia tomentosa, Terminalia belerica* and *Bauhinia retusa*. However, Acacia *catechu, Dalbergia sissoo are frequent in the sand alluvium. Syzygium embryopteris, Cedrela toona* are found humid places. C*innamomum tamala, Eugenia oojneinensis, Machilus odoratissima, Pterospermum acerifolium, Trewia nudiflora* and common gorges. Giant climbers like *Bauhinia vahlii* are very common in lower altitudes. The drier slopes are occupied by Dendrocalamus strictus in association with trees other than *Sorea robusta* luxuriant growth of bushed occurs as understorey. The species are M*allotus phillipensis, Clerodendron infortunatum Woodfordia fructicosa, Indigofera pulchella* and *Carissa spinarum*. However, *Berbaeris spp*., *Rhus cotinus*, and *Rosa moschata* occurs as undergrowth.

Subtropical Pine Forests: in the entire outer ranges between, the altitudes of 800m to 1800m, there occurs *Pinus rozburghii.* Jammu, Kumaon and Tehri Garhwal areas abound with these forests in the pure formation on the quartizite and lime-stone. At lower altitudes this species is mixed *with Shorea robusta, Anogeissus latifolia, Dalbergia sissoo, and Terminalia spp.* On the upper limits of this forest, *Pinus rozburghii* is mixed with *Quercus incana, Rhododendron arboreum , Pieris ovalifolia* and *Myrica nagi*. Species like *Mallotus phillipensis, Punica granatum, Mayrisine africana, Rhus parviflora, Carissa spinarum* and *Berberis ceratophylla* constitute the understorey. *Euphorbia royleana* cover the hot dry slopes. This species is associated with Rhus parviflora and Carissa spinarium. This composition of species occurs in the entire belt of Jammu-Kangra-Kalka-Mussoorie foothills.

Himalayan Moist Temperate Forests: Here, evergreen oaks and conifers are associated between altitudes 1800 to 3300m. In these forests the dominant tree species are *Cedrus deodara, Picea smithiana, and Abies pindrow. Associated oaks are Quercus incana, Q. semecarpifolia. Other trees found are, Cedrela serrata, Lyonia ovalifolia , Rohodendron arboreum, Betula alnoides, Carpinus viminea, Acer cacsium, Fraxinus micrantha, acer pictum, Pyrus lanata, and Prunus cornuta*. Common shrubs found are *Pyrus pashia, Berberis lycium, Dfesmodium tiliae folum, Cotoneaster bacillaris, Rubus ellipticus, Rhamnus pupurea, Litsaea umbrosa, Rosa macrophylla, Strobilanthes wallichii, Melisoma dilleniaefloia, Roasa servicea, Vibrunum cotinifolum and Rubus niveus.*

The ground cover is constituted by Thalictrum foliolosum, Galium aparine, Fragaria nubiocola, Viola canescens, Senecio nudicaulis, Valerianan wallichii, Podophylum emodi, Polygonum vericullatum. Some of the common climbers are Clematis montana and Vitis himalayana.

Himalayan Dry Temperate: The most important component in this forest type is Cedrus deodara which occupies belts ranging from 2000 to 2500m- where it occurs almost in pure formations. However, in the lower altitudes it may either be raplaced or be mixed with Pinus *roxburghii*. In the higher reaches Cedrus deodara is either mixed or replaced by *Abies pindrow* and *Picea smithiana*. In this zone, the broad leaved element is *Quercus dilatata, Ulmus wallichinana, Corylus colurna, Acer caesium* and *Populus ciliata.* Important shrubs of this forest types are *Berberis lycium, Indigofera geradiana Desmodium tiliaefloum, Spireaea lindleyana, Rhus punjabensis, and Skimmia laureola.* The important *herbaceous element* is *Plectranthus rugosus, Salvaia glutinosa Cannabis sativa* and *Fragaria vesca*.

Subalpine Forests: These are located between temperate forests and touch the tree line. This zone extends from 2500 to 3800,. The tree component is *Betula utilis* associated with *sparse* and *stunted Abies pindrow.*

The understorey is formed by *Rhododendron campanulatum, R. lepidotum, R. anthopogon, Pyrus foliolosa, Sorbus aucuparia, Salix wallichiana, Juniperus recurva, Lonicera parvifolia, Viburnum nervosum* and *Rosa sericea*.

The herbaceous component is Polygonum vaccinifolum, Potentialla fructicosa, Primula denticulata, Astragalus oxydon, and Ribes rubrum.

Alpine Pastures and Scrub: These follow the treeline and are composed of green grassy meadows and pastures during the hot summer season but remain under snow for the rest of the period. These are found in the high mountain areas at an altitude of 3500 m, and above. Two sub-types are recognizable:

Moist Alpine Scrub: This occurs above the tree line at 3600m and extends upto 4900m. There are stunted woods alternating with meadows. The scrub consists of *juniperus squamata, j.recurva, j.macropoda and Rhododendron anthopogon*. The herbaceous component is rich and there are many species belonging to the genera *Gentiana, Saxifraga, Corydalis, Rumex, Cardamine Thymus, Aster, Viola, Campanula, Fritillaria, and Epilobium.* The commonly found grasses are *Agropyron spp., Bromus asper and Poa annua. Alpine Scrub*: This type of vegetation occurs at the same altitude as that of the Moist Alpine Scrub. However, the vegetation is often xerophytic with thorny bushes and grass cover.

The common scrub element is *Hippophae rhamnoides, Elaeagnus umbellata, Caragana brevispina, Rosa sericea Cotoneaster microphylla, Oxyria digyna* and *Atriplex hortensis.* Associated herbaceous component belongs to the genera *Festuca, Stipa, Bromus and Carex*.

Eastern Himalaya

This is a area which due to the proximity of the Bay of Bengal and south-easterly bend in the Himalaya, traps much of the monsoon clouds. Therefore, it is indeed a region of high monsoon intensity with humid climate. The areas covered are the hills of West Bengal, Sikkim, Bhutan, Arunachal Pradesh and other northeastern states. There have been many attempt regarding classification of vegetation starting with Griffith (1897) and ending with Miehe (1982) (see Kawosa, 1985). One underlying commonality between all classifications has been altitude.

Tropical Evergreen Forest: These occur in the foothills at an altitude of 800m and are found from Sikkim to Arunachal Pradesh. The tree component in the top storey is rich and some of the more common species are *Dipterocarpus macrocarpus Artocarpus chaplasha, Tetrameles nudiflora, Terminalia myricarpa, Altingia excelsa, Chukrasia velutina, Lagerstroemia speciosa, Bischolfia javanica, Bombax ceiba, and Dysoxylum procerum*. The middle story is characterized by Mesua ferrea. Fuabunga grandiflora, Phoeba goalparensis. Several species of Bauhinia and Melocanna form extensive forests in some valleys. The lower storey is dominated by *Syzygium formosum, Dillenia indica, Talauma hodgsonii and Calamus spp.* The most common tree ferns in the lower storey are *Angiopteris evecta* and several species of Cyathea.

Subtropical Forests: Most of the eastern Himalayan areas between 900 to 1800m are characterized by this type of forest of *Schima-Castanopsis-Engelhardtia-Saurauia* assocation in higher altitudes and *Ducus- Castanopsis-Callicarpa* association in the lower reaches*. Albizzia* and *Morus spp.* Are found in the river valleys*. Populus ciliata* abounds inner valleys*. Pinus roxbrughii* is rare in the inner valleys of Bhutan up to 1600m.

Eastern Temperate Forests: Theses forests range between 1800 to 3500m. The important tree species are *Michelia doltsopa, Magnolia campbelli*, *Rhododendron falconeri, R. thomsonii, R. Griffithianum, Symplocos spicata, Lyonia ovalifoli,* and *Quercus lamellosa*. *Pinus wallichinana* is the main coniferous and is usually associated with other tree species like *Quercus griffithii, Populus ciliata, Acer oblongum Alnus nepalensis, Prunus cerasoides,* and *Picrasma quassiodes*. Other conifers found are *Tsuga dumosa, Abies delavyi, Abies densa, Larix griffithiana and Picea brachtyla*. Associated with these are shrubs like *Znathoxylum armatum, Rubus ellipticus, Carryopteris wallichinana*. Species like Phalogacantus *guttatus, Lasianthus biermanni*, and *Brachytoma wallichii* constitute the undergrowt. These extends from 3500 to 4500m. Abies densa associated with *Rhododendron wightii, Betula utilis, juniperus wallichiana* and *Pyrus aucuparia* are the dominant trees. Important shrubs are *Cassiope fastigiata, Berveris spp.,* and *Salix sikkimensis.* The ground cover includes *Caltha palustris, Meconopsis simplicifolia, Primula capitata, Arisaema griffithii and arundinaria falcata.*

Alpine vegetation: This zone has no trees but it abounds in shrubs, cushion plants and herbs. The most common species are *Rhododendron nivale, Saussurea gossypiphora, Thylacospermum rupifragrum Arenaria musciformis, Ephendra saxatilis, Urtica hyperborea, and Leontopodum himalayanum.*

Stoney Deserts: This type of vegetation is found above 4800 m on rocky ground. It is rich in species of genera *Androsace Sedum* and *Saxifraga*.

8

Agro-Ecosystem

Apart from natural ecosystems, agro-ecosystems are equally important. These systems must also include shifting cultivation, its retinement and making it sustainable. Agro- ecosystems have not received any attention from ecologists eventhough these are permanent changes of the original ecosystems. These systems have to be treated on that basis.

An agro-ecosystem is essentially a man –made ecosystem which is geared to meeting basic human needs of food, fodder, fuel, fertilizer, fiber, timber, medicinal and commodity crops, and also giving some economic returns. The underlying purpose is the production of these goods and services on a sustainable basis. Such an ecological approach to agricultural production is based on the concept of creating productive and sustainable systems with resource-conservation and risk-reducing aspects of traditional farming methods appropriately blended with modern advances in biology, particularly biotechnology. Equally important are socio-economic and other aspects like land and tenure, farm size, pricing policy, local markets and less dependence on sophisticated farm implements and chemicals. The system has to maintain optimum sustainable production of food and income over long periods (Khoshoo, 1992d).

The evolution of agro-ecosystems has been necessitated by the escalating population. From a hunter-gatherer system, humankind became sedentary and got attached o a particular locality. Thus in essence the evolution of agro-ecosystem became inevitable on account of a major change from food gathering to food producing. During this process humanbeing has eliminated all the species except those on which he depended for his food, fodde, fuel, fiber, fertilizer, medicare and some vocations. Over the years, this change has affected the hydrological and geochemical cycles. All in all, agro-ecosystems are a reflection of evolution of human culture. Agro-ecosystems are there to stay and these along with shifting cultivation have to be refined and made sustainable by scientific and technological inputs taking into account the indigenous knowledge (Khoshoo, 1991). This is particularly true for Himalayan agroecosystems.

The concept of agro-ecosystems aims at giving ecological orientation to the agriculture systems so as to reap the maximum benefit from the available resources under a particular set of growing conditions. In simpler words, it aims at using land, water and vegetation for sustainable production/productivity. Before attempting this, there is need to have precise information on various agro-ecological parameters like soil, rainfall, temperature, water, potential evaporation, etc.

However, there are not many worthwhile examples where agricultural scientists have looked into the possibility of application of ecological principles in the agricultural production system(s), and conversely where ecologists have been involved in agricultural sciences. This is the result of an unwitting schism between agriculture and ecology. The nearest the two have gone is in the case of Integrated Pest Management.

The attempt has to match the following aspects for achieving optimum results.

- Identify and map climate of an area based on temperature regime, seasonally of rainfall, soil etc.

- Select crop species out of those that are suited to a particular ecological regime.

- Work out the growing periods based on data on rainfall and potential evapotranspiration.

- Determine specific crop and cultivar requirements for the particular growing period.

This would enable to delineate agroecosystems as land units in terms of major climate and growing period which is ecologically suitable for definite crops and cultivars. There are there major components of agro-ecosystems: soil-scape (physiography and soils), beioclimate (rainfall, temperature, vegetation, potential evapotranspiration, soil storage). Based on these, Sehal et.al (1990) have identified 21 agro-ecological regions, five of which fall in the Himalaya. Cental to the whole concept is soil, climate and land-use. These need to be periodically appraised. Implicit in this is that proper crop species would have to be identified so as to develop suitable cropping patterns, keeping in view the local practices and wisdom.

A brief description of the five agroecosystems in the Himalaya, as identified by Sehgal et.al (1990) is given below:

North-Western Himalaya: This agroecosystem is located in cold and arid regions with shallow skeletal soils. It covers Ladakh and Gilgit. It covers an area of 15.6 Mha.

This region has mild summer and harsh winter. Mean annual temperature is 8^{o}C and rainfall is less than 150mm. It has a short growing period of less than 90 days per year. These soils are nutrient unbalanced for natural crop production. This region has considerable potential for dry fruit plantation crops (like apricots), off season vegetables (like peas) and cultivation of ornament al (like roses) during summer.

Western Himalaya: This region includes Jammu and Kashmir, Himachal Pradesh and North western hilly areas of Uttar Pradesh. The region is about 17.7 Mha. It has a mild summer and cool to cool winter. The mean annual rainfall varied from 1600 to 2000mm which exceeds potential evapotranspiration during most of the year. Moisture availability is for 150-210 days in a year.

In this region, deforestation is excessive with a high degree of soil erosion. The choice of crops is limited to paddy.

Assam Plains: This region includes plains of the Brahmaputra valley. The region has warm summer and mild winters. The mean annual rainfall ranges from 1400 to 1600 mm in Ganges Plains to 1600 to 2000 mm in Brahmaputra valley. The precipitation exceeds potential evapotranspiration for greater part of the year.

The common feature of this region is flooding and water logging.

Eastern Himalaya: This region includes northern tip of West Bengal, Northern parts of Assam, whole of Arunachal Pradesh and Sikkim. It accounts of 8 Mha. Summers are mild and moderate to severe winters. The potential evapotranspiration exceeds 2000 mm. There is limited choice of crops. Major problem is shifting cultivation leading to deforestation.

North-Eastern Hilly region: This region includes hilly states of Nagaland, Meghalaya, Manipur, Mizoran and Tripura. It is about 10.7Mha. The region has warm summers and cold winters. Mean annual precipitation is 1600 to 2600 mm and exceeds potential evapotranspiration in some years. Shifting cultivation leads to deforestation and severe soil erosion hazards.

Ghosh (1991), based on details of physical features, soils, climate, rainfall, temperature, irrigation, land-use and, cropping patterns, livestock production and productivity has distinguished specific zones in each state. In Jammu and Kashmir, Gangopadhyay (1991 a) has recognized four distinctive zones: Cold Arid Zone, Mid to High Altitutde Temperate Zone, Mid High Altitude intermediate Zone and Low Altitude Sub-tropical zone. Gangopadhyay (1991b) while discussing Himachal Pradesh has also recognized four zones. These are: High Hill Temperate Dry Zone, High Hill Temperate Wet zone, Mid Hill Sub- Humid Zone and Sub-Montane and Low Hill Sub-tropical Zone.

In Punjab, out of the five zones, two are adjoining the hills. These are Sub-Montane Undulating Zone and Undulating Plane Zone (Singh, 1991).

Saxena (1991) recognized ten agroclimatic zones, in Uttar Pradesh, two of which Hill zone, and Bhabar and Terai Zone deal with Uttar Pradesh Himalaya.

Out of 6 zones in West Bengal, there is a Hill zone (Darjeeling) and Terai Zone (Jalpaiguri) which are in or near Himalaya (Gangopadhyay 1991c). In Assam, Varma (1991) has recognized six zones. These are North Bank Plain Zone, Upper Brahmapurta Valley Zone, Central Brahmaputra Valley Zone, Lower Brahmaputra Valley Zone, Barrak Valley Zone and Hill Zone of Assam.

The forgoing work of the Planning Commission and Indian Council of Agricultural Research is the first attempt in the direction of identifying discrete agro-ecosystems. The work must be followed by detailed studies by agricultural scientists and ecologists. This would lead to a refined classification and redefinition in concrete terms of the agro-ecolsystems. More importantly, the strategies and actual actions that must follow for their refinement so as to make the agroecosystems. More importantly, the strategies and actual actions that must follow for their refinement so as to make the agroecosystems sustainable (see also Khoshoo, 1992d).

Sustainability in farming systems in mountains has been looked into by Jodha et al (1992). Biomass-based development is most relevant to mountains. The three basic elements are agriculture (including horticulture), forestry and animal husbandry. These together with three interfacing situations agri-silviculture, agri-pastoral and agri-silvi-pastoral are most important for the development in the mountains. Their successful implementation depends on sustainable watershed development, proper land use planning and availability of water and all other inputs. Among the inputs are proper crop varieties suited to the various climatic regimes of the mountains. This aspect has been hardly attended to. Some success has been reported. They need to be critically examined and, if found sustainable, may be advocated for adoption in isoclimatic situations.

Sustainability in mountain agroecosystem is most critical to the wellbeing of highlanders because their poverty and wretchedness can be traced to unsustainable agricultural systems and faulty land-use planning.

9

Conservation and Production Forestry

Although Himalaya essentially falls in temperate region, the climate varies from near tropical to subtropical, temperate alpine to arctic conditions with permanent snow in the entire northern belt at the higher altitudes.

In temperate regions, diversity within forests is far less than in tropics. In the latter case, each tree is so-to-say a mini- ecosystem being laden with epiphytes, ants and other micro and macro –biota. There are fewer species of shrubs and trees in temperate region. The species change in response to altitude. For instance in Western Himalaya *Qurcus incana* (1200-1800 m) is followed by *Q.dialatata* (1800-2100m) and Q. *semecarpifolia* (2400-2700 m). These species have been regarded as barometers on account of their altitudinal specificity. Similary in the conifers we have altitudinal transition from Pinus roxburghii (1000-1500m), P.excelsa (1800-2400m), Cedrus deodara (1800-2400m), Abies pindrow (2400-2700 m), Picea smithiana (2400-3000m) and Juniper species (2700m and above). These cover an altitudinal range from about

1000m to over 4000m in western Himalaya. Furthermore, in temperate regions often one species is dominant and which occupies vast stretches horizontally. Thus, we have almost pure natural seeds of *Pinus rozburghii* or other species which may appear as “monoculture”. However, in strict sense it is not so because there is tremendous genetic diversity within each stand.

According to the Forest (Conservation) act of 1988, 60% of the land area in the hills has to be under forest cover, while for country as a whole it should be 33%. The dense forest cover (more than 40% crown density) for the country as a whole is only 11.71% (Anonymous, 1991). However, forest cover for the Himalayan belt is only for the Himalayan belt is only 21.78%, but ranges from 4.9% (Jammu and Kashmir) to 65.13%(Arunachal Pradesh). A breakup of the forest cover in the Himalayan given in the Forest Survey Report (Anonymous, 1991), is summarized in Table 2. Except for Arunachal Pradesh (65.13%) forest cover in no state is anywhere near 60%. There is a need for a very concerted efforts to reforest as much area, as is possible, keeping in view the constraints like excessive grazing on account of livestock population beyond the carrying capacity; escalating human population beyond the carrying capacity; escalating human population; escalating demand for firewood and small timber and poles far in excess of the mean annual increment; shifting cultivation in north –eastern sector of Himalaya; and private ownership of forest lands in north- eastern sector resulting in unscientific management.

Importance of forest cover cannot be underestimated because our long-range ecological security is intertwined with it. Furthermore, in the mountains there is a deep inter-connection between forests and agriculture as epitomixed saying of a Kashmiri Saint (Nund Rishi b 1378 A.D.): “ food will last as long as the forests last”. Therefore, tangible steps have to be taken to ensure a minimum forest cover at least in the hills.

Table 2 Dense Forest Cover in Himalaya (Area in Sq. km.)

State	Geographic Area	Dense Forest cover (>40%)	Percentage
1. Jammu & Kashmir	222,235	10,986	4.9
2. Himachal Pradesh	55,673	8,911	16.0
3. Uttar Pradesh			
(Hill District)	51,125	17,448	34.12
Almora	5,385	2,095	38.9
Chamoli	9,125	2,519	27.6
Dehradun	3,088	1,234	39.9
Garhwal	5,440	2,156	39.6
Nainital	6,794	2,946	43.36
Pithoragarh	8,856	2,178	24.59
Tehri Garhwal	4,421	1,734	39.22
Uttarkashi	8,016	2,586	32.,26
4. Sikkim	7,09	2,403	8.86
5. West Bengal (Hill District)			

	Darjeeling	3,149	1,109	35.2
6.	Assam	78,438	15,842	20.19
7.	Arunachal Pradesh	83,74	54,542	65.13
8.	Nagaland	16,579	3,531	21.29
9.	Meghalaya	22,429	3,305	14.73
10.	Manipur	2,327	5309	23.77
11.	Tripura	10,406	1,825	17.4
12.	Mizoram	21,081	4,279	20.29
Total		594,361	129,490	21.78

Source: Anonymous, 1991.

At the outset, a distinction has to be made between forests and plantations. The former are natural and often a mixture with a dominant tree cover, a middle storey of shrubs and a ground cover of undershrubs and herbs. There is no commercial objective. Plantations are essentially man-made with some end-use in mind. Both forests and plantation can be managed for the benefit of mankind. Ideal plantations can combine both ecological and economic imperatives properly dovetailed for the good, the benefit and wellbeing of the concerned ecosystems and the communities of human beings depending on them.

The principal goal of forestry in the Indian context are:

- Affording long-range ecological security for the conservation of climate, water, soil and biodiversity
- Meeting the needs of goods and services, including firewood, charcoal and fodder for rural/tribal communities and the urban poor.
- Meeting the wood requirements of the people and industry for timber, pulp, fiber and silvi-chemicals.
- Amelioration of degraded areas and wastelands so as to enhance the productive capacity of such derelict lands and to improve aesthetics in general.
- Conservation Forestry
- Agro-forestry
- Industrial Forestry
- Environmental / Revegetation Forestry

Conservation Forestry

This is most relevant to all water regimes/ watersheds/ catchments; representative forest types, ecosystems and biosphere reserves (located in different biomes); and centres of diversity, national parks and sanctuaries and fragile ecosystems. In all these regions, exploitation of wood and non-wood resources should be normally prohibited, unless warranted on scientific and technical grounds, for maintaining the health of the concerned forests, and that too, not more than the Mean Annual Increment (MAI). The restoration and repair of such areas has to be done with local and indigenous species, and on no account should exotics ever be introduced in the conservation areas.

Conservation forestry benefits all people because it is linked to the stabilization of micro-climate, conservation of soil, water and biodiversity, source of non-wood products and other amenities.

Agro-forestry

Here the objective is the integration of agriculture, forestry and animal husbandry to meet food, fuel and fodder needs through a well chalked out Agri-Silvi-Pastoral, Agri-basic idea is to aim at the intensification and diversification of biomass production in rural areas.

There should be no objection to the use of exotic trees in agroforestry, if their use is warranted on the grounds of landuse and end-use to meet the needs of location-specific edaphic conditions and the demand of the local population, respectively. Here, the beneficiaries are the rural and urban poors whose needs of fuelwood and small timber are also met and it may serve as a source of some income as well. Agro- forestry practiced on a sustainable basis would ultimately relieve pressure on natural forests and thereby help in forest conservation.

Industrial Forestry

Here, the objective is to meet the needs of timber, pulpwood and fiber. It is a commercial venture based on wood quality and input-output considerations. The objective has to be tree-crop farming. The immediate clients are wood-based industries. Industrial forestry has to be related to land use and end use considerations. Since there are commercial ventures, production and productivity are chief consideration, and if warranted on other grounds, fast growing exotics are also welcome.

India can afford to be oblivious to the needs of industrial/commercial forestry only at the cost of ecological security. Industrial forestry should not be ignored on emotional considerations. Realism demands that there be a crash programme on industrial forestry in order to save our forest wealth.

Suggestions regarding the import of timber, firewood, pulpwood, etc., can only help to avert the most critical immediate situation but do not offer a permanent solution, for more reasons than one. Firstly, they only help to shift forest degradation to other countries (most probably developing ones) which is not ethical. Secondly, the kind of money required for import may not always be available. Thirdly, wood can become a political weapon like food and oil, and its prices will keep soaring. The best strategy would be to give very high priority to industrial forestry and take steps to extend all help by suitable modification of land laws, etc.

Environmental /Revegetation Forestry

The objective here is to green derelict and wastelands in order to ameliorate, and finally, restore them. The process can be started by creating natural wilderness areas by using the principles of plant colonization. Owing to litter fall, a decomposer chain will start, followed by soil conservation and increased water retention. This would go a long way in improving the quality of these lands. Starting with plantations of tolerant species which would lead to some improvement of soil, there is a distinct possibility of growing less tolerant species, resulting in further improvement in soil characteristics. In the succeeding cycles, it would be possible to grow increasingly less tolerant species.

The four major uses of forestry outlined above are neither *mutually exclusive*, not is one at the expense of the other. *They are mutually supportive*. Furthermore, it may be pointed out that wasteland development, though laudable, cannot be expected to be the panacea for all our food, fodder, timber and fuelwood problems. Wastelands are essentially derelict lands, and for several years to come, these will be less productive. Unfortunately, forestry is expected to perform miracles on wastelands, but the prime agricultural land continues to be used for non-food purposes such as humans settlements, industries, road and rail systems, airports, etc. The land laws are either too weak or non –existent, as a result of which such ventures are permitted on prime agricultural land.

In the entire Himalayan belt high level of human and livestock population in relation to arable land (Khoshoo, 1986) and general mismanagement of land resources are among the improvement causes which have led to deforestation with serious environment social, economic and biological consequences. Immediate attention needs to be paid to population stabilization and proper management of land and livestock (like stall feeding with hand cut fodder and better quality livestock). This coupled with a programme of fast growing trees and shrubs for fuelwood, timber and fodder can lead to revolution in forestry. Such a change is not easy and must be accompanied by crash educational programme. This alone would ensure conservation of natural forests. Furthermore, sustainable production will itself become a conservation strategy for natural forests.

Much of the biodiversity is in the forested areas, hence for our long-range ecological security, the health of Himalaya is most critical. These mountains must remain clothed with vegetation.

Endemism

Broadly, endemics are of two types: those that are relict as last remnant of old taxa whose distribution has shrunk, and those that are of recent origin which did not have time to extent their range. It appears in Himalaya, the endemics of the second categories are found. Endemism in Himalayan biota is related to a number of physical and biological factors. There is considerable diversity in geology, geography, soil and climate giving rise to many macro and microhabitats. The diversity in flora is particularly apparent in the vegetational types. Three sets of factors underlay diversity. These are:

- Transition from cold desertic conditions in western sector in Ladakh, to cool and moist conditions prevailing in Arunachal Pradesh in the eastern sector.
- Transition from near tropical/ subtropical conditions in south side of Himalaya adjoining Indus-Gangetic Plains, to the cold dry Tibetan plateau in the north; and
- Transition along the vertical gradient from tropical/subtropical conditions at the lower altitudes, to alpine vegetation to arctic conditions at the high altitudes.

Thus, there are three major factors operating simultaneously. These are longitude (west to east), latitude (south and north) and altitude (lower to higher). There is a parallelism in vegetational types on account of latitude and altitude. What grows at higher altitudes at lower latitudes, often grows at lower altitudes at higher latitudes. This brings in a degree of complexity in distibutional pattern due to latitude, longitude and altitude of a particular place in the Himalaya, and creates many microclimatic situations.

There is a considerable gap in our knowledge about not only biotic wealth *per se* but also its distribution and composition of communities and ecosystems. In general bioproductivity per unit area per unit of time is lower in Himalaya (except in the eastern sector). Individual species occupy wide ranges, and population gets broken into smaller isolated units. It is for this reason that there is a higher rate of endemism.

Another dimension is that Himalayan biota is under five different biogeographic influences. These are Palaeoarctic, Mediterranean, Sino-Japanese, Indo- Malayan and Peninsular Indian (Fig. 4). Even so, there is considerable endemicity.

As discussed above, there is parallelism between altitudinal and latitudinal distribution of taxa. Looking at Himalaya from this point of view (i.e. distributional pattern, from West to East, and South to North), there are four situations (see also MacKinnon and MacKinnon, 1986):

- **North-West Himalaya:** These are located primarily in Kashmir, Himachal Pradesh and parts of Western Uttar Pradesh. Here East European and Mediterranean influence is discernible in conifers, several herbaceous elements and animals like Ibex. Palaeoarctic influence is seen in Hippophae and Tibetan Ass.

Fig. 4- Influence of adjoining Biogeographic Realms on biodiversity in India: Mackinnon and Mackinnon 1986.

- **Western Himalaya:** These range from Sutlej Valley to Gandak in Nepal. There is a mixture of western and eastern elements like deodar, rhododendron, red panda, blood pheasant, etc.
- **Central Himalaya:** These occupy entire Nepal, Sikkim into hills of Western Bengal to Bhutan. This is relatively moist area and there are some Rhododendrons and tahr and brown bear indicating Indo-Chinese influence.

- **Eastern Himalaya:** These range from Central Bhutan and whole of Arunachal Pradesh. Here, warm-moist conditions prevail. The tree-line is high. There is considerable diversity in rhododendrons and there is Chinese influence like takin, Temmink's tragopan.

According to the studies of the Botanical Survey, India has about 17,000 flowering plants. Out of which nearly 8,000 species grow in the Himalaya and 5000 species in North eastern India, (Sharma B.D. 1992.personal communication). Several species may be common to these and other parts particularly the Gangetic Plains. The number of species growing exclusively in the Himalaya has yet to be determined.

Chatterjee (1939) made detailed studies on the endemism in the Indian flora. He observed that Indian flora has been influenced by adjoining countries/regions like Myanmar, Malaysia, Indonesia and even Philippines;Eastern Mediterranean; Africa, Madagascar and Sri Lanka. Even so, according to him the number of endemics in the Himalaya are 3165 out of a total of 6850 endemics in India. In other words, Himalaya has a very high percentage of endemics (about 50%). Among the largest genera in India are *Impatients* and *Primula*. The former has 189 species, about 112 of which grow in the Himalayan belt while 77 in Western Ghats. Hardly one species is common to the two disjunct regions. Similarly, *Primula* has 162 species out of which 148 are endemics (Chatterjee, 1939). Special mention may be made of some botanical rarities of Western Himalaya: there are *Blanophora involucrata* (a saprophyte) and *Cyperipedium cordigerum*.

Eastern Himalaya

From the point of biodiversity, North-Eastern region is very rich and harbours the largest number of endemics and Schedule1 species than any where in the country (MacKinnon and Mac Kinnon, 1986). For instance, one of the unique botanical rarity of the Eastern Himalaya is *Sapria himalayana*. It is a parasitic species which has been sighted only twice since 1836. The flowers are 35cm across and buds are about the size of a grape fruit. Sahni (1982) has enumerated several of such vanishing taxa. Unfortunately, protective measures are not commensurate with the biological holdings of this region. This region is a meeting ground of Indo- Malayan and Indo-Chinese biogeographical realms as well as Himalayan and Peninsular Indian elements. In fact, as stated earlier that it is here that the peninsular plate struck against Asain landmass, after it broke off from Gondwanaland. Therefore, it is not surprising to find some of the primitive angiosperm families in this and contiguous areas. These are: *Magnoliaceae, Digeneriaceae, Himantandraceae, Eupormatiacea, Winteraceae, Trochodendracea, Tetracentraceae and Lardizalbaleaceae*. Specific primitive genera are: *Alnus, Aspidocarya, Betula, Decaisnea, Euptelea, Exbucklandia, Haematocarpus, Holboellia, Houttuynia, Magnolia, Magelietia, Pycnarrhena and Tetracentron*. (Malhotra and Hajra, 1977).

Takthajan (1969) was led to believe that this region alongwith contiguous regions is the cradle of flowering plants. The occurrence of Nepanthese khasiana, commonly known as the pitcher plant, is endimic to Khasi Hills. The genus Nepanthes has 67 species out of which one species each is 64 species are found in South east Asia, Malaysia, North Queensland and New Calendonia. The foregoing examples are pointers to the Gondwanaland influence.

The Brahmaputra valley contains extensive areas with natural vegetation- swamps and grassland- with large herbivours fauna typical of alluvial grasslands. Examples are rhinoceros, buffalo, swamp deer, hog deer, pygmy hog and hespid hare (Rodgers and Panwar, 1988). Being tropical/subtropical evergreen forest there is high degree of species richness and high degree evolutionary activity resulting in pockets of high degree of endemism. Added to it is the fact that with the rise of Himalaya, there were many micro-climates due to altitudinal and latitudinal factors leading to large number of small, rather isolated, pockets. Such a situation not only isolated geographically many widespread species but also presented newer sites for colonization.

That this has been and still is a region of high evolutionary activity is clear from the cytogeographic studies on genera like *Rhododendron, Camelia, Magnolia, Buddleia* etc. of Janaki Ammal (1950, 1952 a-b, 1953, 1954, Janaki Ammal and Saunders 1952). The north Eastern Himalaya and North Eastern States together with South Eastern Provinces of China (like Yunnan and Szechwan) are very active centres. There are ecologically and phytogeographically highly diversified and floristically among the richest in the world. Here diploids (2x) geographic ranges of tetraploids (4x), hexaploids, (6x) octoploids, (8x) and do-decaploids (12x). Thus the higher the level of ploidy, narrower is the geograpic range. The higher ploids are essentially endemics confined to narrow region. These are some very meaningful data from chromosome geography. During colonization of the new habitats new polypoid races and species of the foregoing genera were produced which seem to have had a high survival value (Fig. 5 and 6). The highest level of polyploidy in these genera is seen in the species growing in this region.

Fig. 5- Distribution of polyploides of Rhododenderons in North Eastern India Source: Janaki Ammal 1954

Fig. 6- Distribution of polyploids of Buddleia in North Eastern India Source: Janaki Ammal 1954.

There are few temperate species of the Assam Himalaya found in the Nilgiris, which is another floristrically rich area. The species are: Ternstroemia japonica, Rhododedron arboreum, Hypericum hookerianum, Thalictrum javantium, Cotoneaster buxifolia, Parnassia wightiana, Lonicera ligustrina, Gaultheria fragrantissima, Symplocos laurinana etc. (Nayar, 1977). Some botanists believe that the presence of such floristic element in Nilgiris is an indication of their being Pleistocene relicts. According to this view, during Pleistocene glaciation, temperate flora and fauna moved south. On retreat of the glaciation, temperate relicts were left at higher altitudes of southern mountains, and continuous distribution between

North-East and South-West areas was lost after the Pleistocene glaciation. According to Hora (1944, 1948, 1949, 1950), there is also resemblance in fish fauna of these two disjunct areas. He advanced Satpura Hypothesis which envisaged movement of Assam fauna through Satpura System to Western Ghats. Botanists supported this as well. However, the other school of thought believes that resemblance in flora and fauna in the two disjunct areas is the result of convergent evolution. Whatever be the explanation, the fact remains that the NE and SE floras and faunas have some resemblance. Several species of mammals and birds endemic to Himalaya have been listed by MacKinnon and MacKinnon (1986).

11

Centres of Diversity

All crop plants and domesticated animals can be traced to their wild ancestors and other relatives. Former have arisen as a result of both inadvertent and deliberate selection by humanbeing. In fact, the greater the transformation of there taxa to suite the needs of humanbeing, the greater is their degree of dependence on humanbeing. The crop plant genetic resources of the world can be more or less assigned to specific centres of diversity identified by Vavilov (1951) on the basis of varietal diversity, homologous variation, endemism, dominanat allele frequencies and disease resistance (see also Khoshoo, 1991).

The centres are located in different continents and India is one of the important centres of diversity having contributed 167 species of plants whose origin and diversity is in this country (Khoshoo 1991). Within India there are eight subscentres namely Western Himalaya, Eastern Himalaya, North Eastern Region, Gangetic Plains, Indus Plains, Western Ghats, Eastern Ghats and Andaman and Nicobar (Arora and Nayar,1984). The first three of these falls in the Himalayan belt and are shown in Fig.7. The Western Himalaya has contributed species of the genera of *Pyrus, Prunus, Sorbus, Rubus, Ribes , Hordeum, Elymus, Eremopyrum, Avena, Aegilops, Allium Lepidium, Carcum, Linum, Cicer and Cucumis*.

Fig. 7 Three subcentres of plant diversity in the Himalaya source: Arora & Nayar, 1984.

The Eastern Himalaya have been the source of species of genera *Pyrus, Prunus, Sorbus, Rubus, Ribes, Hordeum*.

The NorthEastern Region has contributed species of genera like: *Citrus, Musa, Magnifera, Docynia, Elafocarpus, Myrica, Morus, Vitis. Coix, Digitaria , Oryza, Vigna, Canavalia, Cucumis, Solanum, brassicae, Corchorus, Piper, Amomum, Alpinia, Curcuma, Zingiber, Saccharum and Oryza*.

From the foregoing account, it is clear that Himalayan region has been the source of several species of cereals, pulses, fruits, oil yielding plants, spices, and tuberous vegetables and sugar yielding plants and their wild relatives (Appendix I).

Added to it is a whole range of medicinal and aromatic plants some of which have gone into commerce and have their centre of origin in the Himalaya. Among the important ones are *Asparagus racemosus, Atropa acuminata, Aconitum heterophyllum Berberis spp. Bunium persicum, Carum sp., Colchium luteum, Coptis teeta, Cymbopogaon spp., Cucuma zedoaria, Digitalis purpurea, Dioscorea deltoidea, Ephedra gerardinana, Gentiana kurroa, Heracleum spp., Hyocyamus niger, Inula spp., jurinea macrocephala, Mentha arvensis, Nardostachys jatamansi, Orchis latifolia, Papaver somniferum, Physochlaina praealta, Podophyllum hexandrum, Picrrohiza kurroa, Rheum emodi, Sausurea lappa, Swertia spp. Valeriata wallichii, Viola odorata,* etc. Most of the medicinal plants used in indigenous system are at present extracted from nature.

In addition, wild progenitors of a number of ornamentals are found in the Himalaya. Special mention must be made of species of *Primula*, Rhododendron and whole range of orchids. Bamboo wealth of Himalaya particulary eastern region is consderable. Many species of bamboos extend uupto Western Himalaya, except Kashmir Valley.

The Himalayan region harbours many wild and domesticated animal species whose abode falls on this region.

12

Conservation of Biota

Faculty policies on land, agriculture, foresty, grazing, animal husbandry, fishing, wildlife and tourism have resulted in habitat loss leading in turn to loss of biodiversty. Equally important has been the lack of trained manpower, public awareness and lack of financial support. Furthermore, conservation particulary *in situ* is no in the mainstream of biosciences. Thus conservation of biodiversity has lagged behind as far as its scientific and technological content is concerned (Khoshoo 1991).

Biodiversity is the sum total of species richness (i.e. number of species of plants, animals and micro-organisms) living in a community or an ecosystem. The tropical regions are vastly richer in biodiversity than the Polar Regions. Genetic diversity is part of biodiversity and pertains to the heritable diversity at the species level. It is the basic building block for organic evolution, hence it also affects the evolution and success of a community or an ecosystem. Genetic diversity is also a critical input to agriculture, horticulture, forestry, animal husbandry, fisheries and bio-industry, Biodiversity in general, genetic diversity in particular is today highly politicized issue, much to the disappointment of the scientist who care for the underlying science and service to the society. Politicalization has been the result of the interest taken by multinational corporations, businessmen, diplomats, bureaucrats, politicians and the press (Khoshoo 1987).

Fig. 8: Interactive components of biosphere. Source: Khoshoo, 1997

In nature biodiversity is supported by two major factors; the ecological process, and organic evolution (Fig. 8). There are reciprocal effects between the three. For ensuring that biodiversity is in good health, the processes supporting it need to be strengthened. If these are threatened, biodiversity is *ipso facto* threatened. This aspect already has been discussed by the author in detail (Khoshoo, 1991).

Conservation of biota involves essentially long-range management. It is indeed a holistic concept and encompasses whole spectrum of activities from *in situ* conservation dealing with population, communities and ecosystems on the one hand, an don the other it deals with ex situ involving botanical gardens, arborea, zoos and zoological gardens, and biological banks for storing pollen, seed, sperm, egg, embryo, tissue, organ and genes. Fig. 9 summarizes different options available for conservation.
Fig. 9: Options for conservation of biodiversity source: Khoshoo, 1992.

A distinction has to be made between *in situ* and *ex situ* conservation. In situ conservation is indeed long-term management and with it is implicit that both ecological processes and organic evolution go on unhindered. Under ex situ conservation such processes are cut short. Obviously, ex situ does not have the benefit of continued organic evolution.

A situation intermediate between in situ and ex situ occurs in wild lands in man made wilderness areas, or when such lands are converted for purposes of preserving/conserving biodiversity or genetic diversity. It is clear that right from acclimatization, biota in such habitats would face natural and / or human selection. This is not identical to what exists in their original habitats.

***In Situ* Conservation**

As indicated earlier, *in situ* conservation aims at conserving biota in their natural habitats on a holistic basis more as a system than as separate individuals. The aim is to conserve an integrated system (ecosystem) of plants, animals and microorganisms with its particular atmosphere, hydrosphere and lithosphere. Under such conditions, there are opportunities for mutualism, co-adaptation and co-evolution together with processes like mutation, recombination and natural selection, which work unfettered leading to the survival of the fittest (fig. 8). Ideally, the interacting system, called the ecosystem, has to be auto-sustainable and self-regenerating. There has to be no human-made perturbations unless warranted on scientific and technological grounds.

Conservation of Watersheds: The first and the foremost under in situ category are the watersheds. These are not only rich in biodiversity but with these are intertwined with our long-range ecological security, and perpetuity of our glaciers and river systems. Thus first and foremost, all the watersheds of not only the main river systems Indus, Ganges and Brahmaputra, but all their tributaries together with their glaciers have to be conserved.

Protected Area Network: Already there are a number of recognized protected areas –biosphere reserves, national parks, wildlife sanctuaries. Some are already in existence, other are proposed. Their management has to be on scientific and technological lines so as to ensure in perpetuity the conservation of the biotic wealth found in these areas. Rodgers and Panwar (1988) have given a detailed account of such areas, their data, summarized in Table 3, deal with Trans-Himalayan Ladakh, North-West Himalaya, West Himalaya, Central Himalaya, Eastern Himalaya, Upper Gangetic Plains, Brahmaputra Valley and Assam Hills. This area is 63,318sq. Km which includes both existing (E) and proposed (P) conservation areas. Thus about 8.5% of Himalaya is under conservation (Table 3).

Three Himalayan States are among the best covered states of India as far as protected areas are concerned. These are Sikkim (965 sq. km.=13.2%), Himachal Pradesh (3918 sq. km.=7.0%) and Arunachal Pradesh (14895 sq. km.=4.%). The three states with no protected areas are Mizoram, Nagaland and Tripura. .pa

Table 3: Existing and proposed areas under conservation in Himalaya

Biome	Total Area Sq. Km.	Existing (E) and Proposed (P) Area under conservation (Sq.Km.)		Per cent
Ladakh	1,86,200	E	800	
		P	12,010	
North-West Himalaya	69,000	E	4,025	4.5
		P	4,849	5.4
West Himalaya	72,000	E	3,885	5.3
		P	5,105	7.1
Central Himalaya	12,300	E	1,234	10.0
		P	2,338	19.0
East Himalaya	83,000	E	3,764	4.5
		P	11,187	13.5
Upper Gangtic Plains Plains	2,06,400	E	3,348	1.6
		P	4,512	2.2
Bhahmaputra Valley	65,200	E	1,280	2.0
		P	4,030	6.2
Assam Hills	1,06,200	E	602	0.5
		P	5,351	5.0
Total	800,300		68,318	8.5

Source: Rodgers and Panwar, 1988

Out of the 14 biosphere reserves proposed, six falls in the Himalayan belt. These are: Nada Devi (2600sq. km.), Uttarakhand (also known as Valley of Flowers 3941 sq. km.), Manas (2837 sq. km.), Namdapha (7000sq. km.), Nokrek (60sq. km.) and Kaziranga (37823 sq. km.). Over the years fairly detailed documents have been prepared by the Ministry of Environment giving details of the location; area of core, buffer and command zones;physiography and climate ; and details of flora and fauna, agriculture and forestry, and people living in and near these reserves etc. Only Nanda Devi , Manas and Nokrek have been actually declared as biosphere reserves.

However, land, water and forests are under the state jurisdiction and no worthwhile action has so far been initiated. In each case a management plan needs to be prepared backed by adequate finances. In fact, there is needed a special legislation on the subject including on tenurial security. In short, nothing worthwhile has happened on the ground.

Himalayan plants entered in Schedule I (i.e. endangered and /or those species that are not allowed to be exported) and needing conservation under Indian Wildlife (Protection) Act 1991 are; *Aconitum deinorrhizum, A. heterophyllum, Angiopteris spp., Aristolochia spp., Atropa acuminata, Arundinari jaunsaresis, Balanophora spp. Berberis aristat, Colchicum luteum, Coptis teeta, Cyathea gigantea, Gycas beddomei, Dioscorea deltoidea, D.prazeri, Drosera burmani, D.indica, Gentiana kurroo, Gloriosa superba, Gnetum spp., Iphigenia indica, Meconopsis betonicifolia, Nardostachys jatamans, Nepenthes khasiana, Osmuda claytoniana, O.regalis, Physochlaina praealta, Podophyllum hexandrum, Ruvolfia serpentina, Rheum emodi, Rhododendron spp., Saussura lappa* and all wild orchids and cultivated orchids other than species of *Aerides, Anoectochilus, Ascocentrum, Bulbophyllum, Calanthe, Coelogyne, Cymbidium Byprepedium, Dendrobium, Eria, Phaius, Phalaenopsis, Pleione, Rhynhostylis*,

Furthermore, Nepenthes (Pitcher plat, Assam –Khasi Hills), Hangul (Kashmir), Sangai Deer (Mizoram, Assam and Manipur), Urial (Hemis, Siachen-Shyok), Tivetan Ass (Ladakh) and Rinoceros (Khaziranga) are solely dependent on protection in a single National Park. Essentially all these are based on one natural population and steps need to be taken to introduce these in isoclimatic areas.

The report of Rodgers and Panwar (1988) is indeed a laudable exercise but is based on the traditional view of wildlife. However, today wildlife is a part of overall biodiversity so as to make the former more holistic. It must, therefore, encompass the whole gamut of plants, animals and microorganisms. This change is necessary, because the traditional concepts of wildlife is restricted mainly to large mammals. Therefore, the exercise done by Rodgers and Panwar (1988) may be regarded as a base paper and must be refined further. It also needs to take into account plants including wild relatives/ ancestors of crops, non-crops (medicinals, gum, yielding plants, tannin, fibre, etc.) forest trees, wild relatives of livestock, fish, microorganisms, endangered biota (plants and animals) etc.

Before adoption by the State and Central Governments, Rodgers and Panwar's report needs to be widely discussed not only with the foresters and wildlifers, but also with botanists, zoologists, agricultural scientists (crop, non-crop, animal husbandry, fishery, grassland, arid zone experts), soil scientist, plant and animal geographers, ecologists, geneticists and breeders; biotechnologists, resource economists etc. this exercise is most urgently called for because biodiversity is now a major international enterprise.

The basic aim of protected areas network, including watersheds, is in situ conservation through ecosystems. This approach involves conservation of plants (including forest trees) animals and microorganisms in one attempt as an interacting system. Unless there are major natural cataclysmic events, this approach takes care of the biota ensuring all ecological processes and organic evolution. Thus it is holistic and may turn out to be inexpensive in the long range. Furthermore, there are other benefits that accrue from ecosystem conservation, manly long –range ecological security. Such an approach would be particularly useful in situations where in a unit area there are a large number of species, and where individual species may be in low densities, or there is high degree of endemism. Furthermore, under ecosystem conservation, not only forest trees, but also crop and non-crop plants, and wild and semi- domesticated animals together with their ancestors are conserved. The obvious advantages of ecosystem conservation are:

- Natural Selection, co-evolution (with plant disease and insect pests) and evolution of new taxa would continue unabated.
- The process would be continuing, dynamic and holistic.
- Cost wise, it would be far less expensive than *ex situ*.
- People's participation and their stake would be ensured

The only major problem is tenurial security and continuity, on account of socio-economic compulsions for competing landuses. If the respective government can guarantee this, and there areas are accorded a permanent legal status, it would be the most ideal form of conservation (see Khoshoo, 1991).

Implicit in ecosystem conservation is that their selection has to be done with utmost thought and care. Unfortunately so far, selection has been on the basis of the faunal (wildlife) element only. No doubt, some of the animals in the ecosystems may represent the top of the food chain, but this should not be the sole criterion. Judging from the availability of biomass in an ecosystem, plants constitute upto 90% of biota followed by fungi, bacteria, earthworm, arthropods, algae, protozoa, livestock, humankind, wild mammals and birds. The last two constitute only about 0.008% (Khoshoo, 1988, 1991). While large animals trample and render soil compact, it is the earthworm which enrich and increase its percolation two to four times, but far more importance has been given only to large animals.

Therefore, a detailed survey should be made of the ecosystems in the Himalaya. There is also need for a complete inventory of the crop and non-crop plants, forest tree populations, wild animals, fish etc. Some of these may fall within the centres of diversity of cultivated/domesticated plant and animals. Furthermore, equally important are endangered / vulnerable biota, weather due to over-harvesting of biotypic decline or habitat degradation.

People's participation can be ensured by meeting their needs for which they depend on a particular ecosystems. Such biota could be grown in the buffer zone in this way, it would be possible to integrate rural development and ecosystems conservation.

As indicated earlier, ecosystems have to be selected by design and not on an *ad hoc* basis. The minimum area of the ecosystems will have to be related to the population size of the major species of forest trees and other plants and animals, it may be necessary to consider a minimum number of individuals in a genepool and in some cases, a number of small separate reserves may need to be conserved, taking into account the variation in population in relation to habitats, as well as their breeding system. There could be other location-specific considerations. Inherent complexity and successional status of an ecosystem as also the breeding system of the species have to be taken into account before chalking out a strategy for conservation. For instance, total protection should be given to full climax forests. Many of these considerations have been kept in mind while biosphere reserves were identified (Khoshoo, 1986, 1991). Detailed documents have been prepared which give an idea of their biological holdings.

Judged against the foregoing considerations, there is an urgent need to review the present day protected areas network no only in the Himalayan belt but throughout the country with regard to the particular ecosystems and the biota to be conserved and plans to be adopted. Once such a review is complete, full tenurial and financial security should be granted to these areas.

Management of selected ecosystems will become a major national and international enterprise in the coming decades. Inputs needed are ecological, social economic and scientific in character. Regional planning consideration have also to be built in.

Genetic or Special Reserves: if the present day protected area network does not include habitats of some of the important plant and animal taxa, then a set of genetic or special reserves need to be established. Some of the obvious choices for genetic and special reserves are: rhododendrons, orchids, citrus, mango, banana, nepanthes, muskdeer, markhor, snow-leopard, species of pheasants, important medicinal plants, ancestors and / or wild relatives of crop plants and livestocks.

Forest Tree Genetic Reserves: No worthwhile attention has been paid to forest trees both for in situ and ex situ conservation. In view of the growing importance of forests and forestry, particularly industrial forestry, it is of utmost importance to take up this work on a priority basis. The nearest India has moved towards this, is to identify 188 preservation plots (163 in natural forestland 25 in plantation) covering an area of 8422.35 ha (8395.18ha. in natural forests and 27.17 ha in plantations)(Anonymous 1975). The plot size varies from a minimum of 0.01 ha in Himachal Pradesh to about 4000 ha in Assam. Table 4 gives an account of the preservation plots in the Himalayan States. In all, there are 79 preservation plots, 71 in natural forest and 8 in plantations. These cover an area of 4647 ha out of a total of 8422.35 ha.

Species wise conifers like *Abies pindrow, A. spectabilis, Cedrus deodara, Picea smithiana, Pinus roxburhii* and *P. wallichiana* are well represented.

It may, however, be pointed out that many important forest types are either not represented or the same are inadequately represented. Some of Himalayan states like Jammu and Kashmir, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Tripura and Mizoram do not have any preservation plots. Furthermore, the data presented here are as old as 1975, thereafter there has not been any effort even ascertain if these plots still exist on the ground. Therefore, there is an urgent need to undertake a systematic study to identify forest areas of adequate size in each forest type not covered under the present day protected areas network.

Equally important is to have arboreta and species-wise plantations and seed orchards throughout India including the Himalayan belt. This has to be taken up on a priority basis. Attempts have also to be made to organize seed banks of important forestry species and their provenances. Nowadays, there is tremendous interest in forest tree genetic resources (NRC, 1991) for obvious reasons.

Table 4: Preservation Plots in the Himalayan Belt.

Forest type	State/Union Territory	No. of Preservation plots	Area (ha)
(A) NATURAL FORESTS			
1. Moist Tropical Forests			
1.1 Tropical wet evergreen forest			
1.1.1 Northern tropical wet evergreen forest			
1.1.1.1 Assam Valley tropical wet evergreen forest	Assam	1	4.20
	Arunachal Pradesh	1	9.30
1.1.1.2 Upper Assam Valley tropical evergreen forest	Assam	1	4.00
1.2 Tropical semi-evergreen forest			
1.2.1 Northern tropical semi-evergreen forest			
1.2.1.1 Assam valle semi-evergreenforest	Assam	3	4010.00
	West Bengal	6	76.60
1.3 Tropical moist deciduous forest			
1.3.1 North Indian moist deciduous forest			
1.3.1.1 Very moist sal bearing forest	Assam	1	6.00
	Meghalaya	2	4.00
	West Bengal	4	32.80
1.3.1.2. Moist bearing forest	Assam	1	0.80
	Uttar Pradesh	10	99.06
1.3.1.3. Moist mixed deciduous forest (without sal)	Uttar Pradesh	1	8.00
	West Bengal	2	15.60
1.4 Littoral and wamp forest			
1.4.1 Tropical seasonal swamp forest	Uttar Pradesh	5	67.37

2. Dry Tropical Forests				
2.1 Tropical dry deciduous forest				
2.1.1 Nothern tropical dry deciduous forest				
2.1.1.1 Dry Sal bearing forest	Uttar Pradesh	2		19.83
	West Bengal	2		6.07
2.1.1.2 Northern dry mixed deciduous forest	Himachal Pradesh	1		7.80
	Uttar Pradesh	1		9.91
3. Montane Subtropical Forests				
3.1 Subtropical broadieaved hill forest				
3.1.1 Northern Subtropical broadleaved wet hill forest				
3.1.1.1 East Himalayan subtropical wet hill forest	West Bengal	5		
45.35				
3.1.1.2 Khasi subtropical wet hill forest	_	_		
3.2 Subtropical pine forest				
3.2.1 Himalayan Subtropical pine forest	Uttar Pradesh	2		9.51
3.2.2 Assam subtropical pine forest	_		_	
4. Montane Temperate Forests				
4.1 Mountain wet temperate forest				
4.1.1 Northern montane wet temperate forest	_		_	
4.1.1.1 East Himalayan wet temperate forest	West Bengal		4	71.60
4.1.1.2 Naga hills wet temperate forest	_			
4.2 Himalayan Wet Temperate forest				
4.2.1. Lower west Himalayan temperate	Himachal Pradesh		5	19.90
	Uttar Pradesh		6	64.78
4.2.2. Upper west Himalayan Temperate zone	Uttar Pradesh		2	5.66
4.2.3. East Himalayan moist temperate forest	West Bengal		4	42.40
4.3 Himalayan dry temperate forest				
4.3.1 Dry broadleaved and coniferous forest	_		_	_
4.3.2 Dry temperate coniferous forest	_		_	_
4.3.3 West Himalayan dry temperate deciduous forest	_		_	_
4.3.4 West Himalayan dry blue pine forest	_		_	_
4.3.5 West Himalayan dry juniper forest	_		_	_
4.3.6 East Himalayan dry temperate coniferous forest	_		_	_
4.3.7 East Himalayan juniper/ birch forest	_		_	_
5. Subalpine Forest				
5.1 Subalpine forest				
5.1.1 West Himalayan subalpine birch/fir forest	_		_	_
5.1.2 Rast Himalayan subalpine birch/fir forest	_		_	_
6. Alpine Scrub				
6.1 Moist alpine scrub				
6.1.1 Birch/ Rhododendron	_		_	_
6.1.2 Deciduous alpine scrub	_		_	_

6.1.3 Alpine pasture			
6.2 Dry alpine scrub			
6.2.1 Dry alpine scrub	_	_	_
		71	4636.54

(B) PLANTATION CROP

1. Very moist sal bearing forest	Assam	1	
4.00			
	Tectona grandis		
	West Bengal		
	Shorea robusta	1	4.00
2. Lower western Himalayan temperate forest	Himachal Pradesh		
	Larix decidua	4	0.36
	Castanea sativa	1	1.80
	Fraxinus hookeri	1	0.40
Total		8	10.56
Grand Total		79	4647.01

Source: Anonymous, 1975

Lakes and Wetlands: These systems have not received the attention they deserve, although their overall productivity is reasonably high. Wolstencroft et al (1989) have given some data on only 24 lakes, although entire Himalayan belt abounds with lakes and wetlands. The total area is 7.3 million hectare. The survey is far from complete and does not give full picture of the plant and animals that they harbour. Intensive work is needed.

Ex Situ Conservation

Under this category, commensurate with the biological wealth of the Himalaya there does not exist any worthwhile attempt in *ex situ* conservation. The existing situation is summarized below:

Botanical Garden/ Arboreta: In the historical past in India, there has been a culture of gardens. Even during the British period, there were many Company Gardens (meaning East India Company). However, most of the Institutions new exist only in name and are not being looked after. Today, in the Himalayan belt, there are hardly 11 botanical gardens of some sort (BSI, 1983). In contrast, there are 17 zoos/ zoological parks in the Himalayan belt. Altogether, the botanical gardens in the Himalaya cover about 250ha with no worthwhile plant wealth and hardly any management. These include one orchidarium at Shillong which belongs to the Botanical Survey of India.

In this connection, it may be pointed out that there is an inverse correlation between the number of botanical gardens and arboreta and the richness of flora. Maximum number of botanical gardens exist in Western Europe which, compared to India and the Himalayan belt has very low plant diversity (Khoshoo, 1991)

Compared to the size and climatic and floristic diversity, the present area under the so called botanical gardens is indeed paltry. There is needed a network of botanical gardens and arboreta where important wild germplasm needs to be cultivated and distributed. All the conventional and agricultural universities and institutes need to have botanical/ genetic gardens as a component of their R &D work as also for education of the students and public at large regarding plant diversity. Here, local economic and endangered plants could be grown in small populations not only for conservation but also for purposes of education.

Biobanks: National Bureau of Plant Genetic Resources (NBPGR) under the aegies of Indian Council of Agricultural Research (ICAR), New Delhi has a network of 10 regional stations, base centres, satellite stations, experimental farms and quarantine stations being coordinated by Head Quarter at Delhi. Out of this network, only four stations fall in the Himalayan belt. These are: a base centre at Srinagar (Kashmir) and Regional Stations one each at Shimla (Himachal Pradesh), Bhowali (Uttar Pradesh) and Shillong (Assam). The first three of these represent temperate region, the last falls under humid sub-tropical region. NBPGR has a total of about 1,51,144 samples in the seed repository and about 450 tissue samples in the National Facility for Plant Tissue Culture Repository (NFPTCR). Both repositories deal principally with crops used in agriculture, horticulture and forages for animal husbandry. The accessions in NFPTCR are vegetatively propagated economic species like allium, dioscorea, zingiber, curcuma, musa, citrus etc.

There are no seed, organ, tissue, or gene banks in the Himalaya, although these can be established at minimal cost because of the proximity of glaciers. Appropriate sites, with near perma-frost conditions, need to be identified where materials could be stored almost in perpetuity.

Conservation and Domestication of Wild Economic Plants

The prevailing impression in the country is that about 10% (1500 species) of flowering plants are endangered. However, Botanical Survey of India has listed 625 species in the three Red Data Books (Nayar and Sastry, 1987, 88 and 90). One species, *Hubbardia heptaneuron*, reported from Jog Falls in Karnataka is already extinct. The other species, *Bulbophyllum rothschildianum*, thought to be extinct, has been recently rediscovered (Kumar, 1992). Nearly 214 species of the Himalayan flowering plants are endangered (Appendix II). Attempts to save these must involve both *in situ* and *ex situ* approaches.

While in situ conservation falls within the jurisdiction of Central and State Ministries of Environment and Forests, restocking and domestication of endangered species involve considerable scientific and technical inputs before being translated into action on ground. Besides the crop plants (NCEPC, 1978), there is a large number of wild economic plants such as herbal drugs, underutilized food, fruit, fiber, fuel, gum and tannin yielding plants, which are at present collected from nature Such plants offer age-old vocation and a source of income to the local people. In view of the high demand, during the past few decades, their extraction is far more than their regenerability in nature. Often, a scorched earth policy is followed and very little is left in the natural habitats for regeneration of their populations. Such plants are now under threat on account of over-extraction, and are in urgent need of being rehabilitatd on the one hand, and domesticated to meet the herbal drug and other demands on the other.

Microorganisms which are an important component of any ecosystem have received hardly any attention, particularly their association with the higher plants. While we introduce plants from wild habitats, no attention is paid to the introduction of the associated micro-organisms which constitute an important element in the establishment of the higher plants particularly during domesticated and cultivation. This aspect needs to be looked into, so that plant conservation and domestication becomes as holistic as is possible.

During re-introduction of endangered species in the wild habitats for conservation purposes, and domestication for trade purposes, the genetic composition of the population of the particular species has also be to kept in mind. This would enable basing conservation and domestication on a sound genetic-evolutionary footing. To do this, it would be necessary to make a detailed analysis of genetic system of the concerned species, which would also involve detailed cytogenetic analysis, including at the molecular level.

In order to have an idea about the extent and nature of genetic variability between species/ ecotypes/ and races in natural populations, use has to be made of the standard isozyme analyses. These studies need to be supplemented, in a few cases, with modern tools of genetic fingerprinting. Through this technique, it is possible to study individual identity, family relationship and linkage mapping.

The above data would be useful for simulating, while restocking or reintroducing populations in nature and also during domestication. The underlying idea is to making restocking, reintroduction and domestication as natural as is possible.

Twenty six “hot spots” have been identified in India where there are high rates of deforestation and endemicity which need priority attention (Khoshoo, 1991). One of these is the Himalayan belt as a whole. It constitutes one mega hot-spot; eight areas in the Himalaya are specially critical. These are: Ladakh and Kashmir Himalaya, Kumaon-Garhwal Himalaya, Shiwaliks, Terai, Sikkim Himalaya, Arunachal Pradesh, Lu Shai Hills and Tura Khasi hills. North Eastern Himalaya is also recognized internationally as one of the “hot spots” (Mayers, 1988).

Out of the 214 species listed as endangered in the Himalayan belt (Appendix II), nearly 37 need priority attention. Most of these are in commerce as herbal drugs of repute and one is a botanical curiosity. Their collection offers economic benefits to the residents of Himalaya. These can be multiplied through seed, clonal propagation and tissue culture. These species are listed below:

Aconitum balfourii, A. chasmanthum, A. heterophyllum, A. nepellus, Alpinia galanga, Berberis aistata, B. asiatica, B.lycium, B.vulgaris, Bunium persicum, Cinnamum zeylanicum, Coptis teeta, Cucuma zedoria, Fioscorea deltoidea, Eulophia campestris, Ferula asafoetia, F. jaeschkeana, Gentiana kurroo, Haberaria intermedia, Inula racemosa, Jurinea macrocephala, Macrotomia benthamii, Nardostachys jattamansi, Nepanthes khasiana, Onosma echioides, Orchis latifolia, Panax pseudo-ginsentg. Picrorrhiza kurroa, Podopbyllum hexandrum, Rheum emodi, Saussurea lappa, Swertia chirata, Valeriana wallichii, Vanilla walkeriae, Viola odorata, Violoa serpens.

Furthermore, taxonomical, microbiological, cytogenetical biotechnological and genetic fingerprinting aspects need to be undertaken. This could be a prelude to their restocking or reintroduction in nature and domestication for purposes of meeting their escalating market demand. Thus it is possible to save these high-value wild economic species from extinction. Among other aspects, the work would involve the following elements:

- Prioritize the list of endangered species and exact "hot spot" locations at micro-level.
- Work out in detail the genetic system of the selected species, so as to have a detailed idea about the population biology of the selected species.
- Work out isozyme and RFLP/RAPD patterns to estimate extent and nature of genetic variability within a species in nature.
- Understand the genetic architecture of the natural populations. This is also a prerequisite to organizing any meaningful gene bank where, at present seed samples are collected based only on morphological traits.
- Work out rhizobial and mycorrhizal complex of the selected species for augmenting growth and production in nature and under domestication. Interalia this would involve:

- Selection of efficient isolates of rhizobia and mycorrhizae
- Nitrogen fixation by symbiotic bacteria capable of withstanding environmental stresses.
- Assessment of rhizobial and mycorrhizal isolates for selected species.

- Work out methods for economical but speedy multiplication of species using plant propagules like seed, mist propagated cuttings, and other such conventional methods.
- Use tissue culture methods in such species which otherwise do not respond to the conventional approaches.
- Develop detailed *in vitro* protocols
- Work out package of cultural practices in selected seedlings/plantlets to prospective growers.
- Attempts need to be made at restocking in nature based on the knowledge of the genetic and breeding systems. A proper genetic breeding system. A proper genetic mix of seedlings or plantlets simulating the natural variation should be prepared for purposes of restocking/ reintroduction.

Conservation: The endangered wild economic species would be saved through mass multiplication. The multiplication will be undertaken through techniques appropriate to a species, through seed, clonal propagation, or tissue culture. The plants thus raised would be made available to concerned Departments of Forests, for purposes of restocking in nature and *ex situ* conservation in Botanic Gardens, Arboreta, Botany Departments in Universities, colleges and schools, research institutions etc.

Domestication and Cultivation: A few selected species would be used to take up cultivation to meet the demand of herbal drug trades. In this process, Village Councils (*Panchayats*) would also be involved. The idea is to relieve pressure on the natural populations thus help these species to regenerate under the in situ conditions. At the same time, make cultivation cheaper and easier than collection from nature for trade purposes. The advantages of domestication and cultivation of wild economic plants are given in Table 5. *In short, sustainable production itself would become a conservation strategy.*

Table 5: Advantages of cultivation of wild economic plants.

	Collection from the wild	Cultivation
Botanical identity	Chances of misidentification	Definite
Availability of Material	Questionable-Decrease due to over collection	Definite
Supply	Unpredictable	Definite
Genetic improvement	None	High
Protection from Diseases & pests	Only natural	Can be augmented
Harvesting	Not controlled	Can be very good
Agronomy	None	Possible to increase Yields after standardization
Post harvest Technology	None or poor	Can be very good
Adulteration	High	Rare if ever

Quality control	None, produce is heterogeneous	Large scale multiplication ofelites only
Environmental impact	Decrease of natural Populations due to over-collection.	Conservation status improved. No depletion in nature

Evaluation: The species would be evaluated for tolerance to biotic and abiotic stresses prevalent for tolerance to biotic and abiotic stresses prevalent in their natural habitats. It may also be possible to transfer such genetic traits to other crop species through recombinant DNA technologies.

Awareness, Education and Training: There is an urgent need for creating awareness among the local people about the conservation of biodiversity. This is particularly true in the “hot spot” areas. Attention should be paid to the involvement of school and college students, unemployed youth and other interested in the village community to halt and then reverse dwindling of these genetic resources.

Already some excellent work has been done at the High Altitude Plant Physiology Research Centre of the Hemavati Nandan Bahuguna University (Prof. A. N. Purohit and coworkers), Central Institute of Medicinal and Aromatic Plants Lucknow (Dr. P.S. Ahuja), Regional Research Laboratory, Jammu (Dr. C.K. Atal and coworkers), National Botanical Research Institute, Lucknow , (Dr. H.C. Chaturvedi), Delhi University (Dr. S.S. Bhojwani), Punjab University (Dr. S.P. Vij), and North0Eastern hill University (Prof. P. Tandon). Some of the results emanating from this work using seed biology, clonal propagation and tissue culture have also gone into the field and have also been published (see also Khoshoo, 1988). However, as outlined above, the work needs to be taken up on a holistic basis so that restocking and reintroduction in nature as also domestication for trade purposes is done in tune with nature.

Orchids

The word orchids brings to ones mind some vision of distinctive or incredible form of flower, of colour and beauty, of fragrance, of self-life and what not. Orchids represent the aristocracy and the royalty in floriculture. Today, there is an “Orchid Mania” all over the world. Orchid hunting is a big business and large quantities of wild species are shipped to USA and Western Europe. In India, we have excellent expertise in orchids but orchid trade is till languishing.

Since orchids have a specialized life cycle, we need to stimulate scientific research at the four levels. Firstly, we must understand national and international demand. Secondly, we must work n a priority basis for production of established and well-recognized hybrids already in trade. Thirdly, there is a need to take up multiplication of appropriate indigenous specieswhich may have direct commercial value and/or enrich germplasm. Fourthly, orchids become easily endangered on account of deforestation, habitat –destruction, excessive collection by botanists and over-harvesting by traders. Furthermore, felling a tree in North-Eastern India is not destruction of one tree but also of the whole epiphytic orchid vegetation that is carries on it.

Orchids are a very important commodity of floriculture trade which has just begun to receive attention in India. The country is very rich in orchid flora particularly in the North-east and south-West India, which are the two" hot-spots". Presently, Thailand is the largest exporter of orchids in the world. Sikkim has done creditable well and the names of many Pradhans are associated with orchid trade. Down South, M/s. A.V. Thomas have begun a meaningful programme in Kerala, by involving house wives who can improve their family income. For more than 20,000 housewives, this is an opportunity for self employment. Once the programme is in full swing, it would mean an export earning of at least Rs. 15 to 20 crores for Kerala alone. This venture could also help to increase tourism.

Prof. S. P. Vij (Punjab University), Dr. Foja Singh (IIHR) and Dr. H.C. Chaturvedi (NBRI), have indeed done creditable basis and applied work on orchids, including propagation especially of hybrids and endangered species. In view of excellent orchid wealth in India, it is suggested that an Orchid Research and Development Laboratory be set up somewhere in Eastern Himalaya, proferably in Sikkim.

Bamboo Research and Development Institute

Bamboo differ in their stature and species like *Dendrocalamus giganteus* is about 40m in height, while others are only shrubs. Bamboos grow very rapidly often 1, per day during rainy season.

Bamboos are interwoven with the oriental culture and are put to diverse uses. As a replacement for timber, bamboos are also used for constructional purposes, scaffoldings, ladders, bridges aqueducts, fences, supports, boats, farts, tool handles, cordage, tent poles, brushes, pipes, fans umbrellas, toys, kites, musical istruments, spears, bows arrows, whole range of wicker works, chicks, mats, boxes, walking sticks, funiture, decorative materials and objects of art. For paper pulp, bamboos are very important source and are mixed with other species. Bamboos leaves are a rich fodder. Tenders parts and seeds are also used as human food. On account of its versatility, bamboo has been regarded as "Emperor among grasses"

Bamboo has a major role in our building, paper pulp and cottage industries. However, we depend on natural supplies to meet our needs. A breakthrough in induction of precocious flowering has been achieved at the National Chemical Laboratory, through application of tissue culture technology (Nadgauda, et al 1990). Bamboo has for the first time come within the purview of geneticists. It is now possible to float a major coordinated programme on production, processing and utilization of bamboo biomass for out industries. Bamboo needs to be cultivated on a large scale. Out of the total world harvest of 10 million tonnes, nearly 3.2 million tonnes are harvested in India. These grasses have the potential of becoming one of the mainstays of paper-pulp industry, Obviously, this group of plants is versatile and very useful but has not received the deserved attention, although it is important to the economy, both at the village and national level.

It is high time that an Institute on Bamboo Research and Development be established to give a fillip to this "poor man's plant" by taking advantage of the excellent biotechnological work already done in India. This is all the more necessary, keeping in view the increasing imports of timber and paper pulp.

13

Biodiversity, Bioproductivity and Ecodevelopment

Biodiversity exists at the level of an *individual, population* (interbreeding group of individuals of a species), *community* (population of different species interacting in the same habitat) and *ecosystem* (interacting groups of communities of plants, animals and micro-organisms in a climatic zone). If ecosystems do not face threat of natural cataclysmic changes or of human perturbating, these can be self-perpetuating and auto-sustainable with only one outside input, namely, sunlight.

Biodiversity is the most important element of living systems and the three cardinal processes that lead to and also regulate diversity are mutation, recombination and natural selection (Fig.8). These processes are the basis of both organic evolution and plant and animal breeding. The only difference is that in plant and animal breeding, the selective factor is the human need which makes evolution under such circumstances targeted and purposive, and accordingly, gains high speed. However, in nature selective factors are the whole gamut of climatic and adaphic changes, such as ice age, warm/ drought periods, comet strikes, volcanic eruption dust and black-out of sun, extensive herbivore, disease, etc., singly or in combination. Under natural conditions, evolution is non-purposive and opportunistic. It leads to extinction of those biota that have no selective value in a particular environment, and origin of those with a high selective value to the changed environment, in other words, survival of the fittest.

The second half of twentieth century witnessed the discovery of the structure of DNA by Watson and Crick (1953). DNA soon became the molecular and messenger of life. With this, an era of molecular biology was ushered in, and chemistry of life began to be increasingly understood both at molecular and at cellular levels. There is now an increasing appreciation of the importance of biodiversity at the molecular level. Its importance increases with the possibilities of transfer of genes across the taxonomic and/or phylogenetic barriers. The classical case is the expression in *Escherichia coli* of chemically synthesized gene for human insulin (Goeddel et. al 1979). Soon, bacteria become important as future factories for production of products useful to human being: insulin is an example. Eli Lilly (USA) is now marketing it under the name of Humulin. Similar interphylum transfers have also taken place for pest resistance in crop plants. Thus, there has been progressive widening of germplasm base and the frontiers of molecular biology for the good, benefit and wellbeing of human race.

These discoveries brought out the importance of individual genes on the one hand, and species, populations, communities and ecosystems on the other. On account of this, at the level of populations, communities and particularly ecosystems, genetics and ecology actually coalesce. Thus, there is a continuum form molecular biologists to geneticists, population biologists to community ecologists and finally to ecosystem specialists, all of whom deal with biodiversity at various levels. Underlying the whole series is the increasing complexity.
Fig.10. Increasing biological complexity from individual of ecosystem.

The geneticists have been only concentrating on chromosome dynamics, genetic variation and genes; the population biologists have concentrated on dynamics of populations, community ecologists have primarily concentrated on the role of species in a community, and finally ecosystem specialists have been interested in the species diversity in the ecosystem. The community and ecosystem specialists have totally ignored genetic variation but stressed ecology. On the other hand, those dealing with individuals and populations have in recent years generally ignored ecological aspects but stressed genetics (Fig. 10). However, there have been some notable exceptions. It was the Swedish botanists G. Turesson, who in 1922, suggested the terms genecology and ecotype (the product arising as a result of genotypical response to a particular habitat/ environment). Then followed an era dominated by genecological studies of Clausen Keck & Hiesy (1940, 1945, 1948), and Clausen (1951) (see also Stebbins, 1950; Khoshoo, 1950), who saw this continuum from genes to ecosystems. Today, there has to be revival of such work (Solbrig 1991), then known under a brand name experimental evolution or biosystematics (Khoshoo, 1990). The interaction of morphology, ecology and genetics is depicted in Fig. 11

Systematic, Ecology and Genetics

<table>
<tr><th rowspan="2">Morphology</th><th rowspan="2">Ecology and Area</th><th colspan="4">Genetic Relationship Hybrid</th></tr>
<tr><th>Fertile
F2 vigorous</th><th>Partially sterile F2 week</th><th>Sterile</th><th>None</th></tr>
<tr><td rowspan="2">Distinct</td><td>Distinct</td><td>Distinct
SUBSPECIES</td><td>Distinct
SPECIES
(ecospecies)</td><td rowspan="2">Distinct
SPECIES
COMPLEXES
(ceno-species)</td><td rowspan="2">Distinct
GENERA
(comparia)</td></tr>
<tr><td>The same</td><td>Local variation
BIOTYPE</td><td>Species overlapping in common area</td></tr>
</table>

Similar	Distinct	Distinct ECOTYPE (ecological races)	Genetic species only (Example: autoploidy; certain kinds of chromosomal repattering
	The same	The same entity	

Fig. 11. Relationship between systematics, genetics and ecology

Behind such a common genetic and ecological thread, there are the specific attributes of genetic diversity, life history traits, population dynamics including its genetic architecture which equips a species to interact with other species and environment. Genetic diversity also equips a species at the molecular level to generate new variation through the processes of mutation, recombination and natural selection, leading to elimination of some and selection of others. Thus a phenotype is the result of interaction between genotype and environment. The phenotypic characteristic of an individual are coded into the genes of a taxon which determines whether it is going to be miniscule virus or an amoebae, or a giant like squoia, elephant or a whale. Today's biodiversity is, therefore, the result of mutation, recombination and natural selection having taken place during the last 3 billion years. Life began with a DNA molecule having properties of self-replication, mutation and recombination. Genetic diversity is, therefore a prerequisite for all biological evolution leading to diversity (see also Solbrig, 1991). Biodiversity can be reduced both by habitat destruction leading to failure of populations to recover from mortality caused by habitat disturbances, and also by competitive exclusion thus there is interaction between competitive exclusion and mortality due to habitat disturbance. According to Huston (1991), when these two opposing trends are balanced, there is maximum biodiversity at intermediate disturbance level.

Intraspecific genetic diversity is the fundamental building block of maintaining biodiversity. The natural selection acts on this, and populations are refined to function as interacting units within communities and ecosystems. The genetic consequence of habitat fragmentation leads to restrictions in gene flow and may be, in course time, to genetic differentiation. The particular life form of a species is also the consequence of selection. Thus, there are pine forests in the Himalaya. These are essentially large populations of big individuals with long life and good seed dispersal. Such populations have high productivity and live in low habitat disturbances. Conversely low productivity and high habitat distrubances. Destruction occurs due to abiotic causes (like extreme climatic conditions, fire, floods, etc) or biotic causes; (like parasitism, disease, predation, herbivory etc.). These lead to a competitive advantage for smaller populations, of small individuals with short life cycles. There are many such correlations (Stebbins, 1950;Grant, 1958, Gadgil and Solbrig 1972). The measurement of diversity can be at the allelic level within individuals or species, or at the level of gene pool on a population. This diversity can be studied through RFLP and RAPD. Next follows species richness in a community in particular habitat, finally there is richness of communities in an ecological zone. In any community or ecosystem there are “keystone species” which have direct or indirect effect on the survival of other species in an ecosystem. A simple relationship between habitat destruction and productivity in relation to life form and overall biodiversity is shown in Figure 12. Ecosystem dynamics is still not understood, nor are molecular mechanisms underlying higher categories. There are efforts to bring in molecular aspects in phylogenetic and taxonomic categories like species, genera, families and phyla. Both biosphere and ecosystems are amenable to natural and human induced changes; physical chemical, biological and environment. Ecosystem science is still in infancy. So far, it has been concerned with inventorization of mega-groups of organisms and has overlooked the micro-organisms and marine biota altogether. It has also not paid attention to process underlying ecosystem/ biosphere transformation. A major question remains unanswered: as to what causes extinction of widespread dominance of a species? Are there any physiological, genetic and ecological attributes that lead to extinction or dominance? Systematic investigation on different aspects of this problem need to be taken up.

Some of the usual aspects of study of ecosystems include inventroization and establishment of databases. This would enable to take stock of the present level of knowledge. Generally microorganisms have been left out of consideration in ecosystem studies. But now it must receive special attention. For the collection of raw data, use can be made of parataxonomists, provided however, there is clarity about the sampling techniques. In other words, it should be clear as to what, how and where to sample, so that one is clear about the sites and biotic groups to be maintained. Quality of data is considerable importance for proper monitoring.

Besides enumeration of species their distribution and life forms, at the level of ecosystems, there is need to understand functions that these species perform regarding their capacity for nitrogen fixation, decomposition of organic matter and as saprophytes, pollinators grazers etc; this together with the capability of ecosystems to capture, store and transfer energy, nutrients and water e.g. the whole range of biogeochemical cycles need investigation. Finally, the ecosystem need to be evaluated in terms of the services that these render to humanity: clean air, water, quality of life and above all, resilience to change and capacity for regenerability (Solbrig, 1991). Some of the foregoing aspects are summarized in Fig. 13

- Sustainable service to humanity
- Rselience Regenerability-Degradabiligy
- Extent and nature of Natural/human pertubations
- Energy Transfer
- Ecological processes: Photosynthesis: Water cycle: Soil formation: Biogeochemical cycles
- Organic evolution: Mutation, Recombination and Natural selection
- Life forms: Genetic System: Breeding and Population Biology
- What, where and how to sample
- Database
- Enumeration and Distribution

Fig. 13: Increasing complexity in functions of individual population, community, ecosystem & Bioshpere.

Biodiversity and Bioproductivity

It is well known fact that human beings have lived in hunter-gatherer societies for 99% of the time that have lived on this planet. However, it is during the last 1% of historical time that human beings have lived in agricultural followed by industrial societies. The latter resulted in a total physical and economic transformation of human society with relatively less emphasis on biodiversity. However, during the recent years, which better understanding, conservation of total spectrum of biodiversity (plants, animals and micro-organisms) can no biodiversity. However, during the recent years, with better understanding, conservation of the total spectrum of biodiversity (plants, animals and micro-organisms) can no longer be regarded as an esoteric exercise, but something that affects the totality of environment, on which the very existence of life (including human life) depends. Essentially, it is a question of survival. Furthermore, the prospect of climate change would invoke change in the biotic composition of ecosystems and also their migration. Not knowing the exact nature of genetic changes, there is a most urgent need to conserve as wide a genetic base as possible. As discussed elsewhere (Khoshoo, 1992), biological diversity is the sum total of species richness i.e. number of species of plants, animals and microorganisms living in a community or an ecosystem. Biodiversity is a part of the biosphere supported by biological processes and organic evolution the three elements are inter-dependent (Fig. 8)

Therefore, biodiversity is critical to our survival. More so, of the poorer assetless section of our society whose wellbeing depends on biomass. The basic reason for this is that biodiversity and bioproductivity are inter-dependent (Fig. 14). Hunter-gatherers in harsh ecosystems have low productivity (LP). The pre-green Revolution Agriculture was essentially based on high diversity (HD) and low productivity (LP) and low diversity (LD).

The Green Revolution Agriculture is based on high productivity (HP) and low diversity (LD)

Fig. 14. Interrelationship between bioproductivity & biodiversity: Khoshoo, 1992b.

In the present scheme of things, genetic diversity pertains essentially to domesticated plant and animals and is the result of domestication process of food for feeding escalating the human population. This led to the expansion of agriculture and animal husbandry. In course of time, in actual practice, it means greater dependence on only high-yielding varieties and consequently a shrinkage of genetic base and increased crop vulnerability. However, among other attributes of sustainable agriculture, forestry, animal husbandry and fisheries, are high diversity (HD) and high productivity (HP) (Fig. 14). To achieve this, an innovative biotechnological approach is needed to ensure high agricultural productivity for future.

It is also most imperative to ensure constant supply of genes from such wide storehouses of diversified valuable gene pools existing in the wild species for purposes of insulating agriculture, horticulture, forestry, animal husbandry, pharmaceutical industry (indigenous herbal drugs and allopathy), from future threats of climatic changes and diseases and pests. For maintaining future possibilities of evolution of these important biota, there is need to guarantee their survival under *in situ* conduction for enrichment of food, pharmaceutical and other crops, livestock, forestry and fisheries. Conservation of wild relatives both in natural areas and under cultivation is, therefore, a very important aspect of the overall efforts for conservation of biodiversity.

Changes in the Pattern of Biodiversity

An area of work where ecorestoration can be helpful is reversing the patter of biodiversity that accompanies the process of recession. An example of this is the conversion of Banj (*Quercus incana*) forest into Chirpine (*Pinus roxburghii*) forest. It is not only a change in the dominant tree species but also a change in the entire biotic wealth. At present, a lot of confusion exists in several environmental groups regarding this recession. The underlying fact is that it is the result of biotic influence generated by human being for various reasons (Fig. 15.) Banj is indeed a multiple use species. It is an excellent firewood an charcoal species on account of its excellent wood qualities, but is very slow growing with a rotation of about 150 years. Secondly, it is an excellent fodder on account of its nutritious leaves produced in abundance and it can stands lopping. Thirdly it is an excellent fertilizer, for it produces a thick cushion of leaves which generate a thick humus. On all these counts, there is a considerable demand for banj trees resulting in over-extraction for firewood and charcoal, heavy lopping for fodder and removal of humus from forest floor. Over the years, there follows a chain of events depicted in Fig. 15. The final result is that there follows poor regeneration and ground is laid bare. The forest floor becomes favorable for colonization of chir pine. In course of time, there results a chir pine forest. Such recession from banj to chirpine can be traced to human influence and the associated livestock. These changes take place in historical time.

Fig. 15. Recession of banj forest to chirpine forest

It is not only recession process, but with that comes the wholesale floristic changes in undertrees / shrubs and herbs an the microorganisms and wild animals associated with a particular forest type. Thus, in this case, the whole composition of the forest type changes. Reversing such a recession would need a close study of the problem and working our a definite long term strategy.

Biodiversity and Ecodevelopment

In recent years, ecodevelopment based on principles of restoration ecology has received considerable attention (Khoshoo, 1992 a, see also Wali, 1992). According to Khoshoo based on ecological principles. The ecopart is common to both ecology and economics. In fact, both have the same Latin rot Oikos. An instructive experiment on ecodevelopment lasting over 20 years has been reported by Khoshoo (1987b, 1992a). it involves the use of alkaline land. The major component of this relevant plant and animal diversity was used for creating sustainable biomass production to meet the needs of the local people. Equally important was that due to such amelioration of people. Equally important was that due to such amelioration of people. Equally important was that due to such amelioration of degraded land, even human made wilderness areas were established. Here, a three-story forest of tress, shrubs and herbs was generated. It attracted several species of mammals, birds, reptiles, insects, microorganism and worms, especially of earthworm. These species made it their abode. The presence of earthworms was a definite indication of ecorestoration (Fig. 16)

In the Himalaya, any mention of ecodevelopment (SeeKhoshoo, 1986). Is incomplete without a mention of the exemplary work of the Dasholi Gram Swaraj mandal in the Gharwal Himalayan Region. This movement is being led by the outstanding Gandhian leader, Sri Chandi Prasad Bhatt. There are two major elements involved: raisin of a stone wall around the village complex and stall-feeding of the livestock. The other element is the involvement of local people on a willing basis. The result was miraculous: abundant natural regeneration of trees/ shrubs and grass. This gave green cover and fodder for stall-fed livestock. As the area is expanded, it would also mean recharge of the natural spring.

In essence, it is a movement for restorative ecology and is based on the willing participation of local people to generate sustainable biomass base at the very grassroots. Obviously, it depends on plant and animal diversity of relevance to the local environment and its people.

Fig. 16. Production &Utilization of biodiversity in ecodevelopment of usar land. Source; Khoshoo 1992 a

This movement needs to be monitored by ecologists and economists so as to bring out the principles underlying this biomass based model of development. Such knowledge would be very useful for replication and horizontal spread of this experience in the entire Himalayan belt. In time to come, such a movement will produce miraculous results in short time at little cost to the provincial and the central governments. Together with the Chipko Andolan (Hug-the-Tree Movement), considerable amount of biodiversity has returned. This movement needs to be given a determined fillip. Even biotechnological approaches can be pressed into ecorestoration. By doing so, the lives of poor Himalayan dwellers can be enlivened. At present, they see no hope except to migrate to plains to eke a mere existence and become "ecological refugees" in their own country. More often, these innocent young men and women get involve in menial and even dirty work.

The role of plant genetic resources in the development of hill agriculture is already recognized (Joshi and Rathore, 1986). It needs to be widened to encompass all the relevant biodiversity for diversification and intensification of biomass production. Together with some socio-economic measures, it holds the key to the health and wealth of Himalaya and its people. It is also a critical input to *antodaya* (welfare of the weakest) and *sarvodaya* (welfare to all).

14

The National Biodiversity Conservation Board

How does India plan to take care of its biodiversity? Easiest way is to go on with the business-as-usual approach, i.e. to list and inventorize the species of plants and animals in various habitats without reference to the biogeographic aspects and ecological and genetical characteristics. BSI and ZSI have been doing such work for many years and have developed expertise in this regard. Furthermore, their work is bring done in two components of an integrated whole (biology). Never any attention has been paid to climatic and soil characteristics, microorganisms and association with other species which are all an integral part of biodiversity. Another dimension to biodiversity is the wild life which has maintained its identify as a part of forestry. Wildlife is concerned with macro-animals particularly those with high visibility, the big cats (lion, tiger, leopard), some herbivores (rhino, hangul, musk deer, gaur), birds and reptiles (like crocodile). There has been in –built resistance in the wild life system to new ideas like the biosphere reserves and now also to biodiversity. Most wildlifers are still not convinced about the holistic nature of biosphere reserves in comparison to national parks and wild life sanctuaries, or of biodivesity in preference to wildlife. Such a restricted view of this important biological resource does ignore the dynamic, evolving the holistic nature of biodiversity. Since biodiversity is found mostly in the forest areas, the overriding control and influence of wildlife section of foresters can not be minimized. There will have to be a gradual process of debriefing of this group by briefing of this group by briefing about the holistic dimensions of biodiversity. Biodiversity is also not to be mistaken with forestry. It has taxonomic, physiologic, ecological, genetic, economic, ethical and social dimensions. It is critical to our very survival as it affects climate, soil formation, agriculture, horticulture, animal husbandry, forestry, fisheries, industry based on whole range of biological like microorganisms and medicinal, fiber, and plantation crops. Together, these constitute a sizeable components of our Gross Domestic Product and contribute materially to our Gross National Product.

During the last few years, the subject of conservation of biological diversity has attracted considerable attention at the national and global levels. So far, biological diversity 9the genetic diversity in particular) has been maintained by two groups of caretakers: the subsistence farmers and the individual breeders in universities, government departments and industry. Both kept it alive for different reasons. Furthermore, the saving grace has been that most (about 80 percent) of the germplasm was exchanged around the world (except, notably, the erstwhile USSR and East Germany) not through government channels but from one breeder to another through mail. This formed an informal and totally non-political network of plant breeders who cared more for science and service to the society than for politics. In fact, the Green Revolution in India is the result of such a scientific exchange of the very advanced breeding material of the Mexican dwarf wheat which were subjected to selection under local environmental conditions. Reciprocally, India has contributed to the cantaloupe industry (35,000 acres) in California by powdery mildew resistant genes format he wild melon of India. This has made a significant difference to wherever cataloupe is grown particularly the American cantaloupe industry. Many such instances exist where useful genes came from gene-rich developing countries, but their utilization took place in technology-rich (but gene-poor) industrial countries. (Khoshoo, 1988).

However, eversince germplasm has caught the eye of the Politicians, businessmen (multinationals), diplomats, bureaucrats, economists, lawyers, the press and the public at large, a lot politics ha been injected in biodiversity, on account of wrong and inflated premises. Thus, the subject is becoming increasingly a political issue.

The present descriptive activities of Botanical Survey of India, Zoological Survey of India and Wildlife Institute of India need to be tapared in the next 5 years; these organization need to be reorganized and revamped into one connected whole as biological Resource Survey of India (BRSI). Mere clubbing these together into BRSI will not help, but there has to be a qualitative change in all the three. This can be accomplished in two ways. By screening the present staff and picking up about 40-50 persons (20-35 years) for advanced training in various institutions all over the world. Alternatively, the Ministry of Environment and Forests could organize rigorous training courses by a hand-picked core Indian and a floating foreign faculty. This could be done at the Centre for Ecological Research at the Indian Institute of Sciences (Banglore) and/or at the Centre for Advanced Study, Botany Department Banaras Hindu University. Unless this is done, biodiversity in India will languish and we would lose what we have.

If today, any multinational corporation (MNC) wants to steal any material from India, there is no way it can be prevented. Classical cases of stealing, in historical time, of germplasm out of their native countries are rubber, coffee, cashew, cinchona, etc. Many of the industrial crops are based on introduction of only a few seeds. More often, such stealing took place via the Royal Botanical Garden Kew (England). At present, there is no way we can prove that a particular material has been stolen and used by a MNC. The reason is that biodiversity is still in the descriptive phase in our country. No use has been made of the modern, almost foolproof, techniques which can render identification of a species or a variety or even a strain of a crop easy. The lesson to be learnt is that we must bring in modern science and technology in the area of biodiversity.

National Biodivesity Conservation Board

Simultaneously, the suggestion made during 1988 by the then Task Force on Environment of the Planning Commission that country should have a National Biodiversity Conservation Board (NBCB) rather than Indian Board of Wildlife. Again, mere change in name will not do. There has to be a qualitative change in the Board. The work "wildlife" has outlived its utility. The fountainhead of inspiration of wildlife enthusiasts all over the world has been the World Wildlife Fund. Even this rich and powerful world non-governmental body realized the urgent need for widening its scope and making it holistic. This body has changed its name to World – Wide Fund for Nature.

While theoretically, wildlife means all undomesticated biota (Khoshoo, 1986), in practice, the word wildlife has been restricted to large mammals and big cats in particular, perhaps because of their being at the top of the food chain. The underlying rationale has been that if the big animals are conserved, the ecosystem as a whole would also be conserved. This is a fallacious argument (Khoshoo, 1988, 1991). This is particularly true for India where, parallel to biological diversity, we have a tremendous amount of cultural diversity. The biological and cultural diversities have been mutually supportive. In fact, biological diversity has given rise to cultural divesity. Thus even in every sense cultural diversity is a part of biological diversity. The terms of reference of NBCB need to be drawn and periodically updated to bring in newer concerns. Such a Board, besides over-looking management based on scientific and technological considerations, would also take tangible steps to establish a stake of the people who should be the guardians and protectors of the Protected Areas Network (PAN). As in the case of the sacred groves, it should provide for an ethical and ecological stake of the people. Such stake must be enhanced. So that people become protectors of PAN. In this connection, it may be pointed out that community involvement such national task poses problems, because due to short-sighted policies people are alienated. Even the tribal and rural development and the proposed Panchayati Raj (governance by village council) can be oriented to conservation of biodiverstiy. One way to build the stake of the people is to ensure, on a sustainable basis, the supply of goods on which the people of a particular protected area depend.

NCBC will need to prepare a holistic plan and overseas its implementation. The Board's success will, no doubt, depend on the cooperation it would receive form various agencies.

The time is running out and action on this important aspect needs to be urgently taken. Already, some of the developing countries like Costa Rice, Brazil and Indonesia are well advanced in this area.

Important Action Point

- Declare biological diversity a national resource, its conservation a national goal and its implementation a national priority.

- Constitute an inter-disciplinary National Bio-diversity Conservation Board for conservation, monitoring and overseeing implementation of the work plan, and managing conservation of different biota and the PAN (Protected Area Network).
- Evolve a national policy on conservation of biodiversity and periodically update the same.
- Review the existing PAN, which must include biosphere reserves, national parks, wildlife sanctuaries, sacred groves, fragile and unique ecosystems, game and genetic reserves, etc. with reference to:
  - Bio-geographical aspects involving all habitats from sea to alpine levels, and from moist tropical forests to cold and hot deserts,
  - Biological holdings and area of each protected area in relation to population size of biota to be conserved, forest types, threatened biota, centres of diversity of plants and animals species, and their relatives,
  - Anthropological aspects,
  - National information base on biological wealth, together with its value in economic terms, and
  - Management patterns.
- Review present conservation effort on different biota and prepare special management plan for conservation of marine and freshwater habitats and forest trees and microorganisms
- Draw up a plan to establish a representative PAN by:
  - Excluding those areas that do not satisfy the minimum criteria, and
  - Including new area in order to rectify the deficiencies, such as genetic reserves for rice, sugarcane, mango, forage plants, banana, citrus musk deer, buffalo, pheasants, butterflies, frogs, fish, etc.
- Establish minimal databases for each protected area with regard to:
  - Climate, soil, water, air and other abiotic characteristics,
  - Total biotic wealth with taxonomic identification-wild relatives of domesticated biota
  - Threatened biota and nature of threats, and
  - Linking of such databases to central point
- Draw management plans for PAN by ensuring
  - All-round involvement of people in order to develop a stake of the people in PAN, including the welfare and developmental measures so as to reduce to the minimum their dependence to PAN for goods, and
  - Build up of a cadre of PAN conservators and science and technology professionals fully trained in various aspects of management of these areas and the underlying science and technology including restorative ecology. Since conservation areas are often far away from cities and towns, and the personnel often have to deal with dangerous animals, the rules regarding recruitment, training, salary, promotion and career development need re-examination.
- Examine the tenurial status as well as land and water use patterns. Wherever necessary, take steps to guarantee tenurial status in perpetuity and provide protection against any future disruption in the particular habitat on account of developmental projects. Such a disruption would mar the continuity of the biological process.

- Draw up plans for both ex situ and in situ rehabilitation of the priority threatened/ endangered species and for purposes of restoring and reintroducing the natural populations. In all cases, the basis has to be ecosystem dynamics, population genetics, and conservation biology so as to avoid genetic drift in future.
- Domesticate, where required, those wild biota that have a trade value but are under constant threat, such as butterflies, frogs, turtles, fish, fur animals, herbal drugs, and other economic plants, ornamentals (including orchids), teaching materials, etc. this would reduce pressure on the natural populations and help in their conservation provided breeding methodology is based on evolutionary biology and population genetics.
- Draw up plans for education and awareness about various aspects of PAN for students, lay public, administrators, decision-makers and politicians.
- Support PAN with and effective network of biological (combined botanical and zoological) gardens, arboreta, aquaria and bio-banks concerned chiefly with ex situ conservation.
- Guarantee continued financial support.

15
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APPENDIX-I **17**

Wild Relatives of Economic Plants in the Himalaya

A. NORTH – WEST AND NORTHERN HIMALAYA

Cereals and Millets

- *Aegilops tauschii*
- *Avena barbata*
- *A. fatua var. fatua*
- *A. ludoviciana*
- *Chionachne koenigii*
- *Digitaria sanguinalis*
- *Elymus dahuricus*
- *E. dasystachys*
- *E. nutans*
- *Eremopyrum buonapartis*
- *E. distans*
- *E. orientale*
- *Hordeum aegiceras*
- *H. glaucum*
- *H. leporinum*
- *H. spontaneum*
- *H. turkestanicum*
- *Leersia hackelii*

- *Panicum psilopodium*
- *Setaria viridis*

Legumes

- *Atylosia scarabaeoides*
- *Cicer-microphyllum*
- *Trigonella corniculata*
- *T.emodi*
- *T.polycerata*
- *Vigna radiata var. sublobata*
- *V.trilobata*
- *V. umbellata*

Fruits

- *Citrus aurantifolia*
- *C. aurantium*
- *C. limon*
- *Cordia myxa*
- *Duchesnea indica*
- *Elaeagnus angustifolia*
- *Ficus palmata*
- *Grewia asiatica*
- *Malus baccata*
- *Phoenix sylvestris*
- *Prunus cerasioides*
- *P. napalensis*
- *P. tomentosa*
- *Punica granatum*
- *Pyrus communis*
- *P. kumaoni*
- *P. pashia*
- *Rives graciale*
- *R. nigrum*
- *Rubus ellipticus*
- *R. fruticosus*
- *R. lanatus*
- *R. lasiocarpus*
- *R. niveus*
- *R. nutans*
- *R. reticulatus*
- *Vitis parvifolia*
- *Zizyphus vulgaris*

Vegetables

- *Cucumis hardwickii*
- *Luffa echinata var. longistylis*
- *Malva rotundifolia*
- *M. sylvestris*
- *Momordica balsamina*
- *Rumex dentatus*
- *Solanum incanum*

Tuberous Types

- *Coleus forskohlii*
- *Dioscorea alata*
- *D. bulbifera*

Oil Seeds

- *Carthamus lunatus*
- *Lepidium latifolium*
- *L. ruderale Fibre*
- *Linum perenne*

Spices and Condiments

- *Allium rubellum*
- *A. schoenoprasum*
- *A. tuberosum*
- *Carcum bulbocastanum*
- *Carum carvi*
- *C. angustifolia*
- *Curcuma montana*
- *Zingiber capitatum*

Beverages

- *Cichorium endivia*
- *Fagopyrum cymosum*
- *Saccharum filifolium*
- *S. rufipilum*

B. CENTAL HIMALAYA

Fruits

- *Myrica esculenta*
- *Rubus moluccanus*

Tuberous type

- *Coleus forskohi*

Beverage

- *Camellia kissi*

C. EASTERN AND NORTH EASTERN HIMALAYA

Cereals and Millets

- *Coiz lacryma jobi*
- *Digitaria cruciata*
- *Echinochloa crugalli*
- *E. stagnina*
- *Hordeum agriocrithon*
- *Leersia hexandra*
- *Oryza granulata*
- *O. rufipogon*
- *O. sativa var. spontanea*
- *Polytoca digitata*
- *P. walichiana*
- *Setaria pallide-fusca*

Legumes

- *Atylosia volnbilis*
- *Canavalia virosa*
- *Mucuna bracteata*
- *M. capitata*
- *Vigna capensis*
- *V. radiata var. sublobata*
- *V. trilobata*
- *V. umbellata*

Fruits

- *Citrus assamesis*
- *C. aurantifolia*
- *C. aurantium*

- *C. ichangensis*
- *C. indica*
- *C.latipes*
- *C. macroptera*
- *C. medica*
- *Diospyros lotus*
- *Docynia hookeriana*
- *D. indica*
- *Duchesnea indica*
- *Elaeocarpus floribundus*
- *Euphoria longan*
- *Frangaria nilgerrensis*
- *Garcinia atroviridis*
- *G. cowa*
- *G. hombroniana*
- *G. lanceaefolia*
- *G. pedunculata*
- *G. spicata*
- *Malus baccata var. himalaica*
- *Mangifera indica*
- *M. sylvatica*
- *Morus australis*
- *M. serrata*
- *Musa acuminata*
- *M. balbisiana*
- *M. cheesmanii*
- *M. flaviflora*
- *M.itinerans*
- *M. mannii*
- *M. nagensium*
- *M. sikkimensis*
- *M. superba*
- *M. velutina*
- *Myrica esulenta*
- *Phoenix acaulis*
- *P. robusta*
- *Prunus cerasioides*
- *P. carnuta*
- *P. jenkinsii*
- *P. napalensis*
- *P. wallichii*
- *Pyrus pashia*
- *P. pyrifolia*
- *Ribes graciale*
- *Rubus ellipticus*
- *R. lanatus*

- *R. moluccanus*
- *R. paniculatus*
- *Sorbus aucuparia*
- *S. vestita*
- *Spondias pinnata*
- *Vitis lanata*
- *Zizyphus oenoplia*

Vegetables

- *Cucumis hystix*
- *C. trigonus*
- *Luffa graveolens*
- *Momordica cochinchinensis*
- *M. dioica*
- *M. macrophylla*
- *M. subangulata*
- *Rumex dentatus*
- *Trichosanthus bracteata var. tomentosa*
- *T. cordata*

Tuberous Types

- *Alocasia macrorhiza*
- *Amorphophallus bulbifer*
- *Colocasia esculenta*
- *Dioscorea alata*
- *D. bulbifera*
- *D. hamiltonii*
- *D. hispida*

Oil Seeds

- *Brassica triocularis.*

Fibers

- *Boehmeria malabarica*
- *Corchorus capsularis*
- *Gossypium arboreum*
- *Hibiscus furcatus*

Species and Condiments

- *Alpina speciosa*

- *Amomum aromaticum*
- *Cinnamomum impressinervium*
- *Curcuma amada*
- *C. latifolia*
- *C. zeodoaria*
- *Piper longum*
- *P. peepuloides*
- *P. schmidtii*
- *Zingiber capitatum*

Beverages

- *Camellia caudata*
- *C. kissi*
- *Coffea bengalensis*
- *C. fragans*
- *C. jenkensii*
- *C. hasiana*
- *Eurya japonica*
- *Miscanthus nepalensis*
- *M. wardii*
- *Narenga fallax*
- *Saccharum longisetosum*
- *S. procerum*
- *S. rufipilum*
- *S.sikkimense*
- *S.spontaneum*
- *Sclerostachya fusca*

D. UPPER GANGETIC PLAINS

Cereals

- *Paspalum scorbiculatum*
- *Setaria sphacelata*

Legumes

- *Lathyrus aphaca*
- *Trigonella corniculata*
- *T. polycerata*

Fruit

- *Grewia asiatica*

Oil Seed

- *Brassica quadrivalvis*

Fibres

- *Corchorus trilocuaris*
- *Hibiscus surattensis*
- *Urena repanda*

Spices and Condiments

- *Allium tuberosum*
- *Alpinia galanga*

Beverages

- *Cichorium intybus*
- *Sclerostachya fusca*

APPENDIX – II **18**

Endangered Plant Species in the Himalaya

ENDANGERED PLANT SPECIES IN HIMALAYA

Acer. caesium
A. hookeri ver. majus
A.oblongum var.membranaceum
A.oblongum var.microcarpum
A. osmastonii
A.sikkimense ver.serrulatum
Aconitum deinorrhizum
A.fakonerivar.latilobum
A. ferox
Acranthera tomentosa
Acronema pseudotenera
Adiantum soboliferum
Adinandra griffithii
Albertisia mecistophylla
Allium stracheyi
Alniphyllum forturei
Aneilema glanduliferum

Angelica nubigena
Anoectochilus tetrapterus
Aphyllorchs gollani
A. parviflora
Arhineottia microglottis
Arenaria curvifolia
A. ferruginea
A. thangoensis
Argostemma khasianum
Aspidopteris oxphylla
Athyrium atratum
A. duthei
Begonia aborensis
B.brevicaulis
B.bukillii
B.lushaiensis
B.rubela
B.rubrovenia var.meisneri
B.satrapis
B.scintillans
B. scutata
B. tessaricarpa
B. watti
B. wengeri
Berberis affinis
B. apicuata
B. huegeliana
B. kashmiriana
B. lambertii
B. osmastonii
Bulleyia yunnanensis
Calamus inermis
Calanthe alpina
C. anthropophora
C. mannii
C. pachystalix
Campanula wattiana
Capparis cinerea
Carex fuscifructus
C.Kingiana
C.munroi
C.rependa
Carum villosum
Catamixis baccharoides
Ceropegia angustifolia
C.arnottiana

C.hookeri
C.jainii
C.lucida
Chaerophyllum orientalis
Chondrilla setulosa
Christella clarkei
C.kaumaunica
Christensenia assamica
Christensenia tricuspis
Cissus spectabilis
Clarkella nana
Clematis apiculata
Cleyera japonica var. grandiflora
Codonopsis affinis
Coelogyne rossiana
C.truetleri
Coptis teeta
Corybas purpureus
Coryphopteris didymochlaenoides
Cotoneaster simonsii
Crotalaria meeboldii
C.noveoides
Cyananthus interga
Cyclea debiliflora
C. watti
Cyclogramma squamaestipes
Cymbidium eburneum
C.hookerianum
C.tigrinum
C. whiteae
Cypripedium cordigerm
C.elegans
C.himalaicum
Delphinium uncinatum
Dendrobium aurantiacum
Dendroglossa minutula
Dennstaedtia elwesii
Deyeuzia simlensis
Didiciea cunninghamii
Dioscorea deltoidea
Diplomeris hirsuta
D.pulchella
Drynaria meeboldii
Elaeagnus conferta ssp. dendroidea
Elaeocarpus acuminatus
E.prunifolius

Eremurus himalaicus
Eria occidentalis
Erysimum thomsonii
Eulophia mackinnonii
Euonymusassamicus
Fimbristylis stolonifera
Flickingeria hesperis
Gleditsia assamica
Hedyotis brunonis
H.scarba
Hedysarum astragaloides
H.cachemirianum
H.microcalyx
Heliotropium calcareum
Heracleum jacquemontii
Huodendron biaristatum
Indopolysolenia wallichii
Inula kalapani
Ixonanthus khaisana
Juncus sikkimensis
Kalanchoe roseus
Lactuca benthamii
L.cooperi
L.filicina
L.undulata
Lagerstroemia minuticarpa
Lastreopsis wattii
Lilium macklineae
Lindsaea himalaica
Livistona jenkinsiana
Lloydia himalensis
Mecodium levingei
Meconopsis latifolia
Mesua manii
Metathelypteris decipiens
Michelia punduana
Microschoenus duthiei
Mitrastemon yamamotoi
Nardostachys jatamansi
Neanotis oxyphylla
Neottia inayattii
Nomocharis synaptica
Ophiorrhiza gracilis
O.griffithii
O.hispida
O.lurida

O.subcapitata
O.tingens
O.wattii
Oreopteris elwesii
Panax pseudo-ginseng
Paphiopedilum fairrieanum
P.hisutissimum
P.insigne
P. spicerianum
P.venustum
P.villosum
P.wardii
Pauia belladonna
Phalaenopsis speciosa
Phoenix rupicola
Pholidota wattii
Picrorrhiza kurrooa
Pimpinella evoluta
P.flaccida
P.tangloensis
P.wallichi
Pittosporum eriocarpum
Pleione lagenaria
Pollia pentasperma
Polypodioides wattii
Psychotria arborensis
Pternopetalm radiatum
P.senii
Puccinellia kashmiriana
Pueraria bella
Pyrenaria khaisana
Renanthera imsschotiana
Rhopalocnemis phalloides
Rhynchoglossum lazulinum
Rhynchosia velutina
Rubia edgeworthii
R.himalayensis
Salacia beddomei
S.jenkinsii
Sapria himalayana
Saussurea bracteata
S.clarkei
S.costus
Sclera alta
Selaginella adunca
Senecio mishmi

S.rhabdos
Silene khasiana
S.kumaonensis
S.kunawarensis
S.vagans
Stenogramma himalaica
Sterculina khasiana
Synotis simonsii
Trachyacarpus takil
Trivalvaria kanjilaii
Vanda coerulea
Wallichia triandra
Zeuxie pulchra