G.B. Pant Institute of Himalayan
Environment & Development

25 YEARS
1988-2013

THE HIMALAYAN BIODIVERSITY

Richness, Representativeness, Uniqueness & Life-support Values

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G.B. Pant Institute of Himalayan Environment & Development

G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) was established in 1988-89, during the birth centenary year of Bharat Ratna Pt. Govind Ballabh Pant, as an autonomous Institute of the MInistry of Environment and Forests (MoEF), Govt. of India. The Institute has been identified as a focal agency to advance scientific knowledge, to evolve integrated management strategies, demonstrate their efficacy for conservation of natural resources, and to ensure environmentally sound management in the entire Indian Himalayan Region (IHR). The Institute has headquarters at Kosi-Katarmal, Almora (Uttarakhand) and four regional units, namely, Himachal Unit at Mohal (Kullu, HP), Garhwal Unit at Srinagar (Garhwal, Uttarakhand), Sikkim Unit at Pangthang (Sikkim) and North East Unit at Itanagar (Arunachal Pradesh).

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The Himalayan Biodiversity

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PREFACE

The majestic Himalaya, one of the globally recognized 34 biodiversity hotspots, is a discrete geographic and ecological entity. The variations in topographical features along three dimensional frame work result in diverse climate and habitat conditions within this region that has caused overwhelming richness, representativeness and uniqueness of biodiversity elements.

The region also hosts a diversity of ethnic groups, inhabiting remote and difficult terrains. These communities have been traditionally dependent on bio-resources to meet basic sustenance needs. Among other bio-resources of direct economic potential, the region is well recognized for a plethora of medicinal plants, wild edibles and other non timber forest products. The region is therefore rightly recognized as a cultural landscape wherein culture and biological diversity are mutually supportive. Moreover, the life supporting value of Ecosystem Services, emanating from the Himalayan region is now globally recognized.

In spite of the proven value for human well being, both within and well beyond the region, the patterns and processes of Himalayan biodiversity have remained poorly understood. In this regard it may be pertinent to take note of IPCC (2007) report which states this region to be a 'white spot', i.e., data deficient region. However, with the adoption of 'Mountain Biodiversity Programme of Work' during the Conference of Parties (CoP) to the Convention on Biological Diversity (CBD), at its seventh meeting held in Kuala Lumpur in February 2004, gradually but steadily, as for many other mountain ecosystems of the world, the understanding on Himalayan biodiversity is improving due to increased attention from national/provincial governments. India's National Mission on Sustaining the Himalayan Ecosystem (NM SHE), the only location/area specific mission under the National Action Plan on Climate Change (NAPCC – 2008), is an apt example of priority accorded to this region. The mission, among others, aims to: (i) understand, whether and the extent to which, the Himalayan glaciers are in recession and how the problem could be addressed, (ii) establish an observational and monitoring network for the Himalayan environment, (iii) promote community based management of the ecosystem through incentives to community organizations and panchayats for its protection, and (iv) foster cooperation between regional countries that share the same ecology. This should lead to improved understanding of the direct and indirect linkages between the humans, biodiversity elements, and climate, which may ultimately help in ensuring continuity of long term research and monitoring, so as to benefit the regional countries by way of developing: (i) Reliable and continued availability of data related to climate and biodiversity for this largely data deficient region, (ii) Early Warning Indicators on looming threats, and (ii) Strong research based plans for conservation and sustainable utilization of representative and unique biodiversity elements.

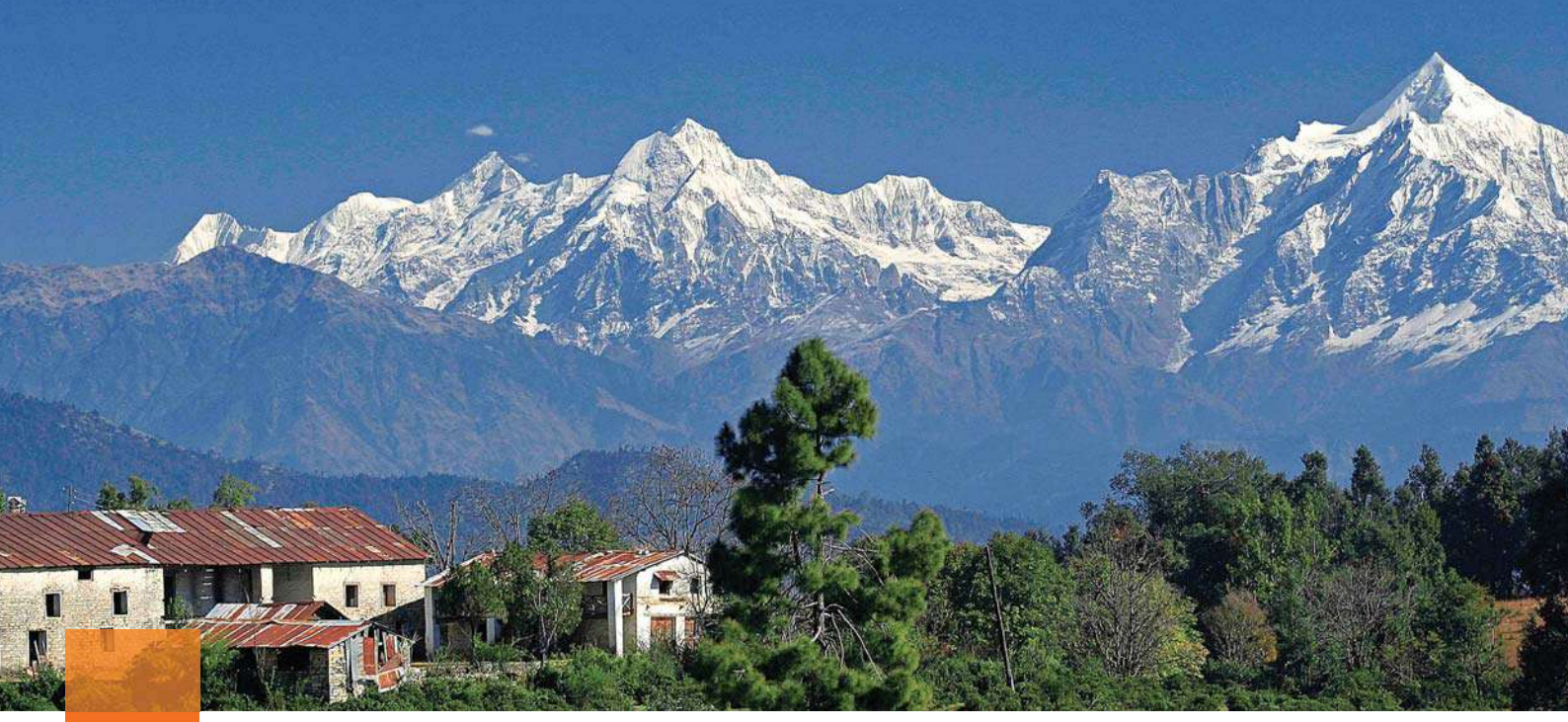
Considering the above, G.B. Pant Institute of Himalayan Environment & Development (GBPIHED) has put together a representative exhibition in CEPA fair of the 11th Conference of Parties to the CBD in Hyderabad in order to showcase richness, representativeness and uniqueness of the Himalayan biodiversity, along with the wide ranging value of this ecosystem for human well being. This booklet aims to complement the poster exhibition. Attempt has been made to compile and present basic facts of Himalayan biodiversity in a manner that would be of interest to a wider audience. While Chapter 1, attempts to give a broad overview of the Himalayan biodiversity, remaining chapters provide more focused information. In order to forge better appreciation of regional diversity, information has been arranged on the basis of biogeographic (Chapters 2–7) as well as thematic (Chapters 8–19) segments.

I am confident that this endeavour of GBPIHED will go a long way in generating greater interest of global community towards building stronger partnerships/collaborations for developing large scale programmes for ensuring long term protection and sustainable use of this region's biological diversity. GBPIHED gratefully acknowledges the financial support received from National Biodiversity Authority of India and the encouragement provided by the Ministry of Environment and Forests, Govt. of India for putting up the exhibition on Himalayan biodiversity. Our grateful thanks are also due to all colleagues from the Institute and other organizations for their valuable inputs.

L.M.S. Palni
Director, GBPIHED
Kosi-Katarmal, Almora
January 2013

“People can visit sacred shrines and imagine the spirits and the murmur of the voices of past generations. Likewise, we should go into natural places and imagine the spirits and murmurs of future generations hoping to experience the diversity of nature”

Paul Dayton



Three dimensional frame work of the Himalaya © Threesh Kapoor

1 The Himalayan Biodiversity

Richness, Representativeness, Uniqueness and Life-support Values

The growing global recognition of mountains as (i) hotspots for biodiversity, and (ii) providers of goods and services to nearly half of the world's human population, concomitant with increase in the level of awareness about the possible impacts of climate change on mountain ecosystems and its consequences for the entire world has brought mountains on the main agenda of global debate on environment & development. This enhanced awareness has helped in mainstreaming developmental agenda in the region, *albeit* with the acceptance that in spite of their evolutionary significance and ecological values manifested by ecosystem integrity, adaptability and services, these regions have largely remained marginalized from sustainable development perspectives. In this context, and on account of richness (diversity), representativeness and uniqueness, mountain biodiversity elements have attracted the attention of scientific community in recent decades. As a result, significant information has been generated on the changing patterns of mountain biodiversity. However, a great majority of stakeholders still appear to be unconcerned about these changes and largely unaware of the Mountain Agenda and follow up actions.

The Himalayan Biodiversity Hotspot (HBH)

Among various mountains of the world, the Himalayan Ecosystems assume special significance being young and dynamic on one hand, and the most complex and diverse on the other, ranging from the wettest to driest areas; the region has been recognized amongst the 34 global biodiversity hotspots. The geographical isolation and varied eco-climatic conditions have supported a large number of ethnic and unique socio-cultural groups with distinct traditional knowledge and practices of resource use and conservation.

This majestic mountain system covers nearly 7.5 lakh km^2 area (spanning over 3000 km in length, and 250-300 km in width, and rising from <300 to >8000 m asl), and stretches from northern Pakistan on the west to northeastern regions of India through its northwestern states, Nepal and Bhutan. The region has a discrete geographic and ecological entity. It produces a distinctive climate of its own and influences the climate of much of Asia. However, the variations in topographical features along three dimensional frame work (i.e., latitudinal: South-North; longitudinal: East-West; altitudinal: Low-High) have resulted in enormous diversity in respect of climate and habitat within the region. This has lead to overwhelming richness of biodiversity elements and to their uniqueness. The region serves as a rich repository of plant and animal wealth in diverse ecological zones, and the prevailing ecosystems reflect a mosaic of biotic communities at various spatial and organizational levels. For instance, as per the reports of Conservation International [http://www.biodiversityhotspots.org] species level diversity and uniqueness of biodiversity elements in number of prominent groups in the HBH include: Plants 10,000 (endemics in brackets: 31.6%), Mammals 300 (4.0%), Birds 977 (1.5%), Reptiles 176 (27.3%), Amphibians 105 (40.0%), and Freshwater Fishes 269 (12.3%).

The Indian Himalayan Region (IHR)

With geographical coverage of over 5.3 lakh km^2, IHR constitutes a large proportion of the HBH and, therefore, contributes greatly to richness and representativeness of its biodiversity components at all levels (i.e., genes, species and ecosystems). Administratively IHR covers 10 states entirely (i.e., Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya), and two states partially (i.e., hilly districts of Assam and West Bengal). The region represents nearly 3.8% of total human population of the country and exhibits diversity of ethnic groups (171 out of a total 573 reported scheduled tribes in India) which often inhabit remote and largely inhospitable terrains.

Richness and Representativeness of Biodiversity Elements

Recognizing the wide ranging affinities of its biota, IHR has been classified into three biogeographic zones and seven provinces (Table 1.1; Fig. 1.1). Of these three zones, the Trans Himalaya and the Himalaya have more boreal elements with Sino-Siberian and Sino-Himalayan affinities, whereas the North East India exhibits more of Palaeotropical (Indo-Malayan) influence.

Across these biogeographic units and based on various reports, the IHR maintains an overwhelming representation of India's biodiversity values (Table 1.2); this has attracted diverse investigators for critical examination towards its evolutionary, ecological and economic contributions.

Uniqueness of Biodiversity Elements

- Considering the evolutionary significance, the east Himalayan part of IHR (i.e., biogeographic province east Himalaya and zone North East Indian) bears huge importance by way of having rich biodiversity and for harbouring largest number of endemics and

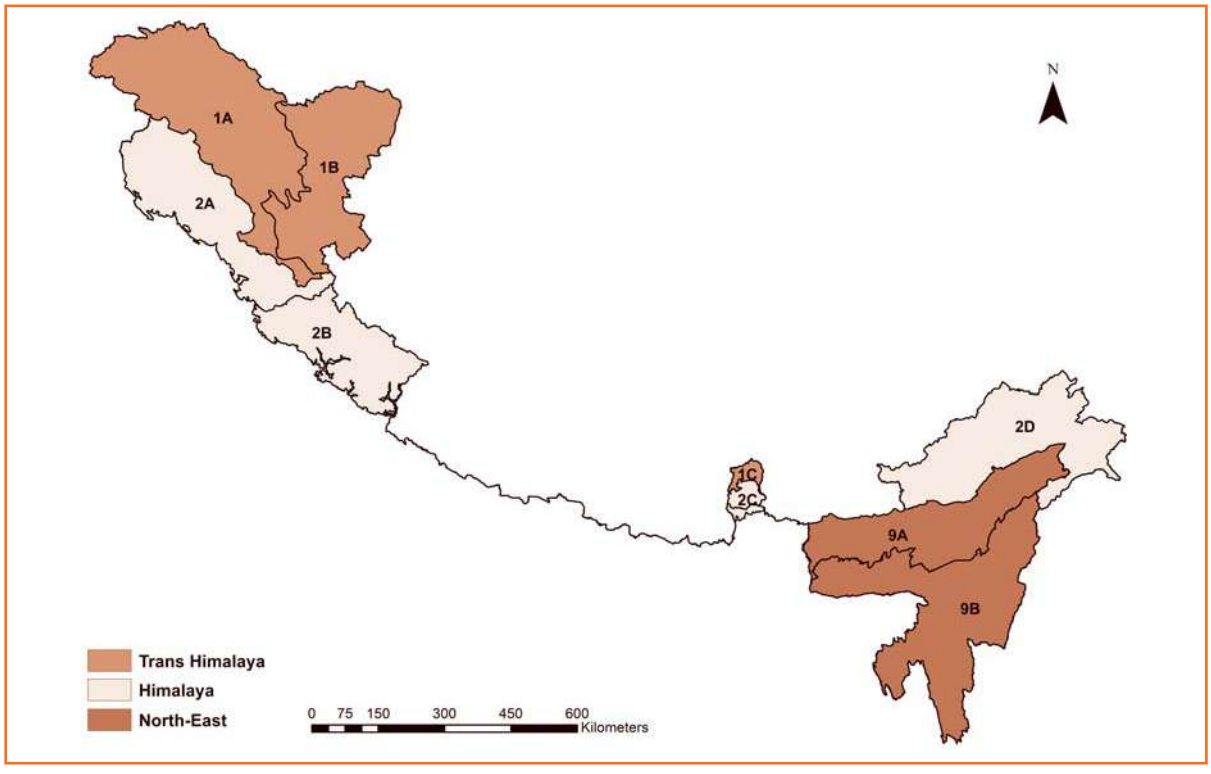


Figure 1.1. Extent and biogeographic divisions of Indian Himalayan Region (IHR).

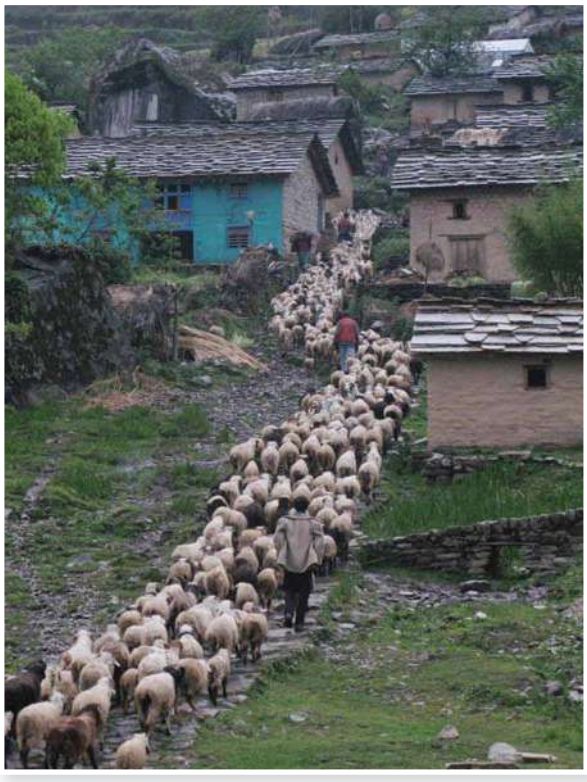
Table 1.1: Bio-geographic representation of Indian Himalayan Region (IHR)

Bio-geographic Zones	Bio-geographic Provinces	Geographical area of India (%)	Major Biome Representation
Trans Himalaya	1A: Ladakh Mountains	3.3	Tundra
	1B: Tibetan Plateau	2.3	Alpine
	1C: Sikkim Trans Himalaya	<0.1	Alpine, Tundra
The Himalaya	2A: North west Himalaya	2.1	Alpine, Temperate, Sub Tropical
	2B: West Himalaya	1.6	-do-
	2C: Central Himalaya	0.2	-do-
	2D: East Himalaya	2.5	-do-
Northeast India	9A: Brahmaputra Valley	2.0	Tropical Evergreen Forest, Very Moist Sal Forest, Tropical Grass Lands
	9B: Northeast Hills	3.2	Tropical evergreen, Tropical Moist Deciduous, Subtropical, Montane Temperate, Wetlands

Source: Rodgers & Panwar, 1988; Rodgers et al., 2000 (Wildlife Institute of India).

Table 1.2: Representativeness and richness of Himalayan Biodiversity

Levels	Representation	
	Total number	% of India
Eco-regions Communities	16	–
Vegetation types	21	–
Forest types	10	26
Formation types	11	–
Species		
Angiosperms	8000	47
Gymnosperms	44	81
Pteridophytes	600	59
Bryophytes	1737	61
Lichens	1159	59
Fungi	6900	53
Mammals	300	69
Birds	979	79
Reptiles	176	38
Amphibians	105	34
Fishes	269	10
Specific groups		
Medicinal	1748	23
Wild edible	675	67
Trees	723	28



Sheep herd in west Himalaya © Balwant Rawat

Schedule I species, as compared to any other parts of India. This region represents a confluence of the Indo-Malayan and Indo-Chinese biogeographical realms. Also, it exhibits intermixing of the elements of Himalayan and Peninsular India. The region has been considered as a cradle of flowering plants, and represents some of the primitive angiosperm families including Magnoliaceae, Degeneriaceae, Himantandraceae, Eupomatiaceae, Winteraceae, Trochodendraceae, Tetracentraceae, and Lardazabalaceae. Specific primitive genera include *Alnus, Aspidocarya, Betula, Decaisnea, Euptela, Exbucklandia, Haematocarpus, Holboellia, Houttuynia, Magnolia, Magnolietia, Pycnarrhena* and *Tetracentron*. The region is known for high evolutionary activities which are clearly evident from the cytogeographic studies on selected genera like *Rhododendron*, *Camellia*, *Magnolia*, etc.

- IHR contributes considerably in the form of wild relatives of several crop plants and domesticated animals. Of the total 8 sub-centers of plant origin, the region represents 3 sub-centers (viz., Western Himalaya, Eastern Himalaya and North Eastern Region). These sub-centers respectively contribute 125, 82, and 132 species of wild relatives. Vavilov

Brahma Kamal (*Saussurea obvallata*) in Himalayan Alpines © K. Chandra Sekar

referred to the north eastern region of India as "Hindusthan Centre of Origin of Cultivated Plants", and is important for tropical and subtropical fruits, cereals, etc. This region forms the richest reservoir of genetic variability of many groups of crop plants. The taxonomical and cytogenetic studies have revealed Assam-Burma-Siam-Indo-China region as the center of origin of *Musa*. The region is also rich in *Citrus* wealth with nearly 64 taxa of *Citrus* growing wild. Also, it is regarded as the center of origin for 5 species of palms of commerce – coconut, areca nut, palmyra palm, sugar palm and wild date palm.

- The region contributes a large number of medicinal and aromatic plants with their origin in the region, including the wild progenitors of a number of ornamentals like *Primula, Rhododendron*, in addition to a huge diversity of Orchids. Among wild and domesticated faunal elements, the region harbours wild chicken, zebu, mithun, yak, etc.
- The prevailing primitive agricultural system of raising crops under stress conditions in the region have resulted in much variability, particularly in adaptive traits. Most of the hilly terrain in the eastern Himalaya is under shifting cultivation and several promising, agronomically and physiologically well adapted types/land races belonging to diverse crop species occur in this region. The specialized habitats in the western part of Himalaya (e.g., cold arid climate) are also responsible for promoting variation in specific traits. In addition, in isolated pockets, various ethnic groups grow their own preferred and locally selected cultivars. All these factors have contributed to enormous enrichment of genetic diversity in land races through conscious and unconscious selections by the indigenous farming communities in the Himalaya.
- The IHR nurtures an amazing faunal diversity. The mammalian diversity in the IHR is one of the richest in the country. Foothills of the IHR are habitats for three major terrestrial flagship species (tiger, elephant, rhino) out of five across the globe, and aquatic flagship species river dolphin also occurs. High altitude habitat nurtures some of the charismatic and unique faunal species (e.g., snow leopard, red panda, hangul, chiru, musk deer, serow, Himalayan tahr, etc.).
- Endemism is yet another important attribute for the region. Among floristic elements, besides nearly 32% of species being endemic, the region represents 71 endemic genera and five endemic families (i.e., Tetracentraceae, Hamamelidaceae, Circaeasteraceae, Butomaceae, and Stachyuraceae). A few families, e.g., Berberidaceae and Saxifragaceae represent >90% species endemic to the Himalaya. A large number of orchids, many representing neo endemic taxa, have been recently reported from Sikkim and Arunachal Pradesh. Likewise, of the nearly 300 recorded mammal species across the region, 12 are endemic to the Himalaya. Of the 979 bird species recorded from the region 15 are endemics, including one species, the Himalayan quail (*Ophrysia superciliosa*) representing an endemic genus. Four Endemic Bird Areas (EBAs) overlap entirely or partly with the HBH. Several studies in IHR have revealed the richness of high altitude Himalaya (alpine and sub-alpine zone) in respect of plant endemic diversity. This feature is particularly prominent in Trans/Northwest and West Himalaya, suggesting thereby that the high altitude zone of these provinces can be considered as one of the endemic centers. Among endemics, prevalence of shizoendemics is reported from the western part (Kashmir) of the region.

Life-Support Values of Biodiversity

The indigenous communities of the region have been traditionally dependent on diverse bioresources to meet their basic sustenance needs, notably food, fodder, fuel, fertilizer, fibre, shelter, health care, etc. More than 80% of the population in the region is involved in agriculture, animal husbandry, forestry and other biodiversity-dependent vocations.

Among other bioresources with direct economic value, the Himalayan region is well recognized in terms of the diversity of medicinal plants, wild edibles and other non timber forest produces (NTFPs).

- IHR supports over 1748 (23.4% of India) plant species of known medicinal values. The unique diversity of medicinal plants in the region is manifested by the presence of a number of native (31%), endemic (15.5%) and threatened elements (14% of total Red Data Book plant species of IHR). The economic potential of Himalayan medicinal plants and their contribution towards novel bio-molecules are well recognized.
- The wild edibles have emerged as potential resources for addressing needs and issues of rural development and biodiversity conservation in the region, particularly on account of their nutritional and pharmaceutical potential. Over 675 species (Angiosperms 647, Gymnosperms 7; Pteridophytes 12; Fungi 7 and Lichens 2 species) of wild edible species are known from IHR. Across biogeographic provinces, richness of known wild edibles is maximum in the West Himalaya (344 spp.; 50.9%) followed by East Himalaya (221; 32.7%), Central Himalaya (173; 25.6%) and Trans/North West Himalaya (169; 25.0%). Of the total reported wild edibles, 39 (5.8%) species are restricted range endemics and 93 (13.8%) near endemics.
- Consumption of wild edibles meets the protein, carbohydrate, fat, vitamin and mineral requirements of poor rural populace in the region. Other reports suggest wild edibles can also generate substantial income. A study in Almora district, Indian west Himalaya, reveals that the sale of *Myrica esculenta* fruits ("*Kaiphal*" – known for edible fruits and other by products in sub-Himalayan region) brings each household Rs. 913–3713 (US$ 26–106) per season, which is significant considering low annual per-capita income in the region. Likewise, other wild edibles have been identified with income-generating potential.

Bioresource dependent hill settlements © Balwant Rawat

The Way Forward

Having briefly showcased the Himalayan Biodiversity, it is not out of place to state that the Himalayan region is a mega biodiversity center of the world, with its biodiversity components (i.e., genetic, species and ecosystems) having global importance. However, the region is often referred as economically marginal and home to the worlds' poorest whose livelihoods depend heavily on natural resources, and any change in the status of these resources would severely affect them. In this context, the Himalayan Mountains being sensitive ecosystems for both human induced and natural perturbations have exhibited rapid changes in its resource base, and thereby affecting the sustenance of its people. As a result, the indigenous communities in the region have, by and large, begun to show discernable disinterest towards the management of natural resources, including the bioresources. Specifically, they feel alienated on account of current policies and programmes of conservation which consider non-use and existence value of biodiversity as points of prime focus.

- There has been a growing consensus that while initiatives for strengthening of conservation areas are essentially required in the region, there is a need for reorienting existing norms and management practices by harnessing the income generating potential of such areas for local communities so as to promote their interest and participation in conservation in line with the statement: conservation without compensation is only conversation.
- Mountains are and should be treated as national/global treasures, of resource and opportunity, for today and tomorrow. In the national context, the survival of north and eastern plains of India would indeed be difficult if IHR plans are faulty and short-sighted. This would also imply that the national policies have to have a mountain perspective so that decisions taken for the rest of the country do not adversely affect the mountain environment, its resources and people. There is a need to be sensitive at all levels, regarding the vulnerability as well as the importance of the IHR (Task Force Report of Planning Commission of India, 2010).
- There is a strong need to promote sustainable use concept which attempts to establish linkages between conservation and economic growth, and recognizes that the bioresources represent a renewable source for sustainable income. Experiences from the region itself have revealed that people become interested in biodiversity conservation when they realize that it has immediate utility value (i.e., subsistence or income-generating opportunity) attached, and that they

can harness benefits from it. Yet another strategy, which has emerged as promising, is to maximize economic benefits by adding value to biodiversity components available in the immediate vicinity of indigenous communities. Further, among others, the efforts made by G.B. Pant Institute of Himalayan Environment & Development (GBPIHED) in Uttarakhand, Himachal, Sikkim and Arunachal Pradesh in terms of capacity-building of the local inhabitants towards effective use of bioresource-based rural technologies (e.g., bio-briquettes, protected cultivation, poly-pit, nursery development, medicinal plant cultivation, mushroom cultivation, etc.) have received considerable attention across IHR. This has led people to reorient their mindset in a way so as to view bioresources (or their products) as an effective source of income for the rural inhabitants.

- With the growing realization that biodiversity elements are intricately linked, and that focusing on the management of any one, ignoring the others, cannot be sustainable. Thus, there is a felt need for considering holistic or ecosystem based approaches of management. It recognizes that humans, with their cultural diversity, are an integral component of ecosystems. This implies that management of biodiversity components in any ecosystem would require integration of research outputs and human dimensions. One example can be drawn from the role of bees as pollinators to enhance agricultural productivity. The extensive researches have proved that the decline in production of apple in Himachal Pradesh is linked with disturbances in the pollination process – a reason largely unknown to many of the growers and even agricultural extension workers. With this realization the rental of bee hives is getting popular for pollination among the apple growers of Himachal Pradesh. This realization has also led India to participate in the formulation and implementation of a "global pollinator project", being coordinated by GBPIHED, with the aim of management of pollinators for sustainable agriculture through ecosystem approach in the Himalaya. Yet another example of holistic view of conservation can be cited as implementation of Village Environment Action Plan (VEAP) developed by GBPIHED. This includes approach of preparing developmental plan for a given village ecosystem by integration of its resources (physical, biological and human) and environmental hazard management through a participatory approach, of village resource mapping, monitoring and evaluation.
- Globally there has been a growing concern to effectively attach monitory value to biodiversity, specifically to the ecosystem services and make provisions for transfer of payments (compensations) to the protectors. An emerging issue is to adequately value the forests. In order to implement the United Nations Framework Convention on Climate Change (UNFCCC), and with a growing global realization that fuller valuation of forests is necessary if forests are to be conserved by the local people, progress has been made to develop carbon markets. The trends on initiatives across the world are indicative of the fact that forestry efforts could play an increasingly important role in achieving the emission reduction targets agreed by the signatories to Kyoto Protocol. Experiences from the Uttarakhand (west Himalaya), which represents one of the oldest and largest system of Van Panchayat (introduced in 1930; over 12,000 Villages; nearly 30% of total forest area of the State), under "Kyoto- Think Global, Act Local" project has revealed that communities can be trained to use technology to measure carbon sequestration rate in their community forests. Estimates suggest that if trained communities are able to submit proposal through proper mechanisms one Van Panchayat alone could receive up to 1.08 Lakhs per annum for the carbon sequestered by "their" forest. The funds generated through the sale of carbon credits can be used to meet their needs and can encourage people to save their forests as "Carbon Sinks".
- Forest ecosystem of IHR provides vital support to the agro-ecosystems of the region through transfer of biomass and energy, thus helping to provide food security, and in maintaining large number of landraces of food crops. Standing forests as resource have not been recognized; indeed they have been undervalued in terms of its contribution to ecosystem good and services. Their value is not reflected in the country's GDP. There is, therefore, a clear need for scientific valuation of ecosystem services provided by forests of the IHR in order to highlight their contribution to the national economy and the quality of life, more so as the world moves towards "green economy" (Task Force Report of Planning Commission of India, 2010)
- The Climate Change (CC) has been recognized as one of the most confounding factors in shaping the future of mountain ecosystems and local people, and the predictions are that the higher altitudes are likely to be more vulnerable compared to lower altitudes. Besides agriculture, insect-pest incidence, and movement of species, climate change is likely to affect the movement patterns of the herdsmen, and transhumant community so dependent on seasonal migrant in the IHR. There is, therefore, an urgent need to understand the intensity and direction of consequent on-going and potential impacts of changes on the structure and functioning of biodiversity elements, including humans, in these regions. In this regard, the Himalayan region with unparallel vertical profile emerges as most 'vulnerable' candidate amongst high altitude landscapes of the world. It, therefore, calls for immediate action towards understanding the patterns and the processes of change so as to

draw realistic and widely accepted action agenda for conservation and sustainable use of its biological diversity under changing climate.

Recognizing the immediate need for such actions in the region, one would need to: (i) take note of and build on existing knowledge and information base across the region, and, (ii) enhance information generation and knowledge discovery through robust globally accepted protocols. This would also imply that all the relevant available knowledge becomes accessible to various users in the region and elsewhere, and the research/scientific, civil society/NGOs community moves ahead from largely qualitative to predictive and adaptive research and actions concerning biodiversity and the changing climate.

In the above context, it is pertinent to mention that the National Action Plan for Climate Change (2008) has shown India's commitment for the Himalayan Region by way of making provision for a National Mission on Sustaining Himalayan Ecosystems, one amongst eight envisaged National Missions. The mission, among others, clearly states "…*Since several other countries in the South Asian region share the Himalayan Ecosystem, appropriate forms of scientific collaboration and exchange of information may be considered with them to enhance understanding of Ecosystem Changes and there effects*…" [NAPCC-2008].

In this regard, the Himalayan Biodiversity & Climate Change Knowledge Network (HBCC-KN) has been envisaged to be established as a multi-stakeholder and inclusive mechanism to acquire and exchange information and knowledge, generated through scientific as well as evidence-based research, and experience sharing on biodiversity and climate change related issues within the Himalayan region. The ultimate aim is to make this knowledge available to various stakeholder groups within the region as well as to the interested international community outside the region. This should promote and enable cross-fertilization of ideas, and strengthen efforts for collaboration between and amongst members of the network. The HBCC-KN, therefore, seeks to ensure availability of reliable/authentic information and knowledge products which could subsequently feed into the national and international policy process and in to the programmes addressing issues of biodiversity conservation and sustainable development, particularly under the changing climate scenario in the region.

Major objectives of HBCC-KN would include:

- ***Promoting synergy*** among specialists/researchers and members of civil society/NGOs who are currently pursuing studies or addressing issues pertaining to biodiversity and climate change at individual level, largely in isolation.
- ***Harnessing knowledge base*** of specialists/researchers and civil society members on the subject area to (i) understand response patterns of Himalayan biodiversity elements, individually and collectively, towards changing climate; (ii) work-out best possible options for natural resource management and livelihood promotion; and (iii) ensure sustainability of ecosystems and improve quality of human life in the region.
- ***Building partnerships*** among member countries for: (i) effective flow and sharing of research and evidence based information/knowledge, and best practices; (ii) enhance understanding of the linkages between biodiversity, climate change and sustainable development in the region; (iii) strengthen region-specific information/knowledge base on biodiversity and climate change so as to positively influence the international negotiations; (iv) enlarge the existing platform(s) of village/community biodiversity monitoring network/committees and build their capacities to participate in climate parameter monitoring.

The envisaged knowledge network would be based on the following principles:

Inclusiveness (to include all sections of society concerned with these issues), *Simplicity* (to be simple, user-friendly, and accessible to all interested groups), *Equity* (to treat all members uniformly) and *Mutual learning* (respect each other's knowledge and contributions).

The envisaged network, while having cross cutting implications, will have particular relevance with the Mountain Biodiversity Work Programme of Convention on Biological Diversity (CBD). Also, it will contribute towards provisions of Article 13 (Public education and awareness), Article 14 (Impact assessment and minimizing adverse impacts), Article 17 (exchange of information) and Article 18 (Scientific and technical cooperation) of CBD.

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Gurudongmar Tso – A High Altitude Wetland in North Sikkim © Bharat K. Pradhan

Biodiversity of Indian Trans Himalaya

2

The Indian Trans Himalaya, which spans over 1,86,000 km^2, is the rain shadow zone lying above the natural tree-line. The zone is characterized by high solar intensity, low temperature, lack of adequate soil and short growing season. As a result, the zone is recognized as one of the most ecologically fragile bio-geographic zones in India (Rodgers and Panwar, 1988). The zone consists of three bio-geographic provinces: (i) Ladakh Mountains with approx. 60% area, these rugged mountains and valleys spread over 2,200 m to 7,000 m in Kargil, Leh, Zanskar and Lahaul-Spiti areas, (ii) Tibetan Plateau (40% area) comprising Changthang (Ladakh), part of Spiti (HP), and (iii) cold deserts in North Sikkim.

The Trans Himalayan region represents one of the most practiced ecosystems for age-old pastoralism in the world and supports a range of wild ungulates and their predators. The zone is globally recognized for its contribution to great rivers systems in the Himalaya, and several water bodies including sacred and glacial lakes. Among others, the zone is also known for representing Buddhism as major religion.

Trans-Himalayan landscape- Lhonak valley, north Sikkim © S. Tambe

Richness and Representativeness

Broadly the Trans Himalayan floristic elements are grouped as: *Alpine Flora*: Plants restricted to moist regions, in depressions and slopes which are moistened by melting snow and glacial streams. *Cold Desert Flora*: Typical desertic elements, which are found in the areas beyond the transition zone of glacial streams and vegetation nearby habitations. *Oasitic Vegetation*: This comprises a variety of exotic as well as indigenous species, growing near habitation, along water courses, streams and in moist places.

While considering Ladakh mountains and Tibetan Plateau, over 1,400 species of angiosperms (distributed in 417 genera and 89 families) have been reported (Srivastava, 2010). The dicots constitute 1030 species (73 families, 310 genera) and monocots 376 species (107 genera, 16 families). The Gymnosperms are represented by 8 species (5 genera and 3 families). Faunal elements comprise 25 species of mammals, 36 species of insects and more than 300 species of birds (Singh and Jayapal, 2001; Uniyal, 2001). With respect to Trans Himalayan part of Sikkim Himalaya, assemblages of highly specialized biota offer interesting ground for scientific investigation (Bhatnagar *et al*., 2002).

Faunal elements represent unique combination of herbivores and high profile predators; the list is interesting even for rare, endangered and threatened taxa.

Uniqueness

Towards ensuring survival in prevailing harsh climate, the plants of Trans Himalaya exhibit a number of ecological, morphological and physiological adaptations. These unique habits include: Cushion-forming, Diminutive or miniature, Bushy, Protective covering of hairs, etc. The Trans Himalayan zone supports many unique endemic elements of plants (Table 2.1).

Table 2.1: Endemic plants of Indian Trans Himalaya

S. No.	Name of the species	Family	Habitat type	Major areas of occurrence
1.	*Allardia stoliczkai*	Asteraceae	Rocky slopes	Pin Valley
2.	*Allium loratum*	Alliaceae	Glacial moraines	Nubra, Zanskar
3.	*Arenaria stracheyi*	Caryophyllaceae	Alpine slopes	Ladakh
4.	*Astragalus munroi*	Fabaceae	Rocky slopes	Pin Valley, Hemis
5.	*Astragalus zanskarensis*	Fabaceae	Moist slopes	Zanskar
6.	*Berberis ulicina*	Berberidaceae	Alpine slopes	Ladakh
7.	*Christolea stewartii*	Brassicaceae	Alpine slopes	Ladakh
8.	*Corydalis crassifolia*	Fumariaceae	Glacial moraines	Pin Valley, Baralacha La, Hemis
9.	*Draba cachemirica*	Brassicaceae	Alpine slopes	Ladakh
10.	*Ferula jaeschkeana*	Apiaceae	Stream beds	Ladakh, Pin Valley
11.	*Festuca sanjappae*	Poaceae	Moist slopes	Pin Valley
12.	*Lancea tibetica*	Scrophulariaceae	Alpine slopes	Dharcha, Ladakh
13.	*Ranunculus trivedii*	Ranunculaceae	Moist slopes	Baralacha La, Tsakchum Tso, Rupshu, Pangong Lake
14.	*Stellaria pinvalliaca*	Caryophyllaceae	Moist stream slopes	Pin Valley
15.	*Silene stewartii*	Caryophyllaceae	Moist alpine slopes	Sissu

Ferula jaeschkeana – An endemic plant in Spiti region © K. Chandra Sekar

Box 2.1. Tso Lhamo Plateau

The Tso Lhamo area lies in the Trans-Himalayan region of the Sikkim State and harbours unique populations of a few highly threatened mammalian fauna such as Tibetan argali (*Ovis ammon hodgsoni*), Tibetan gazelle (*Procapra picticaudata*), Southern kiang (*Equus kiang polyodon*) and Tibetan antelope (*Pantholops hodgsonii*). Tso Lhamo is extensively used by the native Dokpa herders for livestock (yak and sheep) grazing. Compared to other Trans Himalayan region, Tso Lhamo is reported to have higher densities of Tibetan argali and Tibetan gazelle, but these populations are susceptible to decline due to heavy human influx and livestock grazing. [*Source*: Rawat and Tambe, 2012]

Also, several unique faunal species have presence in the region. Availability of several medicinal herbs and high value medicinally used Caterpillar-fungus (*Cordyceps sinensis*) makes this region important. Infrequent availability of *Rheum nobile* (giant Rhubarb) is another fascinating feature. Besides, seasonal migration of domesticated yaks and sheep has a definite interaction with natural biomes. Six plants from the region, namely, *Ephedra intermedia, Juniperus communis, J. indica, J. recurva, Picea smithiana* and *Pinus wallichiana* are under Least Concern (LC) category of IUCN.

Trans Himalayan region harbours a number of wetlands and lakes with high biodiversity potential. These wetlands are grouped under High Altitude Wetlands (HAWs). HAWs are of great importance, especially for endemic and threatened species of plants, migratory birds, wild animals and also for the people living in and around. Considering ecological functions, these HAWs play significant role in defining the hydrological regime of mighty rivers and act as a buffer between glacial melt waters and outflows to smaller rivers and streams. The HAWs of Trans Himalayan region hold the distinction of being the only known breeding ground of Black necked Crane (*Grus nigricollis*) in India. Apart from these, all the water birds found in the region are highly dependent on these wetlands and some species are endemic and endangered.

A total of 68 threatened plant species have been identified in Trans Himalaya. These include 18 plants as Vulnerable and 9 plants as Critically Endangered. Among the avi-fauna, the known threatened species are recorded and provided in Table 2.2. The unique and restricted animals of the region are included.

Table 2.2: Unique and/or restricted avian species in Trans Himalaya

Avian elements	Scientific name	IUCN status*	Major areas of occurrences
Black-necked crane	*Grus nigricollis*	VU	Tsokar, Chandratal, Lhonak Valley
Wood snipe	*Gallinago nemoricola*	VU	North Sikkim
Lesser kestrel	*Falco naumanni*	LC	Ladakh, North Sikkim
Hoary-throated barwing	*Actinodura nipalensis*	LC	North Sikkim (Endemic)
Broad-billed warbler	*Tickellia hodgsoni*	LC	North Sikkim (Endemic)
Tibetan snowcock	*Tetraogallus tibetanus*	LC	Zanskar, Ladakh, North Sikkim
Himalayan griffon	*Gyps himalayensis*	LC	North Sikkim
Tibetan sandgrouse	*Syrrhaptes tibetanus*	LC	North Sikkim
Golden eagle	*Aquila chrysaetos*	LC	Zanskar, Leh, North Sikkim

*IUCN categories – LC: Least Concern; VU: Vulnerable

Table 2.3: Unique and/or restricted animal species in Trans Himalaya

Common / local name	Scientific name	IUCN status*	Major areas of occurrence (s)
Bharal (Blue sheep)	*Pseudois nayaur*	LC	Ladakh, Lahaul, Spiti, Tso Lhamo, Zanskar, Nubra, Pin Valley
Eurasian lynx	*Lynx lynx*	LC	Tso Lhamo
Himalayan marmot	*Marmota bobak*	LC	Tso Lhamo
Kashmir Markhor	*Capra falconeri*	EN	Ladakh
Ladakh uriyal	*Ovis orientalis*	VU	Nubra
Plateau pika	*Ochotona curzoniae*	LC	Tso Lhamo
Siberian ibex	*Capra sibirica*	LC	Pin Valley, Nubra, Hemis
Siberian weasel	*Mustela sibirica*	LC	Tso Lhamo
Snow leopard	*Panthera uncia*	EN	Ladakh, Spiti, North Sikkim
Southern kiang	*Equus kiang*	LC	Tso Lhamo
Tibetan antelope	*Pantholops hodgsonii*	EN	Ladakh, Tso Lhamo
Tibetan argali	*Ovis ammon hodgsoni*	NT	Ladakh, Spiti, Chulung La, Tso Lhamo
Tibetan gazelle	*Procapra picticaudata*	NT	Ladakh, Tso Lhamo
Tibetan sand fox	*Vulpes ferrilata*	LC	Tso Lhamo
Tibetan wild ass	*Equus kiang*	LC	Ladakh
Tibetan wolf	*Canis lupus*	LC	Ladakh, Spiti, North Sikkim
Tibetan woolly hare	*Lepus oiostolus*	LC	Tso Lhamo
Yak	*Bos mutus*	VU	Ladakh, Spiti

*IUCN Categories – LC: Least Concern; NT: Near Threatened; EN: Endangered; VU: Vulnerable

Life-Support Values of Biodiversity

- Trans Himalaya has rich traditions of using medicinal plants, and more than 300 plants are used in Tibetan system (*Amchi*) of medicine.
- The wild edible fruits of *Capparis spinosa, Cotoneaster falconeri, Ephedra gerardiana, Hippophae rhamnoides* ssp. *turkestanica, Ribes orientale* and *Rosa hookeriana*, etc., are consumed by local people.
- Plants or their parts are cooked as vegetable from *Allium carolinianum*, *A. stracheyi, Chaerophyllum acuminatum, Chenopodium album, Cicer microphyllum*, etc.
- Several species are used as fodder and fuel purposes, for example *Astragalus peduncularis, Cicer microphyllum, Medicago falcata, Trigonella emodi*, etc. The wood of *Juniperus recurva, Populus ciliata* and *Salix denticulata* are used for timber and implements.

Black necked crane- A threatened bird of wetlands in Ladakh © B.S. Adhikari, WII

Tibetan Argali (*Ovis ammon hodgsoni*) – A globally threatened herbivore in Sikkim Trans Himalaya © P. Chanchani

- Species of *Arnebia euchroma, Geranium pratense* and *Onosma hispidum* are used as dye.
- The incense and perfumes are obtained from *Chrysanthemum pyrethroides, Delphinium brunonianum* and *Allardia glabra.*
- The pastures, rivers and wetlands of the Trans Himalaya provide great ecosystem services to the people living within and outside the region.

Societal Importance

- Most of the tribal inhabitants consider the entire landscape and adjacent areas sacred, and they have various physical and biological entities as their deity and numerous places to worship in wilderness including the mighty Mt. Khangchendzonga in Sikkim.
- Age-old agropstoralism by indigenous herders in entire Trans-Himalaya provides a strong base for livelihood.
- Being an emerging tourism destination, this region has contributed significantly for economic benefits of inhabitants in recent years; the resulting economy of people is manifested in their changing life-style. Gurudongmar, Chandratal, Pangong Tso, Tsokar lakes are among the greatest fascination for wide range of tourists.

Initiatives for Conservation and Sustainable Use

Towards ensuring the in-situ conservation of biodiversity elements of the region, a total of 2 National Parks (Hemis, Pin Valley), 4 Wildlife sanctuary (Chandratal, Kibber, Changthang, Karakoram) and 1 Biosphere Reserve (Cold Desert Biosphere Reserve) have been designated in the region. In addition, Tso Lhamo cold Desert Conservation Area in north Sikkim is the proposed Protected Area (PA). Through this PA Network, a number of important plant and communities have been conserved. Although following points would require consideration for improved conservation.

- In spite of the fact that the government has been providing several levels of societal benefits through a range of programmes and projects, the poor accessibility due to fragile road network limits the same.
- The *Dzumsa* is one of the unique and hitherto successful traditional community based institution since the 19th century regulating the sustainable use practices for biodiversity and related conservation initiatives. Such traditions would require further expansion.
- Relatively good populations of endangered mammals like Ladakh Uriyal, Siberian Ibex, Tibetan argali, Tibetan gazelle and Blue Sheep in Trans Himalayan region can be attributed to sacred nature of the landscape, especially Sikkim part, which hitherto restricts hunting. The sacredness value of the region can further be harnessed in right perspectives of conservation.
- Traditionally, being sacred for natives, the black-necked Crane is not hunted (Lachungpa, 2009). Further, following adoption of Indian Wildlife (Protection) Act 1972, Sikkim state forest department has imposed ban on hunting of wildlife; and systematic removal of animal traps has yielded encouraging results in recent years.

Challenges

- Invasion of alien flora (*Chenopodium album, Cuscuta europaea, Sonchus asper,* etc.) is causing threats to native flora of the region. Hence, proper documentation on rate of invasion and areas of intense invasion is needed.
- The HAWs are under tremendous pressure due to increasing population, unregulated tourism and developmental activities.
- Grazing by migratory livestock in the pastures and alpine meadows most often remains unregulated.

Rheum spiciforme – An endangered plant of trans Himalaya
© K. Chandra Sekar

Kunzum Pass in Trans-Himalaya © K. Chandra Sekar

- Excessive use of biomass fuel is a major concern.
- The perceived change in climate and resultant manifestations of global warming has indications of impacts on natural flow of ecosystem services and maintenance of natural ecosystem fabric in Trans-Himalaya.
- Various biotic features including large number of feral dogs and spread of human diseases to wildlife, are emerging as serious concern in Trans Himalaya. Also, the wildlife–human conflicts have become wide spread in the region.
- The local inhabitants, most often, lack proper awareness on conservation and sustainable use value of biodiversity elements. Also, they remain ignorant of potential values of goods and services.
- Rapid migration of younger generation in search of better livelihood options is one of the major concerns.

Other Relevant Information

Most of the Trans Himalayan region, due to its strategic importance, has good presence of armed forces and border police. This uniformed and disciplined manpower with proper education and awareness can be effectively utilized for promoting conservation and generating biodiversity information from remote areas.

Conclusions

- Trans Himalaya region is unique from biodiversity and ecosystem services angle.
- The tourism is a growing sector of ecosystem services in entire Trans-Himalayan region, with a potential to reduce poverty, strengthen socio-economic status of people. However, the tourism needs to be regulated and made ecosystem friendly keeping in view the fragility of the region.
- As agropastoralism would continue to be the major livelihood activity of indigenous people, management of grazing free areas for wild herbivores would be vital for protecting viable population of globally threatened taxa.
- Climate change and global warming are the main factors questioning ecosystem maintenance and survival of faunal and floral elements in future; the societal adaptation to the changing conditions is a must and the science-based awareness programme would be the key of success.

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Shruni lake in alpine zone - Nargu WLS

3 Biodiversity of Indian Northwest Himalaya

The North West Himalayan (NWH) Bio-geographic province of IHR forms the part of Himalayan biogeographic zone and includes the parts of Jammu & Kashmir and Himachal Pradesh (i.e., Kashmir to Sutlej in Himachal Pradesh). The provenience covers approximately 69,000 km^2 area (58% J&K; 42% HP). It represents more of Mediterranean climate. Due to typical topography, unique climatic conditions and wide altitudinal range, the province is well known for diverse habitats, and representative, unique and socio-economically important biodiversity. The region supports flow of famous rivers such as Indus, Jhelum, Chenab and Rabi (Jammu & Kashmir), and Satluj, Yamuna, Beas, Chenab and Rabi (Himachal Pradesh). These river basins have traditionally formed the suitable habitats for human settlement and biodiversity as well.

Richness and Representativeness

Across the wide altitude ranges, the North Western Himalaya supports tropical, sub-tropical, temperate, sub-alpine, alpine and tundra biomes/ecosystems. The vegetation upto sub alpine zone is mainly dominated by broad leaved (deciduous and evergreen), and coniferous forests. Alpine vegetation is, however, represented by alpine scrubs and herbs and tundra vegetation. Evidences suggest that the state of Jammu & Kashmir supports about 3,054 species of plants representing different groups and >500 medicinal plants; and about 814 known faunal species representing mammals (including many globally threatened Angulates), birds, amphibians, reptiles, fishes and insects. In Himachal Pradesh over 4000 species of plants representing Angiosperms, Gymnosperms, Pteridophytes, Bryophytes, Lichens, Algae are known. Also, 643 medicinal plants, 169 wild edibles have been reported. About 1262 faunal species are also known. Of the total known flora, over 30% are native Himalayan species. The non-native flora in the region represents species of Indo-Chinese, Indian, Malesian, Eastern Asia, Irano-Turanian, Mediterranean, Asiatic, Circumboreal, Australian, Amazonian, Brazilian, Andean, North American and other biogeographic regions.

The forests in the region are mainly dominated by *Abies pindrow, Acasia catechu, Acer cappadocicum, A. acuminatum, Aesculus indica, Alnus nitida, Betula utilis, Cedrus deodara, Corylus jacquemontii, Diospyros montana, Hippophae salicifolia, Juniperus polycarpos*, *Miscellaneous, Pinus roxburghii, Picea smithiana, Pinus girardiana, Pinus wallichiana, Populus ciliate, Platanus orientalis, Quercus leucotrichophora, Q. glauca, Q. floribunda, Q. semecarpifolia, Shorea robusta, Taxus baccata* subsp. *wallichiana, Tectona grandis, Ulmus villosa and Ulmus wallichaina*. The alpine biomes are dominated by the scrubs of *Cotoneaster, Juniperus, Lonicera, Rhododendron, Ribes, Rosa, Salix* species, whereas tundra biomes by scattered patches of *Caragana versicolor, Ephedra gerardiana, Hippophae tibetana, H. rhamnoides* subsp. *turkestanica, Juniperus indica, Lonicera* spp., *Myricaria germanica, Ribes glaciale, Rosa webbiana* and *Salix* spp., and herbaceous communities. Known records from J&K part of NWH suggest that the fauna of the region comprises 75 species of mammals, including 19 species of globally threatened angulates; 358 birds; 14 Amphibians; 68 reptiles, 44 fishes and 255 insects (Figure 3.1).

A total of 47 traditional agricultural crops including vegetables and other crops such as tea, etc. and 38 horticultural species are known to be cultivated in the area.

Uniqueness

The NWH biogeographic province is important as estimated 20% species of plants in this province are endemic to the Himalaya. The notable one are *Aconitum heterophyllum, A. falconeri* var. *latilobum, A. ferox, A. laeve, Berberis petiolaris, B. aristata, B. pseudumbellata,*

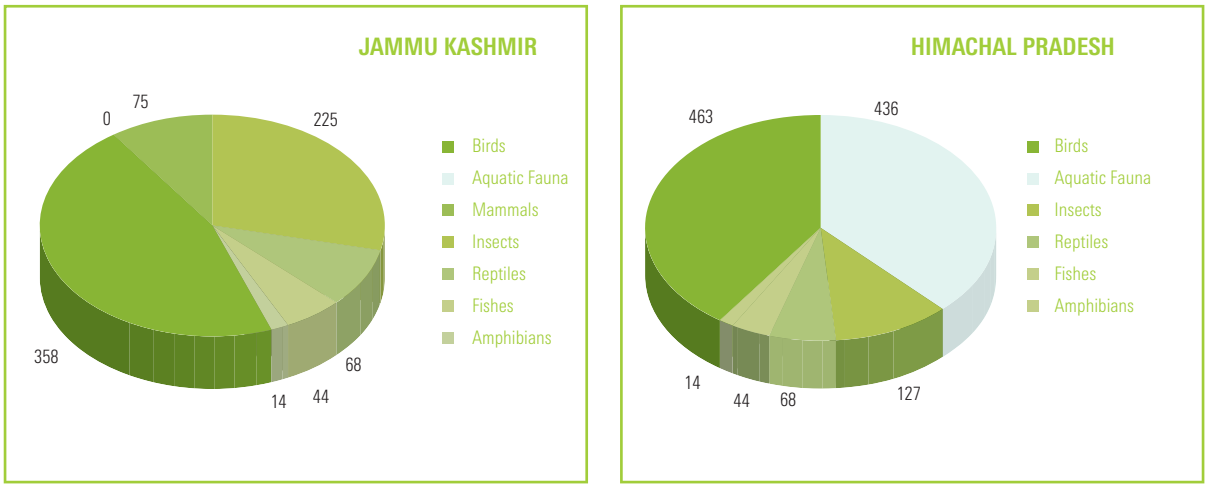


Figure 3.1: Faunal diversity of North Western Himalayan province.

Table 3.1: Critically Endangered Plants of North Western Himalaya

Taxa	Altitudinal range (m)	Occurrence in Trans North Western Himalaya	
		Jammu & Kashmir	Himachal Pradesh
Aconitum chasmanthum (G)	3500–4200	+	–
Aconitum heterophyllum (G)	3300–4200	+	+
Arnebia benthamii (G)	3300–3800	+	+
Arnebia euchroma	2800–4300	–	+
Atropa acuminata	1500–3000	–	+
Betula utilis	3000–4000	+	–
Dactylorhiza hatagirea	2800–4000	+	+
Dienia muscifera	3200–4000	–	+
Gentiana kurroo (G)	1800–2700	+	+
Lilium polyphyllum	2800–3600	+	+
Rauvolfia serpentina	Up to 1000	–	+
Saussurea costus (G)	2800–4000	+	–
Saussurea gossypiphora	4000–5600	–	+
Saussurea obvallata	3500–4500	–	+
Swertia chirayita	1500–2800	+	+

Note: (G), Global significance.

B. kashmiriana, B. lysium, Angelica glauca, Codonopsis affinis, Pleurospermum densiflorum, P. candollii, Lagotis kashmiriana, Lavatera kashmiriana, Saussurea bracteata, S. graminifolia, S. simsoniana, Delphinium kashmirianum, Inula racemosa, Corylus jacquemontii, Buxus wallichiana, Arnebia benthamii, Rhododendron campanulatum, R. anthopogon, Euonymous pendulus, Allium humile, Roylea cinerea, Morina longifolia, Dactylorhiza hatagirea, Salvia lanata, Fritillaria roylei, Cinnamomum tamala, Lilium polyphyllum, Meconopsis acuteata, Fraxinus xanthoxyloides, Pinus gerardiana, Abies pindrow, Pittosporum eriocarpum, Rheum austral, Skimmia laureola, Ulmus wallichiana, etc. The region also supports various critically endangered plants (Table 3.1).

Among the unique faunal species, Himalayan Blue Sheep, Snow Leopard, Tibetan Wolf, Wild Dog, Red Fox, Himalayan Weasel, Marten, Musk Deer, Himalayan Hill Otter, Himalayan Marmot, Tibetan Wild Ass, Tibetan Urial Sheep, Yak, Himalayan Brown Bear, Indian Wolf, Picca, Lammergeyer, Himalayan Griffon, Golden Eagle, Chukar Partridge, Tibetan Partridge, Himalayan Snow Cock, Great Rosefinches, Goldfinch, Red Billed Chough, Snow Patridge, Blue Rock Pigeon, Snow Pigeon, Brahminy Myna, Black Redstart, Jungle Crow, Yellow Headed Wagtail, Brahminy Duck, Guldenstadt'Redstart, Black necked Crane, Western Tragopan, Himalayan Monal, etc., are notable. The traditional practices of forest conservation in the form of Sacred Groves are very popular in the region, especially in Himachal

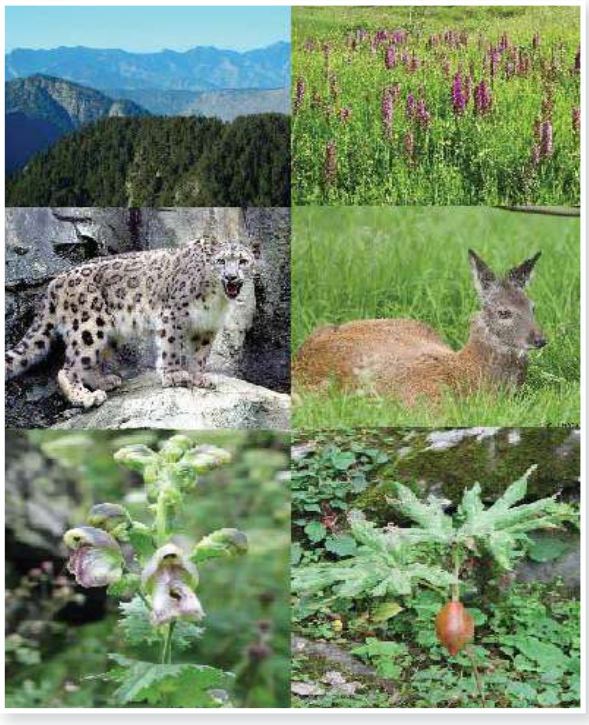
Table 3.2: Some medicinal plants used for various pharmaceutical preparations

Botanical Name	Vernacular names	No. of formulation	Medicinal uses
Terminalia chebula	Hararh	219	One amongst three constituents of famous Triphala
Terminalia bellirca	Bahera	219	As Indian Preparation "Triphala"
Emblica officinalis	Amla	219	Used as digestive & laxative
Adhatoda zeylanica	Vasaka	110	In cough, asthma & bronchitis.
Withania somnifera	Ashwagandha	109	In general & sexual weakness
Cyperus rotundus	Mustaka	102	In gout, nerve tonic, lowers blood pressure
Tinospora cordifolia	Gulancha	88	In periodic fever dyspepsia & general debility.
Berberis aristata	Daruharidra	65	In acute diarrhoea, intermittent fever.
Aegle marmelos	Bael	60	In constitution, amoebic & bacillary dysentery & improve digestion.
Boerhaavia diffusa	Punarnava	52	Promote urination in dropsy & liver disorders
Acorus calamus	Vacha	51	Epilepsy, mental disorders, asthma & stomach disorder.

Pradesh. Over 5,000 Sacred Groves (Sacred Forests: Dev Van, Temple and Cremation) are known from this biogeographic province. These areas are protected due to religious sentiments.

Life-Support Values of Biodiversity

- The diverse ecosystems provide provisioning, regulatory, recreational and supportive services. The rich biodiversity of the province is used by different communities as food / edible, medicine, fodder, fuel, timber, making agriculture tools, fibre, religious, and various other purposes.
- The inhabitants utilize over 643 species of medicinal plants for curing various diseases. Many of these are also used in the Pharmaceutical industries (Table 3.2).



Varying shades of biodiversity in North West Himalaya

- Inhabitants consume 169 species of wild edibles raw, roasted, boiled or cooked. Some notable wild edibles include mushroom (*Morchella esculenta*), Kaphal (*Myrica esculenta*), Kathu (*Fagopyrum debotrys*), Chora (*Angelica glauca*), Fern (*Allium humile*), Lingari (*Diplazium esculentum*), Thangi (*Corylus jacquemontii*), Rhododendron (*Rhododendron arboreum*) flower juice, *Hippophae* fruit juice, and pickle made from various species, etc.
- Bamboos namely, Maggar Bamboo (*Dendrocalamus hamiltonii*), Ningal (*Arundinaria falcata*) and Gauro (*Thamnocalamus spathiflorus*) are used for making various articles, and are major sources of income generation. Pullas prepared from the fibres of *Cannabis sativa* and *Girardiana heterophylla* are highly traded.
- The inhabitants are mainly dependent on agriculture and horticulture for their sustenance and income generation. The major commercial fruits include Apple, Plum, Peach, Apricot, Pear, Cherry, Kiwi, Pomegranate, Persimon, Strawberry, Almond, Walnut, Mango, Litchi, Guajava, Papaya, Grapes and Banana; and crops including vegetables are Mays, Wheat, Barley, Pea, Paddy, Lentil, Rajmah, Potato, Garlic, Mustard, Soyabean, Ginger, Cabbage, Ragi, Kulth and Black Gram.

Cultural Diversity and Biodiversity Linkages

The province is very rich in cultural diversity. It comprises of various cultural groups like Kashmiri, Dogra, Gujjars, Bakkarwalas and Gaddis (in Jammu & Kashmir) and Lahaulis (Swangla & Budhist), Kinnars, Pangawals, Gujjars, Gaddis, Rathis , Kolis, Sulehria, Grith and Kannets (in Himachal Pradesh). Traditionally, most of these are largely dependent on biological resources such as medicinal, wild edible/food, fodder, fuel, timber/house building, fibre, religious and various other purposes for their sustenance. They conserve biodiversity in the form of Sacred Groves, i.e., Sacred Forests, Temples and Cremation Groves.

Initiatives for Conservation and Sustainable Use

- National Biodiversity Action Plan; National Biodiversity Federation Mission; National Biodiversity Refuge Mission; National Mission on Sustainable habitat; National Mission on Sustaining Himalayan Ecosystem; National Mission for a Green India; National Mission for Sustainable Agriculture; National Mission on Strategic Knowledge for Climate Change; Wildlife Protection Act 1972; National Afforestation Programme; National Biodiversity Authority; National Medicinal Plant Board, Protected Area Network; Indian Man and Biosphere Programme (MAB); Botanical Garden Scheme, Launch of CAMPA, inclusion of forestry within NREGA, etc., are some of the major initiatives at national level that support conservation in the region as well.
- State Biodiversity Board; State Medicinal Plant Board; State Climate Change Cell, Establishment and maintenance of Botanical Gardens, Arboreta, Nurseries, etc., at state level are major initiatives.
- Cultivation of medicinal plants; Biodiversity conservation in the form of Sacred Groves (Dev Vans); Restoration of degraded lands, Launch of CAMPA, inclusion of forestry within NREGA, Sanjha Van (JFM), CAT Plan, Compensatory Forestry, etc., at local/community level form major initiatives for conservation.

Challenges

- Biodiversity response assessment and monitoring consequent impacts to understand patterns and processes of biodiversity of the protected and unprotected areas at gene, species and ecosystem levels in relation to climate change.
- Assessment of biomass dependent energy requirement (fuel and fodder resources) of inhabitants and addressing issues emerging from this need.
- Impact assessment of invasive species (exotic/alien, weeds), forest fire and developmental activities (Hydropower projects, roads, etc.) on biodiversity.
- Lack of packages of practices for maintenance and optimal use of sensitive biodiversity components and improvement of bio-resource based livelihood options for indigenous communities.
- Poor network/coordination amongst the State and Central Government Departments and NGOs for conservation of biodiversity.

Conclusions

- NWH province is important from biodiversity point of view, therefore, development of user friendly electronic data base would help in formulation of adequate management plans.
- Harnessing potential of NTFPs including wild edibles, orchids, bamboos, etc. for sustainable livelihood and small scale enterprise development and monitoring biomass dependent energy requirement (fuel and fodder resources) of inhabitants are required.
- Development of packages of practices for maintenance and optimal use of sensitive biodiversity components and improvement of bio-resource based livelihood options for indigenous communities is needed.
- Promotion of awareness and education on conservation and sustainable utilization of bioresources and strengthening network/ coordination with the State and Central Government Departments and NGOs for conservation of biodiversity is required.

Pickle preparation by rural woman for marketing © S.S. Samant

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Amaranth – A typical traditional crop in West Himalaya

4 Biodiversity of Indian West Himalaya

The West Himalaya (WH) biogeographical province of Indian Himalayan Region (IHR) due to its biophysical and sociocultural diversity has long been recognized as one of the most astonishing natural regions in India. The province includes east Himachal Pradesh (HP) and entire Uttarakhand (UK) state (i.e., the area east of Sutlej in HP to Kali in UK). Starting from foothills in the south, the region extends up to snow clad peaks of the Himadri and forms the Indo-Tibetan boarder in the north. Three major river systems, i.e., Ganga, Yamuna, and Sharda (Kali) originate from this region and are source of water, food and hydropower for over 10 millions of people inhabiting upstreams and several millions more in downstreams of northern Indo-Gangetic plains. The province covers an area of 72,000 km^2 (26% HP, 74% UK), of which about 65% is under forests. The unique topography, great variations in altitude, climate and soil types support a wide range of vegetation and ecosystem types endowed with rich faunal and floral diversity. The province has about 14% of its geographical area under Protected Area Network (PAN) as compared to national average of <5%.

Richness and Representativeness

Richness of floral and faunal species is represented under varied vegetation and ecosystem types ranging from sub-tropical deciduous forests to alpine vegetation. Richness of species in different plant and animal groups is depicted (Table 4.1). While considered the threat status, approximately 350 higher plant species and nearly 70 species of pteridophytes are listed

Table 4.1: Floral and faunal diversity in West Himalaya (Uttarakhand)

	Families	Genera	Species
Plant groups			
Angiosperms	**192**	**1198**	**4248**
Dicot	160	950	3420
Monocot	28	240	780
Gymnosperms	**4**	**8**	**48**
Pteridophytes	**10**	**41**	**214**
Bryophytes	**56**	**142**	**323**
Liverworts	31	54	143
Moss	25	88	180
Lichen	**48**	**125**	**521**
Animal groups			
Mammals			102
Birds			521
Insects			1263
Moluccas			56
Amphibians			19
Reptiles			70
Pisces			124
Annelides			57

Source: NBSAP, Uttaranchal, 2002.

Varying shades of colours in biological and physical features of West Himalaya © Sandeep Rawat

under various threat categories from the western Himalaya. The percentage of threatened faunal texa from this region is comparatively higher in different groups such as mammals 38%, birds 21%, reptiles 13%, beetles 2% and fishes 30%.

Uniqueness

The entire landscape of the western Himalaya is referred to as Dev Bhumi. Presence of important religious shrines such as Gangotri, Yamunotri, Kedarnath and Badrinath Dham and Hemkund Sahib make the region sacred and an important tourism destination in the country. Various small and large rivers and streams (rain and snowfed) originating from this region have huge hydropower potentials (about 25,000 MW over 200 locations) and are critical for maintaining hydrological balance. In addition about more than 14% of the geographical area of the region is under protected area network (PAN), and few of these PAs are globally significant such as Corbett Tiger reserve and Nanda Devi Biosphere Reserve (NDBR) having two core zones (Valley of Flowers and Nanda Devi national parks) inscribed under UNESCO natural World Heritage Sites. The region serves as home for number of endemic and threatened floral (e.g. *Aconitum heterophyllum, Dactylorhiza hatagirea, Nardostrachys grandiflora, Podophyllum hexandrum, Taxus baccata,* etc.) and faunal (e.g., Musk dear, Snow leopard, Black bear, Brown bear, Bharal, Himalayan tahr, Serow, Tiger, Elephant, etc.). The traditional settled agriculture exhibits huge diversity of crops, landraces and their wild relatives. Among other, WH is known as the place of origin of the Chipko movement (tree – hugging) of local people that forced the government to put ban on green tree felling in the region in 1974 and subsequently in all fragile hilly regions of the country.

Life-Support Values of Biodiversity

Bestowed with rich biodiversity that provides distinct goods (products) and services, the province has a comparative advantage of the mountain niche products to support income generation and socio-economic development. Local communities derive many essential goods from biodiversity such as food, fodder, fuel, medicine, fibre, timber, non-timber forest products (NTFPs), etc. The services provided by biodiversity include pollination, climate regulation/moderation, nutrient cycling and soil fertility maintenance, hydrological regulation, soil formation and soil functions such as the purification of water and air, the detoxification and decomposition of waste, sedimentation and flood control. Besides, the carbon sequestration is among the most important services provided by WH forest biodiversity to reduce impacts on changing global climate.

Cultural Diversity and Biodiversity Linkages

Biodiversity is at the centre of many religions and culture, which influence its abundance through cultural taboos and norms and regulate how resources are used and managed. It is particularly true for many traditional, tribal and ethnic groups inhabiting the region (i.e., Van Rajis, Buxas, Jodh, Marchas, Tolchas, Bhotiyas, Tharus, Jaunsari and Van Gujjars). The ethnobiological and traditional ecological knowledge available with these groups is immense. Over 1200 plant species in the region are used for various purposes and directly linked with cultural belief systems and have often played a major role in controlling over-exploitation. The cultural practices and regulations indicate the conservation ethics and have a significant effect on the ways how specific species is used and conserved (Box 4.1).

Cultural belief system aligned with biodiversity in West Himalaya

Box 4.1. Cultural and biological diversity linkages

- Cultural and biological diversity are closely intertwined. This is particularly true for tribal and traditional communities of West Himalayan region (WHR) for whom biodiversity is not only a source of well-being but also the foundation of their cultural and spiritual identities. It is particularly apparent in sacred mountain sites or in sacred groves, those areas which are held to be important because of their religious or spiritual significance. For example in the Rudraprayag District of Uttarakhand, Hariyali sacred grove maintain significant populations of threatened tree and shrub species. The grove has greater biodiversity than any of the managed forests in this area.
- Strict rituals, specific harvesting requirements and locally enshrined enforcement of permits regulate the amount of bark collected from *Betula utilis*, a threatened tree of timberline ecosystem which plays key role in local medicine and socio-cultural-religious belief system and keeps bark collection within sustainable limits.

The traditional communities in WH have generated deep knowledge of plants used for various purposes such as medicines in traditional health care systems, mixed cropping and related agronomic practices for crop insurance and maintaining soil fertility. The sacred groves/sacred sites maintained by traditional communities in this region are example of socio-cultural belief system developed mainly for conservation of rich and unique biodiversity.

Conservation and Sustainable use Initiatives

Many initiatives and models of Biodiversity conservation and sustainable development have evolved from the species to the landscape management level with the initiatives of various institutions at different levels. In addition to various national- and state-level programmes, as indicated in other sections, a few specific initiatives in the WH need mention.

- Unique model for livelihood enhancement and biodiversity conservation through participatory action research for resolving policy–people conflicts in Nanda Devi Biosphere Reserve (NDBR) with the effort of GBPIHED with the cooperation of Mac-Arthur – UNESCO.
- The community-regulated livestock and pasture management through rotational grazing are some unique successful examples in alpine meadows of Byans and Niti vallies in western Himalaya.
- Hariyali Devi sacred forests covering an area of about 22 km^2 is typically managed by the Jasholi village institution (Gram Sabha) in district Rudraprayag, Uttarakhand.
- Community conserved areas in India to support moderate use and ensure long-term availability of resources and wild germplasm – "Kalpavirsha" (a NGO), Pune.
- Restoration, afforestation of degraded forest sites, wildlife corridors, forest fire prevention measures and control in fire prone areas with the use of CAMPA funds (Uttarakhand Forest Department – initiatives)
- With the efforts of Ministry of Environment & Forests (Govt. of India), under MAB programme, a significant progress has been made for conservation and management of biodiversity in representative biosphere reserves across the country.
- Established seven (7) medicinal plant conservation areas (MPCAs) for in-situ conservation of globally significant medicinal and aromatic plants – Uttarakhand State Medicinal Plant Board (USMPB).
- Van Panchayats in Uttarakhand state of WH are represented as success story of involvement of community in conserving forests. With the legislative support, the Van Panchayats have now assumed greater roles in conservation and management of forest resources.
- Transboundry biodiversity conservation and management in Mt Kailash Sacred Landscape – a collaborative effort of India, Nepal and China with the cooperation of ICIMOD, Nepal.
- *In-situ* conservation of traditional mountain agrobiodiversity through village community participation in Urgam valley of District Chamoli (a joint initiative of GBPIHED, NBPGR- New Delhi and village community).
- Conservation and management of belowground biodiversity (BGBD) in Nanda Devi Biosphere Reserves of West Himalaya – GBPIHED-KFRI-UAS initiative with the cooperation of JNU-TSBF/GEF/UNEP.

Challenges

- Conservation and management of ecologically and culturally important and economically valuable plants and faunal species found in diverse ecosystems and fall under category of rare, endangered and threatened due to over exploitation, habitat destruction over grazing, illegal collection and poaching (Box 4.2).
- Invasive alien plant species have emerged as major threat in different forest ecosystem types (e.g., *Lantana* in tropical and sub-tropical forests, *Eupatorium* in moist temperate forests and *Polygonum* in alpine meadows), and require strong scientific measures to prevent, control and eradicate such invasive species.
- Loss of mountain agrobiodiversity and traditional knowledge of cultivation is major cause of concern and need effective conservation and management strategies (Table 4.2).

Table 4.2: Area change of traditional crops in Western Himalaya (after Maikhuri *et al*., 1997)

Crops/cropping season	Area (ha/village)		Replaced by	Area declined (%)
	1970–74	1990–94		
Kharif season				
Panicum miliaceum	14.2	4.9	High yielding rice varieties (HYV)	65.5
Oryza sativa	14.2	14.2	High yielding rice varieties (HYV)	-
Avenal sativa	15.8	3.4	Potato	78.5
Fagopyrum tataricum	8.6	1.5	Potato + Rajma	82.5
Fagopyrum esculentum	4.1	0.3	Rajma	92.7
Perilla frutescense	1.3	-	Soyabean	100.0
Setaria italica	2.3	0.8	Soyabean	65.2
Oryza sativa	11.2	11.2	High yielding rice varieties (HYV)	-
Eleusine coracana	9.6	6.1	Soyabean + Amaranth	36.5
Macrotyloma uniflorum	2.1	0.5	Soyabean + Amaranth	100.0
Echinochloa frumentacea	2.5	0.7	Pigeon pea	72.0
Vigna spp.	3.3	-	Pigeon pea + amaranth	100.0
Rabi season				
Triticum aestivam	14.2	14.2	High yielding wheat varieties	-
Hordeum himalayens	17.1	4.7	Potato, Amaranth + Rajma	-
Hordeum vulgare	7.0	1.1	Improved mustard varieties	-
Brassica compestris	2.0	2.0	No change	No change

Box 4.2. *Cordyceps sinensis* (*Kira-jari*)

Cordyceps sinensis (**"*Kira-jari*"**): A rare and unique fungus that grows in alpine meadows above 3500 m asl. Studies in Niti valley highlight that on an average a family of 3–4 members may collect about 1.5–2.0 kg of Kira-jari over a period of two months. The quantity of collection depends upon the skill of collectors. Price of about Rs. 2,50,000 to 3,00,000 per kg were quoted by collectors during 2009--2010. Though the quantum of collection is unknown but it is reported that 300--350 kg per year is collected from the valley which is monetary equivalent to over Rs. 90 million and is illegally trafficked into Nepal from Dharchula (India). It is mostly used in Chinese and Tibetan traditional system of medicine. More recently a study (Srestha and Baba 2013) has indicated the overharvesting of the species and associated degradation in the Himalaya has caused significant challenge to ecology and socio-cultural system in the region.

Kira-jari (*Cordyceps sinensis*) – Adding new dimensions to the local economy

In search of *Kira-jari* – Looming challenge to highaltitude ecology and socio-cultural systems

- Recurrent forest fires (deliberate/accidental) in western Himalayan forests particularly in pine forests is causing irreparable damage to forest biodiversity and therefore fire prevention measures in fire prone areas need top priority.
- Restoration of forests, wildlife habitat and corridors to control and reduce man-wildlife conflict, mainly caused due to crop raiding, livestock depredation and frequent attack on human by wildlife such as wild bear, leopard, elephant, etc.
- Unsustainable harvesting and indiscriminate use of high value medicinal plants has reduced their populations to the large extent and, therefore, requires urgent measures and methods for sustainable harvesting.

Conclusions

- Protection of critical habitats and conservation of biodiversity cannot be achieved without improving the socio-economic conditions of the people living in and around forested areas.
- Inhabitants being the focal point of every conservation efforts, attempts should be made for a balance between conservation, development and people's needs.
- Involved local people in the formulation and implementation of conservation policies and management plan so as to achieve the biodiversity conservation goals.

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Bio-cultural Landscape in Sikkim © Ghanashyam Sharma

Biodiversity of Indian Central Himalaya

5

The state of Sikkim and west Bengal hills form Central Himalayan biogeographic province that covers an area of approximately 12300 km^2 and represents an important biodiversity-rich cultural area in the country. Falling within the Eastern Himalayan Biodiversity Hotspot, the province with its close proximity with Tibetan Plateau and Bay of Bengal has affinity with tropical moist forests in the South and cold deserts in the North. The province also represents the merger of biotic elements from the Indo-Malayan and Sino-Indian biogeographic realms. Due to its location, the province has strong influence of biotic elements of both west and east Himalayan biogeographic provinces.

The province provides a different scenario on richness, variability and evolutionary dynamics. A series of cytogeographical studies on *Buddleia*, *Camellia, Rhododendron*, etc. shows the work of ploidy being responsible for large-scale speciation in the region. Availability of many primitive plants (e.g., *Bucklandia populnea, Holboellia* sp., *Magnolia pterocarpa*, etc.) in such a young landform is yet another riddle which calls for research to resolve the mystery.

Richness and Representativeness

While considering the known biodiversity representation across various groups, following deserve attention:

Orchids (75%), Primulas (57%), Ferns (48%) and Rhododendrons (42%) among floral group, and Butterflies (50%), Birds (45%) and Mammals (31%) represent a large proportion of total known representation in India (Table 5.1). The species diversity patterns in Central Himalaya (Sikkim) as compared to other neighboring areas in Eastern Himalayan region are depicted (Table 5.2).

Table 5.1: Diversity Representation across various groups

Biotic groups	Taxa representation		
	Sikkim Himalaya	% representation for India	% representation for World
Floristic Groups			
Ferns	480	48	4.0
Lichens	506	22	2.8
Orchids	527	57	3.1
Primulas	58	57	13.0
Rhododendrons	38	42	3.8
Bamboo	25	18	1.7
Faunal Groups			
Amphibians	50	19	0.7
Birds	574	45	5.7
Butterflies	689	50	0.4
Fishes	48	7	0.4
Mammals	125	31	2.5
Reptiles	88	17	0.9

Source: Arrawatia and Tambe, 2011.

Agrodiversity in the form of domesticated animals and cultivated plants is very diverse. While the province is well known for large cardamom agroforestry systems, the communities belonging to various ethnic groups (e.g., Nepalese, Bhutiya, Lepcha, Limbu and Sherpas) have contributed for the maintenance of rich indigenous knowledge on bioresources (Anonymous, 2012).

A Lepcha cardamom grower in Sikkim © Ghanashyam Sharma

Uniqueness

- The province represents a contiguity of habitats from sub tropical forests of Sal (*Shorea robusta*) to cold deserts within a distance of less than 100 km.
- Poorvi Botapa, a primitive maize group which bears a close semblance to primitive wild maize so far found only in fossilized form has been discovered in northern Sikkim. Locally called as Muralimakai the plant actually has been found to be growing as two separate variants which are presently known as Sikkim Primitive-1 and Sikkim Primitive-2.
- The alpine Sikkim Himalayan shrub, *Rhododendron nivale*, is the only species in the world with a shrub habit growing at and above 5000 m elevations. This in a way suggests a relatively high species presence in alpine Sikkim Himalaya which, in reality, is represented by over 580 alpine plant species recorded from the region.
- *Scutiger sikkimensis*, the Sikkim Snow Toad, is the only amphibian in the world which survives at 5900 m elevation. It is found in the Lhonak Valley in north Sikkim which also doubles up as the only breeding ground of the very rare Black-necked Crane (*Grus nigricollis*) within the Eastern Himalayan biome.

Societal Importance

- Agrobiodiversity in regard to cash crops and staple food crops (paddy, corn, lentils) provides ample choice on selections imparting difference in quality/ taste/blends. Rich agrodiversity effectively provides products in a cyclic manner at different seasons throughout the year.
- IKS and folklore, etc., on biodiversity provides

Table 5.2: Comparison of biodiversity richness with other East Himalayan areas

Biotic Groups	Eastern Himalaya			
	Sikkim Himalaya	**Bhutan Himalaya**	**Arunachal Himalaya**	**Darjeeling Himalaya**
Floral Diversity				
Flowering plants	4500	5500	5000	4000
Rhododendrons	38	46	61	31
Orchids	527	579	601	453
Ferns	480	411	305	416
Paddy landrace	48	280	182	6
Maize landrace	45	80		12
Bamboo	25	31	50	23
Faunal Diversity				
Birds	574	670	600	210
Mammals	125	200	85	104
Butterflies	689	850	183	
Fishes	48	41	131	71
Land Area (km^2)	7,096	38,394	83,743	3,149

Source: Arrawatia and Tambe, 2011.

Bamboo Prayer Flags in Sacred Karthok in Yuksam, Sikkim
© Ghanashyam Sharma

methods of *ex situ* genepool preservation, valuable storage methods for using bioproducts at a later date, appropriate time for sowing/ cropping/ harvesting, etc., as indicated by various bird calls, insect sounds and weather situations.

- Wild food supplements (edibles) and heath care products (medicinal plants) support directly towards societal sustenance and people's well-being. This aspect was of much more importance in the region till the middle of 20th century.
- Providing cultural support to various regional tribes in carrying out their traditional rituals/cultural beliefs, music/merrymaking and legend/stories/anecdotes.
- Constructional timbers and household/farm implements as well as clothing/draping materials all are derived directly from the local biotic pool.

Conservation and Sustainable Use Initiatives

- "10-Minutes-to-Earth" program observed on 25th June every year for planting over 500,000 seedlings all over the state following the UNEP "Plant for Planet: Billion Trees Campaign" program (initiated in 2009).
- Studies related to regional wetland mapping, snow cover mapping and forest fire, its significance and impact on biotic wealth are being carried out.
- Closing down of "G-firing range" over an area of 17,250 ha acquired by the army establishment in north Sikkim by community/govt. agencies to save multiple alpine habitats.
- Joint Forest Management Committees (158 Units) and Eco-Development Committees (49 Units) working at village block level for vigilance and upkeep of local biodiversity (since 1998).
- Brought out Sikkim Biodiversity Action Plan (2012).

Challenges

- In spite of high percentage of area under forests, deforestation and habitat loss continue to be a constant threats to biodiversity.
- Swelling tourist influx accompanied by lack of control and management is making direct impact on biodiversity and its conservation.
- Rise of developmental projects all over the province is damaging natural habitats
- Population growth escalating every year in the region has direct impact on existing biodiversity
- Cordoning the PAs and ban on grazing have adversely affected and limited the livelihood options for people depending on these as means of primary resource.
- Success in conservation has increased the wildlife populations which now appear in human settlements and resulting in man–animal conflicts of various types and extents.
- Poaching of animals and harvesting of plants has threatened the existence of several sensitive species.

Conclusions

- Province represents rich biodiversity, with uniqueness & societal importance
- There are effective ongoing projects
- Province is experiencing emergent new challenges against biodiversity conservation
- There is a strong compliance to 5 strategic targets of AICHI 2020

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Murung festival of *Apatanis*, Arunachal Pradesh

6 Biodiversity of Indian East Himalaya

The state of Arunachal Pradesh, located in the eastern most part of India bordering Myanmar in the East, Tibet in the north and Bhutan in the western direction, forms the East Himalaya (EH) Biogeographic Province. It covers an area of 83,743 km^2 sharing 2.5% of the total geographical area of the Indian Republic, 15.76% of the Indian Himalayan Region and 43.62% of the Himalayan Biodiversity Hot Spot (Samal *et al*., 2013). The wide altitudinal range (100 to >7000 m asl) within Arunachal has brought about a great diversity of habitats and forest types, and a rich diversity of animal and plant life. The state is well acknowledged for its rich biological and cultural diversity. The state has rich forest cover with highest percentage of highly dense forest (30.60% of the total forest area) and second highest forest cover of 68000 km^2 (81.14% of TGA) in the country (Anonymous, 2012). The state harbours more than 23.5% of flowering plants reported in Indian sub-continent, i.e., about 5000 plant species that include 450 species of medicinal value (Sinha, 2008). It has recently been designated as a globally important endemic bird area.

Culturally, the state is rich being home to 26 major and more than 110 minor tribal communities. According 2011 Census of India, the state with a population of approximately 13.82 Lakh (approximately 0.11% of India's total population) shows relatively low density of population (17 per km^2) as compared to the national average of 382. The state holds highest hydro-power potential in the country (58676.40 MW) having five major rivers: Siang, Subansiri, Lohit, Tirap and Kameng.

Richness and Representativeness

The unique location at the junction of two biogeographic realms contributes to richness of biodiversity of EH, harbouring biological elements from both the Palearctic and Indomalayan realms. As per the millennium biodiversity assessment, in the Indomalayan realm there are 940 species of mammals, 2000 birds, 1396 reptiles and 882 amphibians out of which 544 species mammals, 758 birds, 1094 reptiles and 11 amphibians are endemic, respectively. In the Palaerctic realm, there are 395 species of amphibians, 1528 birds, 903 Mammals and 774 Reptiles out of which 255 species of Amphibians, 188 birds, 472 mammals and 438 reptiles are endemic.

The province is estimated to have nearly 50% of the total flowering plant species of the Himalaya. Among others, the state has the highest number of orchids (580 species) with 12 endangered, 16 vulnerable and 31 near threatened species. As a globally important Endemic Bird Area, it harbours nearly 600 species of birds. The perennial rivers and streams offer life to many aquatic biodiversity, and till date about 213 species of fishes have been described. Recognizing the value of rich biodiversity (ZSI, 2012), the Government of India and state government had made significant contribution by way of establishing 11 Wildlife Sanctuaries, 2 National Parks and 1 Biosphere Reserve in the province. The description of the region as "cradle of flowering plants" by Armen Thaktajan (1969) is quite apt as the Angiosperms form 77.78% of total flora of the region.

Uniqueness

As the province lies in the junction of two Global Biodiversity Hotspots, i.e., Himalaya and Indo Burma, it represents several unique elements. Among others, Arunachal Pradesh is unique in terms of its Rhododendrons as the region is having about 71 species out of which 9 species are endemic (Paul *et al*., 2005). Further, the ecosystem is inhabited by many endemic mammals, including endangered species like Takin, Red Panda, Snow Leopard, Clouded Leopard, and Spotted Linsang. Arunachal is the only region on earth known to harbour all three species of goral – the Chinese goral (*Nemorhaedus caudatus*), the red goral (*N. baileyi*), and the Himalayan goral (*N. goral*). Considering faunal uniqueness, Arunachal represents 10 globally threatened species and 13 restricted range species.

Life-Support Values of Biodiversity

The enormous biodiversity of the province has both tangible and intangible ecosystem services and benefits. The state is the lowest greenhouse gases (GHG) emitting state in India. Less infrastructure development, low level of urbanization, and power generation from renewable source (hydro) are the major factors contributing to low GHG emissions. Further, the forests of Arunachal Pradesh sequester highest quantity of carbon in the country, which is emitted elsewhere. According to the study conducted by the Indian Institute of Forestry Management, the state is giving highest ecological service to the country estimated to worth Rs. 4527293.76 Million (Rs. 4,52,729.376 Crore). The state's total carbon storage value is estimated at Rs. 77,879.609 Crore and Carbon flux at Rs. 458.234 Crore (Anonymous, 2012). Further, the forest-sustained perennial rivers of the state provide water for agriculture, horticulture, fishery and day to day use down in Assam. The indigenous communities of the state continue to be dependent on forest resources for shelter, food, fodder, medicine, performance of traditional rituals and customs, etc. Many wild relatives of cultivated crops like wild Apple, wild Kiwi, wild Bananas, wild Citrus, wild Mango, wild Cherry, wild Litchi, wild nuts, wild Cardamom and many others found luxuriantly growing in natural form in the forests and thus form an important gene pool for future use. More than 90% of state population depends on biomass as primary source of energy for cooking, water heating, space heating, lighting and livestock rearing.

Myoko festival Priest of *Apatanis* (Arunachal Pradesh)

Cultural Diversity and Biodiversity Linkages

The biodiversity rich Arunachal Pradesh is also equally rich and unique socio-culturally. Despite many variations among the communities, there is obvious homogeneity in their social structure; all the communities are endogamous divided in to clans, a kinship based exogamous social unit. These communities have distinct socio-cultural practices and rich traditional ecological knowledge of natural resources conservation and management acquired over the centuries. Richness of forest is maintained through traditional ecological knowledge by means of selective harvesting, as well as by conserving the potential, ritualistic and socio-culturally valued species. The tribe specific distinctive elements have emerged as consequences of living in different habitats and pursuing different economic activities and diverse religions. Few examples are paddy-cum-fish cultivation by Apatanis, a community famous for its skill, custom and indigenous institutions in natural resource management. The life of Nyshi, another community, revolves round difficult shifting agriculture, which still continues to be a livelihood for many tribal communities of the state. In Arunachal Pradesh, indigenous community institutions play an important role in forest protection, management and administration with much of the forests listed as "unclassed sate forests".

Conservation and Sustainable Use Initiatives

- The major policies and acts operational in Arunachal for biodiversity conservation include: (i) Wildlife Protection Act, 1972; (ii) Environment Protection Act, 1986; (iii) Forest Rights Act, 2006; and (iv) Arunachal State Biodiversity Rules, 2011.
- At the national level, out of the Eight Missions of National Action Plan on Climate Change, National Mission for Sustaining the Himalayan Ecosystem aims to conserve biodiversity, forest cover and other ecological values in the Himalayan region. Under, Green India Mission Forests and Horticulture are being targeted. The existing State Policies and programs include social forestry programmes through distribution of seedlings and creation of Apnavan through involvement of people, development of Non Timber Forest Produce (NTFPs) including medicinal and aromatic plants, strengthening of Forest Protection measures including protecting against fire, to improve and extend protected area network for conservation, protection and development of Biodiversity. At the state level, adopted initiatives like Compensatory Afforestation Fund Management and Planning Authority (CAMPA) aim at addressing shifting agriculture and conservation issues.

Challenges

Shifting cultivation, habitat destruction, hunting and biodiversity loss emerge as most serious challenges. Shifting agriculture, commonly known as *jhum*, once considered to be an efficient system of cultivation being sustainable both ecologically and economically,

Namdhapha Flying Squirell © Dhritiman Mukherjee

Shifting cultivation "*Jhum*" – Challenge and opportunities.

is gradually becoming untenable under reduced fallow period. As per the report of *India State of Forest 2011 Assessment*, there is total decrease of 7400 ha of forests as compared to 2009, which includes 500 ha of highly dense forests and 5500 ha of moderately dense forest. However, considering the unique resource ownership and utilization pattern of the shifting cultivators and social and economic dependency of the ethnic communities on this practice, the system needs to be viewed holistically. Prevalence of hunting in diverse forms and lack of opportunities of alternate livelihoods for the forest dependent tribal communities are other major challenges for management of biodiversity.

Conclusions

Inventorization of biodiversity of the region and strengthening of peoples livelihood, skill and participation will help the community capitalize on its indigenous knowledge, protect its IPR and conserve its natural resources. Deciphering and validating the TEK and indigenous best practices will help formulate people-friendly development policies vis-a-vis conservation. The conservation policies should absorb the essence of Forests Rights Act, 2006, respecting tribal peoples symbiotic relation with forests and other forest-related resource use.

Asiatic Golden Cat © Salvador Lyngdoh, WII

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Northeast region – A forested landscape

7 Biodiversity of North East Region

The North East Region (NER) of India consists of the contiguous "Seven Sister" states namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura, along with Sikkim (MoEF 2010). This region, officially recognized as a special category of states, covers an area of 2,62,179 km^2, constituting 7.9% of the country's total geographical area. Located at the tri-junction of Indo-Chinese, Indo-Malayan and Palaearctic biogeographic realms (Takhtajan, 1969), the region exhibits diverse hilly terrain with wide altitudinal range. It is a true frontier region as it has over 2000 km of common borders with Bhutan, Bangladesh, China, Myanmar, and Nepal (Fig. 7.1).

As per the biogeographic classifications (Rodgers et al., 2000; MoEF 2009) the region represents three biogeographic zones and 5 provinces (Table 7.1).

Richness and Representativeness

Roughly, NER contains more than one-third of the country's total biodiversity and represents the Himalayan and the Indo-Burma (Myanmar) Global Biodiversity hotspots. Takhtajan had termed this region as the "cradle of flowering plants", with at least 7,500 species of flowering plants, including 700 orchids, 58 bamboos, 64 citrus. Besides, it has over 28 conifers, 500 mosses, 700 ferns, and 728 lichen species. Some of the important gene pools of citrus, banana, and rice have originated from NER. Of the estimated 800 species consumed as edible plants in India, nearly 300 species occur in the NER. Diversity of Orchidaceae in the region is amazing with > 57% of total Indian orchids. In case of genus *Rhododendron* (*family* Ericaceae) nearly 98% of India has representation in NER (71 species). Rattan, commonly known as cane, with over 26 species (total 60 species in India) and bamboo with 63 species (22 genera) contribute maximum to India in these groups.

The contribution of NE region for faunal diversity can be gauged from following:

- Of the 15 known species of primates in India, 9 occur in NER. Among 6 big cats in India, four– the tiger (*Panthera tigris*), the leopard (*Panthera pardus*), the snow leopard (*Uncia uncia*), and the clouded leopard (*Neofelis nebulosa*) have been reported from the region. All the Indian bear species are recorded from the NER.
- The foothill grasslands and broadleaved forests of NER harbor important populations of Asian elephant, one-horned rhinoceros, and wild water buffalo.
- The region probably supports maximum diversity of birds in the Orient. Among lower vertebrates, 137 species of reptiles 64 species of amphibians are recorded from the region. The NER has reported 3,624 species of insects and 50 molluscs.

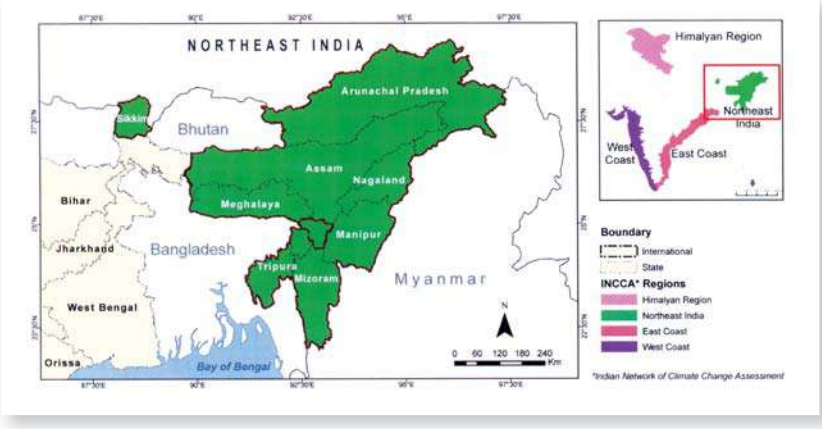

Figure 7.1. The North Eastern Region and its constituent states in India. (*Source*: MoEF, 2010)

Table 7.1: Biogeographic divisions of North East Region

Bio geographic zones	Bio geographic provinces	% of India	Representative Indian States
Trans Himalaya	1 C: Trans Himalaya Sikkim	<0.1	Sikkim
Himalaya	2C: Central Himalaya	0.2	Sikkim & West Bengal Hills
	2D: East Himalaya	2.5	Arunachal Pradesh
Northeast India	9A: Brahamputra Valley	2.0	Assam, Nagaland, Meghalaya
	9B: Northeast Hills	3.2	Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Assam

In general over 54% of the geographic area of the region is recorded as notified forests – reserves, protected and un-classed forest under the control of forest Department. However, the landscapes in NER are predominated by age old agricultural practice – *Jhum* (shifting cultivation, a traditional land use associated with the socio-cultural framework of the indigenous communities). There are various other traditional land-use practices linked with *Jhum*, namely valley rice cultivation, home gardens and traditional plantation systems. The area under *Jhum* cultivation differs widely amongst the states.

The striking feature of socio-economic representativeness of NER includes prevalence of tribal culture (Table 7.2). Region is the home for over 166 separate tribes, 160 schedule tribes and over 400 other tribal and sub-tribal communities and groups, speaking a wide range of languages.

Table 7.2: Tribal population in the NE States of India (2001)

States	India's ST population (%)	Total population of State (%)
Sikkim	0.13	20.6
Arunachal Pradesh	0.84	64.2
Manipur	0.88	32.3
Meghalaya	2.36	85.9
Mizoram	1.0	94.5
Nagaland	2.1	89.1
Tripura	1.18	31.1
Assam	3.9	12.4

Source: Census of India 2001.

Uniqueness

The NER holds great significance from ecological and evolutionary point of view. This region harbours largest number of endemics and Schedule I species as compared to any other part of India (MacKinnon and MacKinnon 1986). The region represents some of primitive angiosperm families (e.g., Magnoliaceae, Degeneriaceae, Himantandraceae, Eupomatiaceae, Winteraceae, Trochodendraceae, Tetracentraceae, and Lardazabalaceae). Specific primitive genera include *Alnus, Aspidocarya, Betula, Decaisnea, Euptela, Exbucklandia, Haematocarpus, Holboellia, Houttuynia, Magnolia, Magnolietia, Pycnarrhena* and *Tetracentron*. NER is known for high evolutionary activities as evident from the cytogeographic studies on *Rhododendron, Camellia, Magnolia, Budleia,* etc. Of the total 8 sub-centers of plant origin in India, the region represents 2 sub-centers (i.e., Eastern Himalaya and North Eastern Region). These sub-centers respectively contribute 82 and 132 species of wild relatives, ref. Table 7.3 (Arora & Nayar, 1984; Arora, 1997).

Table 7.3: Diversity of wild relatives in the Himalayan sub centers

Category	Distribution in Himalayan Sub-Centers		
	West Himalaya	East Himalaya	NER
Cereals and millets	29	07	16
Legumes	09	05	06
Fruits	37	32	51
Vegetables	25	12	27
Oilseeds	06	03	01
Fibers	04	04	05
Spices and condiments	10	09	13
Miscellaneous	05	10	13
Total spp. Diversity	125	82	132

Vavilov considered the north eastern region of India as "Hindusthan Centre of Origin of Cultivated Plants", which is very important for tropical and subtropical fruits, cereals, etc.

Studies have revealed Assam–Burma–Siam–Indo-China region as the center of origin of *Musa*. The region is

rich in *Citrus* wealth with nearly 64 taxa of *Citrus* in wild. Also, NER is the centre of origin for 5 species of palms of commerce – coconut, areca nut, palmyra palm, sugar palm and wild date palm (Rao, 1993). Among wild and domesticated faunal elements, region harbours wild chicken, zebu, mithun, yak, etc.

The prevailing primitive agricultural system of raising crops under stress conditions in the region have resulted in much variability, particularly in adaptive traits. Most of the hilly terrain in the region is under shifting cultivation and several promising, agronomically and physiologically well adapted types/land races belonging to diverse crop species occur in this region.

The region is the habitat of many botanical curiosities and rarities, including *Sapria himalayana* (family Rafflesiaceae) - one of the largest root parasites. Among insectivorous plants *Nepenthes khasiana*, endemic to Meghalaya and listed in Appendix I of CITES and placed in Schedule VI of the Wildlife (Protection) Act, 1972, and two species of *Drosera* (*D. peltata and D. burmanii*) are important. Many families represented by a solitary genus with one or two species are found in

Table 7.4: New plant discoveries during year 2010 from NE region of India

S.No.	New species/var./sub spp.	Family	NE State from where discovered
Angiosperms			
New Genera			
1.	*Larsenianthus (4 spp)*	Zingiberaceae	NE India
2.	*Stapletonia (1 sp)*	Poaceae	Arunachal Pradesh
New Species/varieties/sub species			
1	*Bambusa dampaeana*	Poaceae	Mizoram
2	*Boehmeria listeri*	Urticaceae	Arunachal Pradesh
3	*Boehmeria manipurensis*	Urticaceae	Manipur
4	*Cephalostachyum longwanum*	Poaceae	Nagaland
5	*Coelogyne pendula*	Orchidaceae	Mizoram
6	*Dendrocalamus manipureanus*	Poaceae	Manipur
7	*Epigeneium arunachalense*	Orchidaceae	Arunachal Pradesh
8	*Heteropanax dhruvii*	Araliaceae	Arunachal Pradesh
9	*Larsenianthus arunachalense*	Zingiberaceae	Arunachal Pradesh
10	*Larsenianthus assamensis*	Zingiberaceae	Assam
11	*Dendrobium falconeri var. senapatianum*	Orchidaceae	Manipur
12	*Morus macroura var. laxiflora*	Moraceae	Arunachal Pradesh
13	*Tibetoseris depressa sub sp gauri*	Asteraceae	Sikkim
Ferns and Fern allies			
14	*Pteris mawsmaiensis*	Preridaceae	Meghalaya
Bryophytes			
15	*Leptolejenea mirikana*	Lejeunaeceae	West Bengal Hills
16	*Leptolejenea udarii*	Lejeunaeceae	Sikkim
17	*Notoscyphus darjeelingensis*	Jungermanniaceae	Sikkim
Lichens			
18	*Leirreuma subpatellum*	Graphidaceae	Arunachal Pradesh
19	*Pyrenula darjeelingensis*	Pyrenulaceae	
Fungi			
20	*Russula khanchanjungae*	Russulaceae	Sikkim
21	*Russula tsokae*	Russulaceae	Sikkim
22	*Phallus calongei*	Phallaceae	Sikkim
23	*Russula griseocarnosa*	Russalaceae	Sikkim
Algae			
24	*Stigeoclonium iyengarii*	Chaetophoraceae	Sikkim

Nepenthes khasiana – A pitcher plant in North East Region

this region, for example Coriariaceae, Nepenthaceae, Turneraceae, Illiciaceae, Ruppiaceae, Siphonodontaceae, and Tetracentraceae.

The region, being remote and inaccessible in most cases has not been explored completely and holds great potential for new plant and animal discoveries. For instance, during year 2010, two new genera and 24 new plant species have been discovered/ described by different workers from NE region of India, ref. Table 7.4 (BSI, 2011).

Recently reported occurrence of a new species of barking deer, the leaf deer (*Muntiacus putaoensis*), from the forests of Arunachal Pradesh (Dutta *et al*., 2003) and more recent discovery of the Tawang macaque (*Macaca munjala*) as a new record for India, justify that much is yet to be identified, named and studied in NER. Regarding faunal uniqueness following may be highlighted:

- The golden langur (*Trachypithecus geei*) is one of the most localized species discovered in the Chakrashilla Hills Reserve in Dhubri District of Assam (Budruk, 1996). This Schedule-I animal is listed in Appendix-I of CITES. In Tripura, within 5.8% of the state's protected area, seven species of primates are distributed (Gupta, 1994). The stump-tailed macaque (*Macaca arctoides*) and the northern pigtailed macaque (*M. leonina*) have sympatric distributions in NER and both have become endangered. The slow loris (*Nycticebus bengalensis*) inhabits tropical forests in NER.
- The Indian population of the clouded leopard is restricted to the NER. Presence of snow leopard has been confirmed in Khangchendzonga National Park of Sikkim and Mago Chu valley of Tawang in Arunachal Pradesh.
- The red panda, protected under Schedule I of the Indian Wildlife (Protection) Act, 1972, and listed in Appendix I of CITES and as endangered by IUCN, is reported in NER. The region forms the western end of range of the Malayan sun bear (*Helarctos malayanus*).
- The elephant population in Assam is one of India's largest and most important. In NER the great Indian rhinoceros (*Rhinoceros unicornis*) is now restricted to Kaziranga, Pabitora, and Orang in Assam.
- The brown-antlered deer (*Cervus eldi eldi*), endemic to Manipur, is most localized subspecies of deer in the world. The pygmy hog (*Sus salvanius*), the smallest and the rarest wild suid in the world, has few isolated wild populations in NER. The newly discovered Chinese goral (*Naemorhedus goral*), the red goral (*Naemorhedus baileyi*), the takin (*Budorcas taxicolor*), and the serow (*Capricornis sumatraensis*) are other important species in NER.
- Of the seven Endemic Bird Areas (EBAs) in the country, two EBAs – the eastern Himalaya and Assam plains are in NER. With respect of birds some of the peculiarities include: recently reported Elliot's laughing thrush (*Garrulax elliotii*) and the brown-cheeked laughing thrush (*G. henrici*); the Sangte valley of Arunachal Pradesh being only habitat for wintering black-necked crane (*Grus nigricolis*); majority of world population of the greater adjutant (*Leptoptilos dubius*) is confined in Assam; presence of globally threatened species like the spot-billed pelican (*Pelicanus philippensis*), the black-necked stork (*Ephippiorhyncus asiaticus*), the lesser adjutant (*Leptotilos javanicus*), and the pale-capped pigeon (*Columba punicea*); availability of endemic swamp francolin (*Francolinus gularis*) and largest global population of globally rarest bustard, Bengal florican (*Houbaropsis bengalensis*).
- The gharial (*Gavialis gangeticus*), recently reported chelonian species, *Amyda cartilaginaea*, rediscovered black softshell turtle (*Aspideretes nigricans*) have great conservation significance.
- *Python reticulatus*, the largest snake in India; the king cobra (*Ophiophagus hannah*), *Typhlops jerdoni, T. tenuicollis, Stoliczkaia khasiensis, Elaphe mandarina, Oligodon melazonotus, Xenochrophis punctulatus, Bungarus bungaroides*, and *Trimeresurus jerdoni* are a few examples of elusive and rare snakes of NER.
- The Orang Wildlife Sanctuary in Assam is the only known site for the Orang sticky frog (*Kalophrynus orangensis*).

- One of the largest known tropical Lepidoptera -the atlas moth (*Attacus atlas*), is found in NER. *Princeps polyctor ganesa* from NER is one of the most beautiful butterflies in the country, while *Erysmia pulchella* and *Nyctalemon patroclus* are beautiful moths that occur in the region.

Socio-Cultural Significance

About 38.5 million people inhabit the region of which 88% population is rural. Barring Mizoram (19.47%), the NE states have higher proportion of the people below poverty line (Arunachal Pradesh: 33.47; Meghalaya: 33.87; Manipur: 28.54; Nagaland: 32.67; Tripura: 34.44; Sikkim: 36.55%) as compared to the national average (26.10%). The inhabitants depend heavily on bioresources for sustenance. The economic potential of Himalayan medicinal plants, including those of NER, and their contribution in providing novel bio-molecules is well recognized. Frequent and large consumption of wild edibles by poor tribal communities in NER meets their protein, carbohydrate, fat, vitamin and mineral requirements (Sundriyal and Sundriyal, 2001). Other reports suggest wild edibles also generate substantial income to the poor rural populace in the region. A large number of orchid genera, with considerable diversity in NER, have been recognized with commercial value (e.g., *Dendrobium, Paphiopedium, Vanda, Phaius, Celogyne, Cattleya, Cymbidium*, etc.). Likewise diversity of rattan and bamboos in the region has significant socio-economic value for the region.

Being a forest dominated landscape there is a need to attach value to these forests in particular their services. The rough value of ecosystem services that have been estimated for forests in Himalaya, including the forests in NE states is huge (Table 7.5). There is a growing realization to recognize such values emanating from regional forests and develop mechanisms for compensations/incentives to people who have contributed towards maintenance of such services.

Biodiversity Conservation Initiatives

- The NER states have received considerable attention under PA network programme with 16 National Parks and 53 Wildlife sanctuaries covering an area of 6912 km^2 and 11,261 km^2, respectively. Besides PAs, NER is well represented under coverage of Biosphere Reserves (BRs). A total of five BRs (Dehang–Dibang, Arunachal; Dibru-Saikhowa and Manas, Assam; Khangchendzonga, Sikkim; Nokrek, Meghalaya) have been established in the region. Among others, three wetlands (i.e., Deepor Beel – Assam, 4000 ha; Rudrasagar Lake – Tripura, 240 ha; Loktak Lake – Manipur, 26600 ha) with global significance in NER have been listed as Ramsar sites.
- As for other parts in the country, the National Biodiversity Action Plan (NBAP) of India provides major opportunity to address the issues of conservation and sustainable use in the region.
- The *Scheduled Tribes and Other Traditional Forest Dwellers* (*Recognition of Forest Rights*) *Act, 2006*, which recognizes and vests forest rights and occupation in forest land in forest dwelling Scheduled Tribes and other traditional forest dwellers who have been residing in such forests for generations but whose rights could not be recorded, has significant implications for NER.
- The National Mission on Sustaining Himalayan Ecosystem under National Action Plan on Climate Change (NAPCC) 2008, that aims at evolving management measures for sustaining and safeguarding the Himalayan glaciers and the mountain ecosystem, will have considerable relevance for NER region.

Conclusions

Considering the uniqueness and richness of biodiversity in the target region, intricate linkages of human and natural resources, and realizing the sensitivity of biodiversity elements of the region for human and climate induced changes, following recommendations can be made:

- Give special attention to sustain the ecosystems through conscious efforts for conserving all the representative systems in the region and promote natural resource based livelihood options for indigenous communities.
- Establish integrated regional biodiversity and climate change information system with distributive linkages for easy storage, retrieval and dissemination, and also having linkages with the national database.
- Place special attention to maintain the evolutionary significance of Traditional Ecological Knowledge (TEK) in the region and encourage and promote practice of establishing "Community Conserved Areas" (CCAs) in the region.
- Ensure community support for maintaining and conserving the uniqueness of biodiversity by way of promoting the concept of 'natural cultural landscape' which sees cultural and biological diversity as mutually supportive.
- Promote sustainable use concept which attempts to establish linkages between conservation

Table 7.5: Forest Ecosystem Services (ESs) provided by different Northeast states of India

Himalayan State	Value of ESs as of 1994 (billion rupees)
Sikkim	14.02
Arunachal Pradesh	232.95
Manipur	59.67
Meghalaya	55.16
Mizoram	56.61
Nagaland	49.39
Tripura	20.40
Total IHR	**944.33**

Source: Singh, 2007.

Loktak Lake in Manipur with Phumdi (Floating Vegetation) © Sangeeta Angom

and economic growth, and recognizes that the bioresources are a source for sustainable income.

- Build scenarios for future population projections for each NE state and accordingly plans for meeting the demand.
- Identify appropriate *Jhum* practices and propagate those for benefit of people and environment. Technologies to complement rather than those focused on the replacement of *Jhum* are likely to work.
- Give due consideration to the concept of PES (Payment for Ecosystem Services realizing) the contribution of the region for maintenance of Ecosystem Services (e.g., forests and their goods and services).
- Strengthen proper coordination for management of biodiversity under changing climate scenario across various NE States of India and neighbouring countries through appropriate Regional Cooperation Frameworks on transboundary matters.

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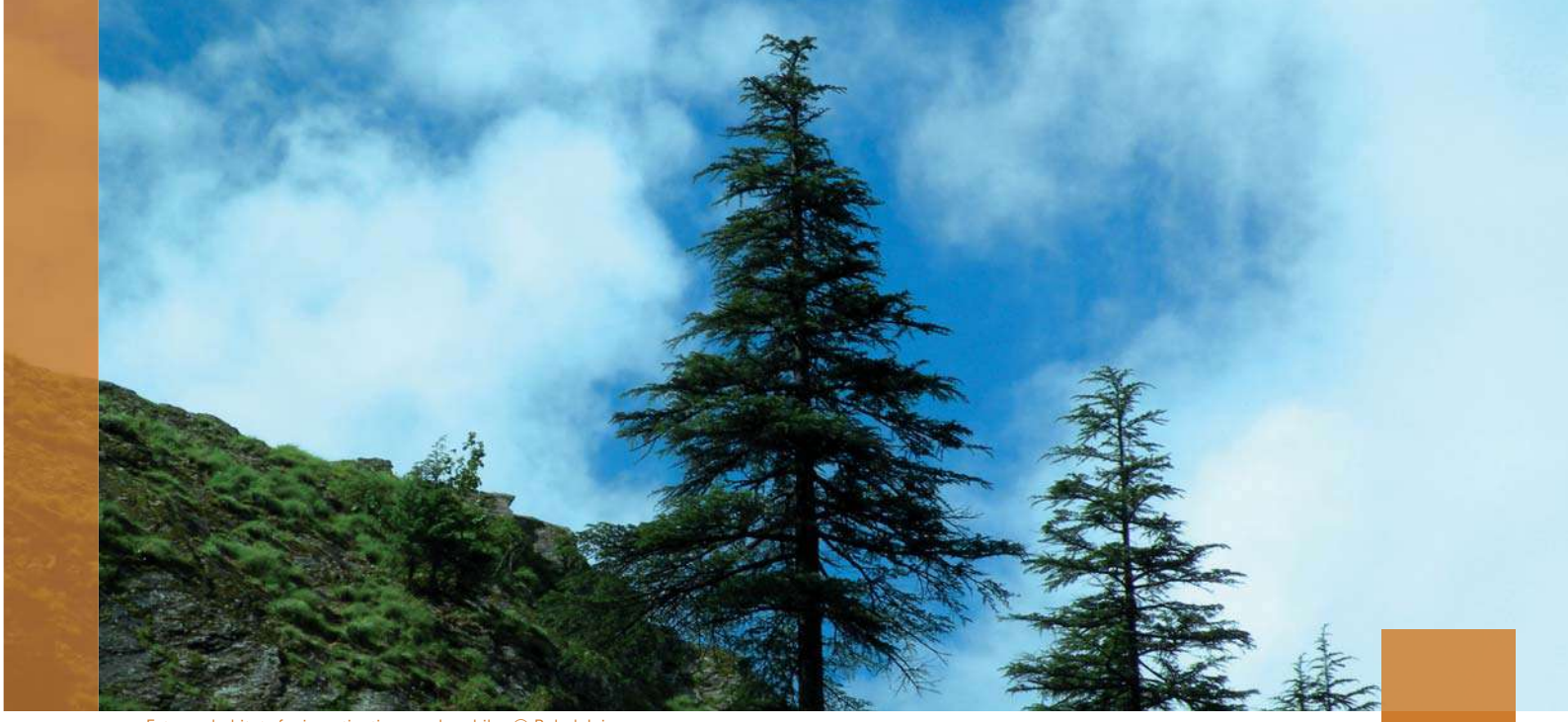


Extreme habitats for investigating psychrophiles © Rahul Jain

8 Microbial Diversity

Biotechnological Applications for Harnessing Commercial Potential

Microorganisms are ubiquitous in nature and form vital components of all known ecosystems on earth. Their ubiquity is attributed mainly to the small size, easy dispersal, ability to survive and multiply in diverse habitats, their metabolic versatility and flexibility to utilize a wide range of substrates as source of nutrients. One of the fascinating attributes of microorganisms is that some have evolved to thrive under "extreme" conditions that are too harsh for the animals and plants. The microorganisms that thrive under extreme environments, from polar deserts to geothermal springs, are known as "extremophiles". Such microbes contain enzymes which function in extreme environments, and have several biotechnological applications. Extremes of temperature, pH, oxidation-reduction potentials, salinity and humidity, and various combinations thereof, that characterize many of the diverse terrestrial and aquatic habitats, are colonized only by the microorganisms. During the major climatic and geological events, the least affected life forms are microorganisms.

Richness, Representativeness and Uniqueness

The Himalayan region presents great variation, particularly in respect of topography as well as geographic and climatic conditions; this variation, in turn, supports a wide variety of habitats. Hot springs-manifestation of geothermal activity, provide niche habitat for a diversity of microorganisms, thermophiles in particular. The low temperature environments, such as the glaciers and cold deserts, provide excellent opportunity for investigating the psychrophiles. The rhizosphere of diverse vegetation, growing under low temperature environments, is colonized by selected groups of microorganisms. Unique agricultural practices, such as shifting cultivation (slash and burn), extend opportunity to understand the diversity of microorganisms as influenced under man-made ecosystems. Himalayan rivers, mainly due to anthropogenic activities, are also rich source of microbial diversity (Table 8.1). Various formes of microbs are described below.

Thermophiles: Microorganisms that grow at temperature ranging 45–113 °C are referred as thermophiles. The high temperature environs are associated with volcanic activity, e.g., the hot springs. Such natural habitats have probably existed throughout the time in which organisms have continued to evolve on the planet earth. Diversity of thermophiles associated with the hot spring sites in IHR has received attention. The microorganisms isolated from these sites have been grouped as thermotolerants, thermophiles, and

Table 8.1: Microbial diversity in IHR

Ecological niche areas	**Low temperature environments** (e.g., Cold desert, Glaciers)	**High temperature environments** (e.g., Hot springs)	**Rhizosphere, Agriculture, forest soil**	**Prescribed fire under shifting cultivation, Forest fire**	**Himalayan rivers**
Microbial communities	Psychrophiles, psychrotrophs	Archea,thermophiles, hyperthermophiles, thermotolerants	Plant growth promoting microorganisms	Thermophiles, thermotolerants	Biological indicators, bacteriophages, pathogens

Hot spring – Habitat for thermophiles

hyperthermophiles. These investigations revealed the dominance of bacteria, mainly species of *Bacillus* and *Geobacillus*. The representative species have been identified as *Bacillus firmus*, *B. smithii*, *B. subtilis*, *Geobacillus kaustophilus* and *G. stearothermophilus*.

Psychrophiles: Psychrophiles are found in permanently cold environments. The colder regions in IHR, e.g., cold deserts and glaciers, represent ideal sites for exploration of cold tolerant microbes. A large number of *Bacillus* and *Pseudomonas* species have been isolated from low temperature environments. Several pigmented psychrotolerant species, belonging to genera, such as *Micrococcus*, *Nocardia*, *Rhodococcus*, *Serratia* and *Streptomyces* have been isolated frequently. Such environs have also been found to be colonized by several species of fungi, mainly those belonging to *Penicillium*, *Aspergillus*, *Trichoderma* and *Paecilomyces*, and yeasts.

Rhizosphere microorganisms: The rhizospheres of diverse vegetation, under low temperature environments of IHR, are found to be colonized by a variety of microorganisms including mycorrhizae and endophytes. Investigations on the rhizosphere effect and the associated microflora observed in plants growing under temperate and alpine conditions have led to interesting findings. The rhizoflora of Himalayan trees, experiencing harsh climatic conditions, such as low temperature, heavy rainfall and winter snow, undergo successional changes due to a range of biotic and abiotic factors resulting in the development of specific microbial communities.

Microbes under Fire: Fire, either as a natural or anthropogenic activity, is likely to influence the microbial dynamics which in turn affects fertility of soil. Shifting cultivation (slash and burn), locally known as "*jhum*", is a predominant form of agricultural practice in hills of northeast India. The survival and dominance of plant growth promoting microorganisms (mainly species of *Bacillus*, *Streptomyces* and *Trichoderma*), after fire operations, have been reported recently.

Water microbes: Himalayan rivers are considered sacred and find an important place in Indian culture. These rivers are also rich source of microbial diversity. The anthropogenic activities performed through these water bodies give a way to colonization of enteric pathogens. Occurrence of coliform bacteria, mainly *Escherichia coli*, is considered as biological indicators for monitoring the water quality with a view of bacteriological pollution. It is indicative of the presence of pathogenic bacteria, such as species of *Enterobacter*, *Proteus* and *Staphylococcus*, of intestinal origin.

Biotechnological Applications

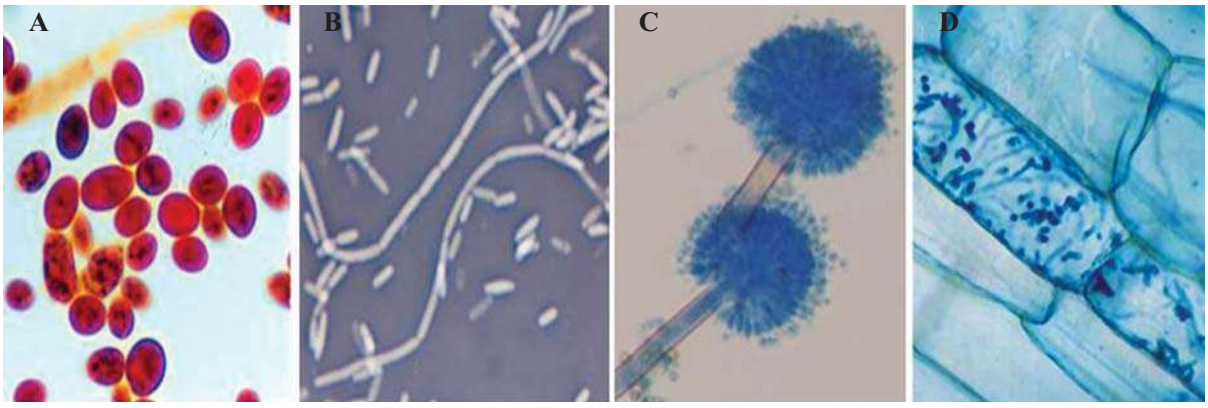
Biotechnological applications of microbial resources mainly revolve around the discovery of bioactive compounds, their taxonomic and genetic diversity, and their ability to colonize various environments. The extraordinary diversity of microorganisms is based on their remarkable metabolic plasticity and genetic adaptability resulting in the production of unique, often novel biologicals. This has potential for the development of technologies for the production of a wide array of compounds, such as, antibiotics and therapeutic agents, biofertilizers and pesticides, fermented foods and beverages, bioleaching of metals, generating biofuels, monitoring air pollution, waste water treatment, bioremediation, and as tools in biomedical research. Extremophiles have been characterized with a view to produce industrially useful enzymes, such as amylase, chitinase, cellulase, lipase, protease, taq polymerase, etc. Isolation, screening, characterization for desirable traits, such as nitrogen fixation, mineral solubilization, production of antimicrobials, has led to the development of cold tolerant microbial inoculants for field application under colder regions of mountain ecosystem (Table 8.2).

Documentation and Conservation

With advances in the knowledge and understanding of this subject, the pivotal role of documenting biodiversity, at the global level, and the importance of conservation of the biological gene pool has begun to receive the much needed and increased attention in the recent times. It needs to be emphasized that large amounts of biological material may not be stored physically for use in the future. It may be adequate only to store tissues, small samples of soil, etc., as frozen micro-ecosystems. While the pure microbial cultures can be maintained by regular subculturing and deep-freezing methods, additional efforts, such as, use of modified media, oligotrophy, along a variety of growth conditions like pH and temperature levels and prolonged incubation, are required for isolation and conservation of the Himalayan microbes including extremophiles.

Table 8.2: Ecological and Biotechnological importance of microbial communities

Ecological Importance	Biotechnological Importance
Diversity	Extremozymes and Secondary metabolites
Resilience	Antibiotics and therapeutic agents
Associations	Fermented foods and beverages
Adaptations	Biopesticides and biofertilizers
Cope-up mechanisms	Bioleaching of metals
Biodegradation	Waste water treatment
Bioremediation	Biotechnological tools



Diversity of Microbes (A–D)

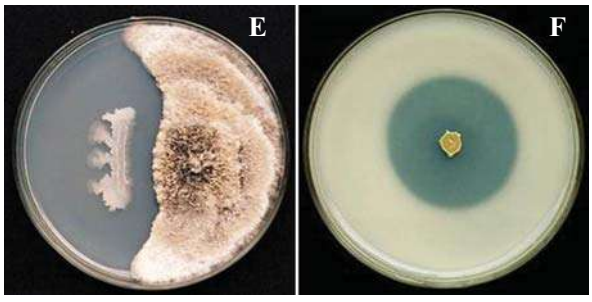
Culture Collections and Linkages

Establishment of culture collections with a view to conserve microbial diversity under *ex situ* conditions is important; such collections also provide ready availability of pure microbial cultures for carrying out specific investigations as well as the essential raw material (cultures) for developing novel products. Microbial culture collections are recognized as germplasm banks which are a storehouse of resources for bioprospecting. While a collection of microbial cultures, isolated from different locations in IHR, has been initiated in the Institute GBPIHED, the cultures are also accessioned in the National / International repositories, e.g., MTCC (Institute of Microbial Technology, Chandigarh, India), MCC (National Centre for Cell Science, Pune, India), ITCC (Indian Agricultural Research Institute, New Delhi, India), NFCCI (Agarkar Research Institute, Pune, India), ARS Culture Collection (NRRL, Illinois, USA), DSMZ (GmbH German Collection of Microorganisms and Cell Cultures, Germany). Similarly, the nucleotide sequences are accessioned regularly with International gene banks, such as NCBI (Maryland, USA).

Global/ National / Regional / Local Relevance

National and Global

- Documentation and conservation of extremophiles
- Microbial culture collection from IHR
- Linkages with National / International Culture Collections and Gene Banks
- Potential applications (source of novel enzymes and cellular metabolites)
- Potential for Addressing the Green India Mission



Biotechnological applications of microbes (E, F)

Regional

- Use of microbial cultures / inoculants under similar edaphic and climatic conditions

Local

- Bioinoculants for improving local crop production / rehabilitation of degraded landscapes / biodegradation / value addition of traditional fermented foods / cleaning of affected sites, etc.

Challenges

- Harnessing maximum culturable diversity
- Exploration of unculturable diversity
- Role of "Viable but not culturable" (VBNC) microorganisms
- Legitimate use of microbial resource
- Maximizing production of secondary metabolites of industrial value
- Developing linkages between Regional culture collections (Laboratory based) and National / International Depositories

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Forest-Agriculture landscape- rich habitat for soil fauna © K. Chandra Sekar

9 Micro and Soil Fauna

Soil biodiversity is important for stabilizing and regulating the earth's climate. It is a vast frontier and potential gold mine for countless new genes and biochemical pathways to probe for enzymes, antibiotics, and other useful agricultural and industrial products. The diversity of soil fauna in orders of magnitude is higher than above ground diversity. However, the life in soil is under-valued and neglected in biodiversity debates.

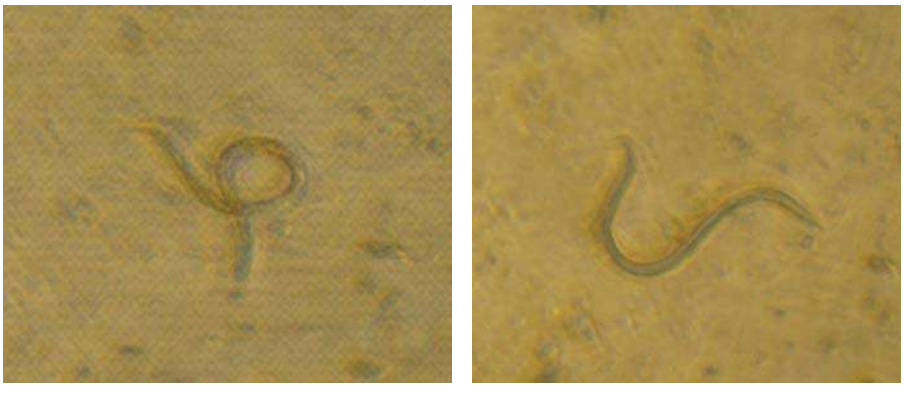
The invisible soil biota which gives rise to healthy soil and subsequently supports healthy plants and animals is losing its genetic diversity due to injudicious use of pesticides, unabated soil pollution and negligible or no replenishment of organic residues. The life in the soil needs to be unraveled and understood, only then we can conserve and better utilize its life-sustaining services.

The soil fauna operate at three levels of resolution: (i) the micro-food web involving nematodes, protozoa and their predators; (ii) litter – transformers involving meso fauna, principally mites and springtails and some macrofauna, and (iii) ecosystem engineers, e.g., earthworms which build organ mineral structures that create habitats for smaller organism. The interactions that occur at each of these three scales are critical in determining microbial activity which is in turn important for regulating the functions of the below-ground subsystem.

Richness and Representativeness

The Himalaya has been recognized amongst the 34 global biodiversity hotspots. The region has a distinct geographic and ecological entity and the variations in topographical features along three dimensional frame work causes diversity in climate and habitat conditions within the region. Data for Himalayan soil fauna are few and fragmented. Few studies have been reported for earthworms and nematodes in agroecosystems and natural forests.

The earthworm diversity and abundance in a sacred grove of Garhwal region was estimated. The exotic and endemic species occurrence under forest and agroecosystems are included (Table 9.1). Earthworm species richness in a village landscape in Himalaya was 8, which was within the range of reported local richness 5–12 species (Geissen *et al*., 2009). Species richness and community structure within land use, however, is highly



Active Nematodes as seen under simple microscope

Table 9.1: Distribution of endemic and exotic earthworm species in natural and derived ecosystems in the Hariyali sacred landscape

	Endemic species	Exotic species
Forest Ecosystem		
Oak dominated mixed forest	*Eutyphoeus sp., Drawida nepalensis, Perionyx sp.*	
Pine dominated mixed forest	*Drawida nepalensis, Perionyx sp.*	*Allolobophora parva, Octochaetona beatrix*
Pine forest	*Drawida nepalensis*	*Allolobophora parva*
Agroecosystem		
Oak irrigated	*Drawida nepalensis, Lennogaster pusillus*	*Octochaetona beatrix*
Pine irrigated	*Drawida nepalensis, Lennogaster pusillus*	
Oak rainfed	*Drawida nepalensis, Lennogaster pusillus*	*Amynthas corticis*
Pine rainfed	*Drawida nepalensis, Lennogaster pusillus*	*Amynthas corticis*

Source: Sinha *et al*., 2003.

Table 9.2: Nematode genera classified across trophic groups from paddy-foxtil-millet soil and c-p ranking

Bacterivores	Fungivores	Herbivores	Omnivores	Predators
Mesorhabditis (1)	*Tylencholaimus (4)*	*Psilenchus (2)*	*Prodorylaimus (4)*	*Clarkus (4)*
Caenorhabditis (1)	*Dorylaimoides (3)*	*Tylenchorhynchus (2)*	*Mesodorylaimus (4)*	*Prionchulus (4)*
Cephalobus (2)	*Promumtazium (4)*	*Helicotylenchus (2)*	*Thornenema (4)*	*Coomansus (4)*
Eucephalobus (2)	*Aphelenchus (2)*	*Hemicriconemoides (3)*	*Opisthodorylaimus (4)*	*Mylonchulus (4)*
Acrobeles (2)		*Xiphinema (5)*	*Morasia (4)*	*Paramylonchulus (4)*
Acrobeloides (2)		*Trichodorus (4)*	*Eudorylaimus (4)*	*Itonchus (4)*
Chiloplacus (2)		*Paratrichodorus (4)*		
Zeldia (2)				*Discolaimus (5)*
Pseudacrobelus (2)				*Ironus (4)*
Plectus (2)				*Tripyla (3)*
Chiloplectus (2)				*Coomansinema (4)*
Prismatolaimus (3)				*Aporcelaimellus (5)*
Alaimus (4)				*Labronema (4)*
Amphidelus (4)				

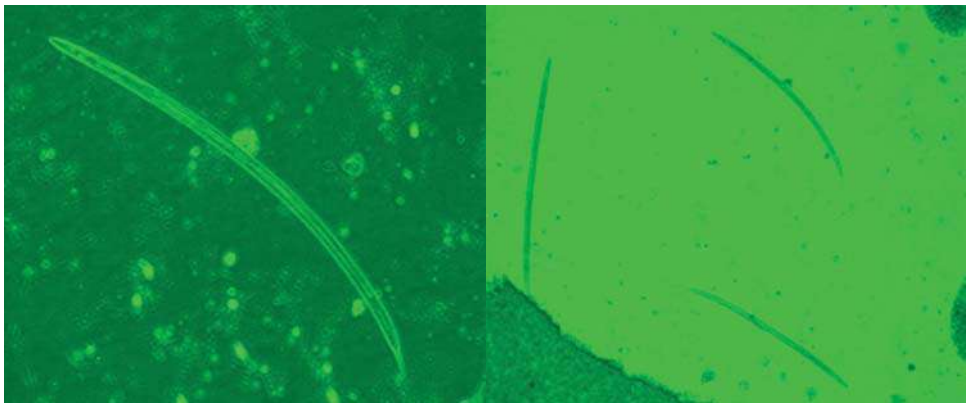
Source: Ghosh, 2010.

variable with 1–5 species reported in cultivated lands, and 3–8 species in forests in the past studies (Kaushal & Bisht, 1994).The patchy distribution of soil fauna particularly earthworms in the region can be attributed to huge variations in local climatic / edaphic conditions, land use history, management practices and high level of competition within communities. For the Himalayan region the generalization that forests may represent biodiversity "hot spots" in agriculture landscapes (Hagvar, 1998) may not hold good. This generalization is more applicable where forests are relatively intact and agriculture is intensive. However, in Himalayan region the forests are perturbed since long and agrochemicals are not used at all, and agricultural and forest land use are interlinked production systems.

The diversity of free living nematode in a central Himalayan traditional agroecosystem is depicted (Table 9.2). They were given the coloniser persister (c-p) ranking and presence of c-p group 1–5, and particularly 4 and 5 indicated that the high altitude agroecosystem of the region is stable.

Societal Importance

- Earthworm and nematode (beneficial spp.) species with wide ecological amplitude can be promoted for inoculation into litter-farmyard based organic



Fixed Nematodes seen under different magnification under phase contrast microscope

residue management pits to enhance agricultural production.

- Soil biodiversity plays an important role in stabilizing and regulating the earth's climate.
- It is a vast frontier and potential gold mine for countless new genes and biochemical pathways to probe for enzymes, antibiotics, and other useful agriculture and industry.

Conservation and Sustainable Use Initiatives

People in the region maintain sacred groves for protection of biodiversity. In almost entire Indian Himalayan Region agriculture is largely organic or coming back to organic with State interventions. Government of India has set up several agencies for stocking agriculturally important microorganisms, however, such initiatives on meso and macro soil fauna are still lacking.

Their occurrence is sporadically documented by survey agencies like Zoological Survey of India. The ICAR is undertaking projects to understand the plant nematodes and their interaction using RNAi. There are several coordinated research projects such as NAIP, AICRP, etc. to study socioeconomic and biological benefits and harm caused by nematodes.

Challenges

- Every plant or animal that becomes extinct is likely to take several soil species along with it.
- By unraveling the life in the soil and linking the cause & effect relationship, the loss of soil biodiversity and the impact on ecosystem processes can be reduced and better utilized for life-sustaining services.

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Red Base Jezebel (*Delias pasithoe*) © Peter Smetacek

Diversity of Himalayan Butterflies 10

The Himalayan range comprises the northern boundary of the Indian subcontinent, extending from Pakistan in the west to the Indian state of Arunachal Pradesh in the east. Unlike other mountain ranges that extend on an east to west axis like the European Alps, the Elburz, the Tien Shan or the Kunlun Shan, the flora and fauna at either end of the Himalaya are quite different. At the western end, one finds Palaearctic life forms, with many northern Asian and European species among the communities. In the east, typically Indo-Malayan groups predominate, with a healthy component of Sino-Himalayan species.

With reference to butterflies, the dividing line between the two zones was assumed to be somewhere in Nepal west of the Kathmandu valley. As our understanding of Himalayan zoogeography improved, it turned out that there actually was no dividing line, but that the species extended as widely as larval host-plants and climate permitted. There is a dry zone in western Nepal which might be considered to represent the dividing line, but recent work west of that has discovered populations of many typically eastern zone species, so they did manage to bridge the gap and survive. The Indian state of Uttarakhand is the extreme western limit for many Indo-Malayan species.

Richness and Representativeness

The Himalaya thus represents a mixing ground of Palaearctic and Indo-Malayan communities, which has caused a proliferation of species usually not found outside the tropics. If one considers that the Indian Peninsula is home to 333 butterfly species, the Himalaya and associated ranges that are home to roughly 1200 species emerge as a paradise for butterflies and other insects.

The interaction between the Palaearctic and Indo-Malayan fauna has proved an interesting field of study. In a pioneering study using Hawkmoths (family Sphingidae), the direction of climate change in the Western Himalaya was predicted in 1994. This was based on the observation that the hawkmoth community known from the Western Himalaya in 1937 had almost doubled in terms of species by 1994. All the new entrants were from the Eastern Himalaya (Smetacek, 1994).

While Arunachal Pradesh in East Himalaya is home to over 1000 butterfly species, the number gradually reduces towards the west, with 640 species in Nepal, around 450 in the Indian state of Uttarakhand and less further west. While the numbers decrease, the species, too, change, so that many butterflies found in Pakistan and the Indian states of Jammu & Kashmir and Himachal Pradesh are not found in the eastern Himalaya and vice versa.

Uniqueness

Opinions concerning taxonomy vary, therefore, the reported number of endemic species varies. However, there are several indisputably endemic butterflies and moths. Most of these Himalayan endemics are species belonging to genera with a pan-Asian or even global distribution, such as the Blue Apollo (*Parnassius hardwickii*); the Common Wall (*Lasiommata schakra*); the Common Argus (*Callerebia nirmala*); the White Bordered Copper (*Lycaena pavana*) and so on. While India lacks a national butterfly, the National Butterfly of Bhutan, Ludlow's Bhutan Glory (*Bhutanitis ludlowi*) is a narrow endemic which has recently been re-discovered in the Bumdeling valley in Bhutan. Similarly, the narrow endemic *Crebeta lehmanni* is the only member of its genus. This brown-and-white butterfly is so far known only from Manang in Central Nepal. Except for these two, there are no known endemics that are believed to be in danger of extinction.

Striated Satyr (*Aulocera saraswati*) – A Himalayan endemic © Peter Smetacek

Cultural Diversity Linkages

Unfortunately, while Asian culture is rich in references to vertebrates and several species are even venerated, this awareness and empathy was not extended to insects. The reasons for this are certainly to do with the small size of these creatures, as well as the lack of ability to preserve them in any form resembling a collection. Being largely ephemeral, they were completely ignored.

The Plain Tiger butterfly (*Danaus chrysippus*) is depicted on 4,500 year old panels of hunting scenes from the tomb of Nebamun in Egypt. No similar record has been unearthed in Asia. The oldest known representation of butterflies in India is found in 400 year old Mughal art where, again, the Plain Tiger butterfly has been depicted!

As a result, over the greater part of Asia and especially in the Himalaya, butterflies occupy no part of the popular imagination, except as examples of unfaithfulness, in that they are believed to visit flowers at random and never return to a flower in what would be considered an act of faithfulness.

In the plains of Bengal, though, butterflies are considered highly auspicious and a butterfly entering a house is believed to signify that a marriage will soon take place there. In this context, the butterfly symbol is considered as auspicious as the swastika and the water jar (kalash) and often replaces these symbols on marriage invitation cards of the Hindu Bengali community.

Threats & Conservation Priorities

The main threat to insect populations anywhere in the world is habitat destruction. Earlier, this took the form of clear felling of forests for lumber; forest fires and fires set as part of the process of shifting cultivation; lopping fodder for cattle and the damage caused by free ranging cattle. None of these factors have in any way been mitigated in the current scenario, but these are all pushed into secondary slots by the looming threat of urbanization and development of large tracts for human recreation, production and housing. Such land use change is irreversible in the long run and results in the shrinking of insect populations, since the habitat is irreversibly modified beyond any hope of re-colonisation when the forest grows back, as was the case earlier.

Given the lack of interest by Governments worldwide to slow down the pace of this land use change, it is clear that many populations and communities of insects are going to be eradicated in the course of investing funds in real estate by individuals and corporates. Since such development also fragments existing colonies of insects, the populations outside such manicured area are also susceptible to destruction, not only because of increased pressure from those exploiting the commons, but also as a result of unviable small populations.

Added to this, the lack of reliable data about the insect community inhabiting the areas concerned is a serious constraint. The result, naturally, is that we do not know what we are losing. Therefore, the most urgent need is to have reliable data bases. This would require a vast amount of field work by dedicated workers, a network of consulting experts and last but not least, the political will to act on the evidence that might emerge from such studies.

Given the burgeoning human population and its growing pressure on resources, the long term conservation of insect communities will have to be based on the concept of islands. India has a good network of protected areas in the Himalaya. Some are contiguous, but others are isolated. While the vertebrate fauna of such areas is relatively well known, the invertebrate fauna is more often than not, entirely unknown.

While clear felling of forests is not common practice anymore, two other major factors need to be looked into: the first is the forest fires that, since the 1980s, have ravaged Himalayan forests every summer. The second is the problem posed by free ranging cattle. Both of these are closely interrelated. In the Himalaya, broadleaf forests rarely catch fire. Forest fires mainly spread in coniferous forests.

A gathering of Common Punches (*Dodona durga*) © Peter Smetacek

Free ranging cattle are significant causes of bio-diversity erosion, since they tend to wipe out edible shrubs and saplings in an area. This naturally leads to the eradication of the insects dependent on those shrubs, while the lack of saplings is responsible for the lack of re-generation once the standing broadleaf trees die out or are felled. Conifers take over such areas, since cattle do not feed on the resinous leaves. This succession in turn introduces forest fires in the area. For this reason, large tracts of land around villages are "butterfly-free zones". In fact, for this reason, healthy butterfly communities are few and far between in the outer ranges of the Himalaya.

Challenges

The challenge faced by butterfly conservation throughout the Himalaya is to overcome differences of scale, so that something is not dismissed and allowed to face extinction because it is rather small.

A very rare butterfly, Lister's Hairstreak (*Pamela dudgeoni*), is definitely under threat, since its last known habitat in the Himalaya is undergoing illegal urbanization (Smetacek, 2012). This butterfly was only known from four specimens collected over a period of a century from different parts of the Himalaya. Despite possessing legislative protection equivalent to that extended to the tiger, nothing is being done to save this butterfly from extinction in India.

The other challenge is to obtain enough importance for insects and other small things so that their continued existence cannot be challenged on economic grounds. It is clearly wrong to compare economic profitability with life supporting systems or their components. Since insects are a vital part of natural ecosystems, propounders of the greater importance of profitability vis-a-vis insects and their habitat are merely demonstrating their ignorance of factors responsible for feeding humans, providing them with water, providing an equable climate and clothing them with natural fabrics. Before entering into debates concerning this, it is important to confirm the level of ignorance of the economists – surely they cannot be consciously desiring the destruction of life-support systems for centuries and even millennia so that they can turn a profit today? If so, then the lacunae in our educational systems that permit such aberrant views to be entertained need to be seriously addressed!

White-bordered Copper *(Lycaena pavana)* – A West Himalayan endemic © Peter Smetacek

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Forest rich Himalayan landscape – Major faunal habitats © Randeep Singh

11 Macro Fauna

The Indian Himalayan Region (IHR) remains among one of the most biologically rich, youngest, mysterious, and largest mountain systems on the Earth. It harbours various rare plant and animal species and forms significant part of Himalayan global biodiversity hotspot. It represents the junction of two biogeographical realms (Indo-Malayan and Palearctic) and, therefore, has faunal components of both the realms. The landscapes of the region have biological richness due to variation in geological, climatic, and altitudinal ranges. The extraordinary altitude variation and topographic complexity, provides wide range of habitat conditions that are inhabited by several unique and threatened faunal species. Many of these habitats still remain unexplored for faunal diversities. This is reflected in the discovery of 50 new species (2 mammals, 2 birds, 16 reptiles, 16 amphibians, and 14 fish species) in the region over the past 10 years.

Richness and Representativeness

The representativeness of faunal species in the Himalayan mountain ecosystem varies from the subtropical forests of the Shivalik to alpine meadows and scrub in the higher peaks of Greater Himalaya which create fabulous habitats for many small to large faunal species. While low grassland and forests of Himalayan foothill are home for dense population of Bengal tigers (*Panthera tigris*) along with sizable population of Asian elephants (*Elephas maximus*) and one-horned rhinos (*Rhinoceros unicornis*). The temperate mountains sustain species like Himalayan black bear (*Ursus thibetanus*), Takin (*Budorcas taxicolor*).The alpine region offer refuges for snow leopards (*Panthera uncia*), brown bears (*Ursus arctos*), musk dear (*Moschus moschiferus*), Tibetan wild ass (*Equus kiang*) and Black-necked cranes (*Grus nigricollis*). Of the 64202 faunal species in the world, 5081 species occurs in India and 1827 species in the Himalaya. Few animals like Red Panda (*Ailurus fulgens*), Clouded leopard (*Neofelis nebulosa*), etc., which occur in the Himalaya exhibit their affinities with the Indo-Chinese and Indo-Malayan regions.

IHR, with three biogeographical zones (Trans, Himalaya and North East) and with one of the largest altitudinal gradients in the world (Rodger and Panwar, 1988), covers 16.2% of total geographic area and supports over 36.0% of faunal species of India. Out of the known faunal species of India, 69.1% mammalian species; 79.3% of bird species; 38.1% reptiles; 33.7% amphibians and 10.2% fishes have been recorded from the region (Table 11.1).

Uniqueness

Ghosh (1997) has described as many as 12 species of mammals, 15 of birds, 29 of reptiles, 35 of amphibians and 36 of fresh water fishes, endemic to the Himalaya. Area rich in endemism in IHR are north-east India, the Western Ghats, and the north-western and eastern Himalaya. The diversity of endemic species in different groups of fauna is presented (Table 11.2). Of the 79

Table 11.1: The number of faunal species in World, India and Himalaya

Faunal Group	No. of species in world[1]	No. of species in India[2]	No. of species in Himalaya[3]
Mammal	5702[a]	434	300
Birds	9934[b]	1232	977
Reptiles	9766[c]	462	176
Amphibians	6300[d]	312	105
Fishes	32500[e]	2641	269
Total	64202	5081	1827

[1a]Wilson & Reeder (Eds), 2005; [1b]www.birdlife.org; [1c]http://www.reptile-database.org; [1d]http://amphibiaweb.org; [1e]www.actionbioscience.org; [2] Alfred & Sanyal, 2006; [3]www.conservation.org

endemic bird species of India, 15 species are confined to the Himalayan range and 3 species are exclusively restricted to IHR. IHR also embraces two Endemic Bird Areas (EBA), namely 128 (Western Himalaya) & 130 (Eastern Himalaya). The 128 EBA supports 55 Important Bird Areas (IBAs) whereas the 130 EBA supports 90 IBAs. Of the total 145 IBAs, 95 IBAs (65.5%) are supported by the IHR. The IHR region supports a total of 33 restricted range species falling in different categories of threat status.

Societal Importance

- Large faunal species, i.e., tiger, elephant, act as umbrella species in most of the ecosystems. Large intact forests are required for their survival, and these forests act as natural sinks of carbon; therefore, saving these large intact forests as habitat for umbrella faunal species can result in larger carbon credit stock and other ecosystem services.
- Top predators play an important role in the structuring and maintenance of biodiversity and act as guardian and indicators of healthy forests. Their conservation automatically ensures conversation of a large number of flora and fauna and/or entire ecosystem. Thus, a properly planned conservation programme for top predators does protect and conserve the pool of genetic diversity.
- Wildlife tourism is the world's biggest industry, and therefore, impacts the tourist influx thus impacting everyone, associated from the tour companies to the local tour guides thus supporting livelihood as well.

Conservation and Sustainable Use Initiatives

- Man and Biosphere (MAB) programme for building harmonious relationship between human activities and ecosystem conservation is operational in IHR. It also ensures *in situ* conservation at all levels of biodiversity in totality as part of wider ecosystem and achieving integrated development, improved quality of life for indigenous communities living in and around of the area.
- Government of India has initiated projects at national level for the conservation of umbrella species for *in situ* conservation (i.e., Project tiger, Project elephant, Project snow leopard), that equally covers IHR.
- Nature Conservation foundation, Mysore and Wildlife Institute of India, Dehradun have initiated a long term monitoring program on carnivore conservation and sustainable development.

Challenges

- Habitat loss, deforestation, poaching, trade of animal parts, competitive exclusion by domestic livestock, human–wildlife conflicts are some of the key conservation challenges to the faunal communities in the Himalayan region.
- Himalayan ecosystem is fragile and low in primary productivity. The area is fragmented and degraded, with the increase in human population, livestock over grazing, unplanned development, increasing agriculture practices and unsustainable use of natural resources.
- Alpine habitat loss and species migration due to climate change presents further threat of decrease in habitat for represented mega faunal species (i.e., snow leopard) and thus may bring them closer to human settlements.

Panthera pardus (Leopard) in West Himalaya © Ravindra K. Joshi

Table 11.2: Comparative account of endemic faunal species

Faunal group	Total species	Endemic to India[3]	Endemic to Himalaya[4]	Endemic to IHR
Freshwater Fishes[1]	801	355	36	12
Amphibians	312	175	35	–
Reptiles	462	206	29	–
Birds[2]	1232	79	15	03
Mammals[3]	434	47	12	06
Total	3241	862	127	08

Source: [1]Indian Endemic freshwater fishes - http://Intreasures.com/indiaff.html;
[2]http://bnhsenvis.nic.in/Endemic%20Birds/Endemic%20Birds%201.htm;
[3]Endemic species of India – http://Intreasures.com/india.html; [4]Ghosh, 1997.

Suggested Interventions

- Addressing the causes and rate of natural habitat loss and development of appropriate strategy to reduces these losses.
- Developing Wildlife trade policies and ensuring implementation in coordination with other government policies and relevant ministries and agencies.
- Developing fisheries stock database for fish harvesting within the safe ecological limits, so that there is no significant adverse impacts on threatened species.
- Preparing spatial database of threatened species to plan adequately to prevent them from extinction by improving their conservation status.

Conclusions

- Need to develop a more precise distribution data set for each faunal communities w.r.t. eco-climatic regions.
- Development of conservation reserve network using habitat retention and connectivity for survival of species in the face of future environmental changes.
- Initiate effective community-based eco-tourism, participatory management and eco-development programmes for the benefit of local communities
- Promote trans-boundary projects and co-operations between neighboring countries for ensuring effective movement of wildlife and to control illegal trade of wildlife products.

One-horned rhinoceros in Himalayan foothills © Udyan Borthakur

Black-necked Cranes (*Grus nigricallis*) inhabiting Trans Himalaya © G.S. Bhardwaj

Cobra (*Naja naja*) in Himalayan foothills © Randeep Singh

Himalayan Black Bear (*Ursus thibetanus*) – VU © Ravindra K. Joshi

Serow (*Capriconis sumatranensis*) – VU © Ravindra K. Joshi

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Hippophae rhamnoides L. subsp. *turkestanica* Rousi.– A potential species © K. Chandra Sekar

Wild Edible Plants 12

The IHR supports over 18,440 species of plants, of which about 26% species are endemic. The richness of the flora is due to the occurrence of species of other biogeographic regions like Irano-Turanian, Mediterranean, Indo-Chinese, Indian, Malesian, Eastern Asiatic, Circumboreal, Australian, Amazonian, Brazilian, Andean, North American and others. The region is inhabited by a number of ethnic groups such as Gaddi, Gujjars (Trans/Northwest Himalaya), Bhotias, Rajees, Tharus, Buxas, Jaunsarees (West Himalaya), Bhutias, Lepchas (Central Himalaya) and Chakma, Nagas: sub tribes – Singpho, Tangsa, Hillmiri, Adis, Nishi, Apatani, etc. (East Himalaya). These ethnic groups, since time immemorial, have been dependent on the wild plant resources of the region for meeting their nutritional requirement. Wild edible plants form an important source as a supplement or substitute food in time of scarcity for mountain communities. However, in recent times use of wild edibles has remained confined to certain communities /areas in spite of their potential in local, national and international markets. Considering the potential, there is an emerging need to promote wild edibles not only as resource for sustenance but also as an income generating resource for the mountain communities.

Richness and Representativeness

Of the nearly 800 species of wild edibles reported from India, 675 species are found in IHR. Across altitude range, maximum representation of wild edibles (477 species) is in the range of 1001–2000 m, followed by 392 species below 1000 m, 279 species in range of 2001–3000 m, 135 species in range of 3001–4000 m and 30 species above 4000 m. Across the biogeographic provinces of the IHR, the distribution of wild edibles is presented (Table 12.1).

Representation of wild edibles under different taxonomic groups and life forms is presented (Table 12.2). The family Rosaceae (45) has the highest number of known wild edible species, followed by Polygonaceae (30), Moraceae (26), Asteraceae (20), Fabaceae (20), Euphorbiaceae (15), Anacardiaceae (13), Rubiaceae (13), Apiaceae (13), Urticaceae (14), Lamiaceae (12), Alliaceae (12), Rutaceae (12), Poaceae (13), Berberidaceae (11), Caprifoliaceae (10) and Vitaceae (10). Among the genera, *Rubus* (20), *Polygonum* (18), *Ficus* (15), *Allium* (12), *Dioscorea* (9), *Berberis* (8), *Prunus* (7), *Viburnum* (7), *Rubus* (6), *Piper* (6), *Grewia* (5), *Rhus* (5) and *Chenopodium* (5) exhibit diversity of wild edibles.

Table 12.1: Known diversity of wild edibles in different biogeographical provinces of Indian Himalaya

Biogeographical Provinces	Species number (%)	Sub-region	Species number (%)
Trans/Northwest Himalaya	169 (25.04)	Jammu & Kashmir	132 (19.56)
		Himachal Pradesh	94 (13.93)
West Himalaya	344 (50.96)	Kumaun	344 (50.96)
		Garhwal	176 (26.07)
Central Himalaya	173 (25.63)	Sikkim	173 (25.63)
East Himalaya	221 (32.74)	Arunachal Pradesh	221 (32.74)

Source: Samant & Dhar, 1997.

Table 12.2: Species richness of wild edible plants in major taxonomic groups in IHR

Taxonomic groups	Life Forms					
	Families	Genera	Species	H	Sh	T
Angiosperms	127	361	647	285	169	193
Gymnosperms	5	6	7	–	3	4
Pteridophytes	9	9	12	–	–	–
Fungi	6	6	7	–	–	–
Lichens	2	2	2	–	–	–
Total	149	384	675	285	172	197

Source: Samant & Dhar, 1997. Abbreviations used: H =Herb, Sh = Shrub, T = Tree..

Uniqueness

Of the total wild edibles recorded from the IHR, 39 are restricted to Indian Himalaya, hence classified as endemics. On the other hand, 93 species showed range extension to adjacent countries/states and are considered as near endemics. In a broader sense (*sensu lato*), the near endemics represent endemics for the Himalaya. East Himalaya showed the highest number of endemics (18 taxa). The distribution of endemics in different phytogeographical provinces across IHR is presented (Table 12.3). Different plant parts such as roots, tubers, rhizomes, stems, leaves, inflorescence/ flowers, fruits/seeds/embryo, thallus, fruiting body or fronds are consumed either raw, roasted, fried, cooked, boiled or in the form of oil, spice, seasoning material, jams, pickles, etc.

Societal Importance

- Wild edible plants are cheap sources of protein, carbohydrates, fats, vitamins and minerals; moreover, their dietary contribution goes highly as they are available during most seasons, including the periods when the conventional staple crops and vegetables are scarce. Nutritive values of some of the wild edibles are comparable or even better than the values for cultivated/domesticated plants.
- The wild edible mushrooms (*Morchella esculenta, M. conica, Pleurotus ostreatus, Boletus edulis, Cantharellus cibarius, Hydnum coralloides* and *Lycoperdon gemmatum*) are used as a delicacy for domestic consumption as well as in commercial hotels. They are rich in proteins, especially in lysine and leucine, which are lacking in most of the staple cereal foods.
- Wild edibles have also medicinal, multipurpose, commerce/trade values. For example, oil yielded from seeds of *Diploknema butyracea* and *Prinsepia utilis* are used as a cooking medium.

Conservation and Sustainable Use Initiatives

- National Biodiversity Conservation Strategy; National Biodiversity Federation Mission; National Biodiversity Refuge Mission; National Mission on Sustainable habitat; National Mission on Sustaining Himalayan Ecosystem; National Mission for a Green India; National Mission on Strategic Knowledge for Climate Change; Wildlife Protection Act 1972; National Afforestation Programme; Protected Area Network; Indian Man and Biosphere Programme (MAB); Botanical Garden Scheme, Launch of CAMPA, inclusion of forestry within NREGA, etc.
- State Biodiversity Boards; Climate Change Cell, Establishment and maintenance of Botanical Gardens, Arboreta, Nurseries, etc.
- Biodiversity conservation in the form of Sacred Groves (Dev Vans); Afforestation Programme, Launch of CAMPA, inclusion of forestry within NREGA, Sanjha Van (JFM), CAT Plan, Compensatory Forestry, etc.
- Assessment and quantification of nutritive and anti-nutritive values of the wild edibles.

Challenges

- Assessing status and responses of the wild edible species in relation to disturbance gradient and climate change.
- Assessing impact of invasive species (Exotic/alien, weeds), forest fire and developmental activities (Hydropower projects, roads, etc.) on the status of wild edible plants
- Ensuring packages of practices for maintenance and optimal use of wild edible plants and improvement of livelihood options for native communities
- Strengthening network/coordination of the State and Central Government Departments and NGOs for *in situ* & *ex situ* conservation and marketing of wild edible plants.

Conclusions

- Indian Himalaya represents a rich diversity of the wild edible species which are capable of supplementing the food requirements of hill communities. For harnessing its full potential, adequate information on population biology (i.e., habit, habitat, life form, distribution range, population size, phenology, reproduction, pollination, seed biology, seedling ecology and several other aspects) is essential.
- Mass scale propagation of wild edibles in the nurseries, arboreta and botanical gardens through conventional methods needs to be popularized among the hill communities for their conservation and management.

Table 12.3: Endemic wild edibles of Indian Himalayan Region

Biogeographic Provinces	Endemic Species
Trans / North West Himalaya	*Allium consanguineum, Caralluma tuberculata, Campanula cashmiriana, Sedum tibeticum, Ribes nigrum & Linaria incana*
West Himalaya	*Allium stracheyi, Cordia vestita & Ribes uva-crispa*
Central Himalaya	*Mahonia sikkimensis, Rubus treutleri, R. wardii & Sterculia roxburghii*
East Himalaya	*Calamus erectus, Caryota obtusa, Livistonia jenkinsiana, Begonia rubro-venia, B. episcopalis, Streptolirion volubile, Stixis suaveolens, Gaultheria discolor, Baliospermum calycinum, Garcinia pedunculata, G. sopsopia, G. cowa, G. stipulata, Illicium griffithii, Musa sanguinea, Phoenix rupicola, Rubus insignis & Spiradiclis bifida*
Trans/Northwest/West	*Berberis zabeliana*
Northwest/West/Central	*Lonicera parvifolia*
West/Central	*Angelica glauca*
Central/East	*Elaeagnus pyriformis, Elaeocarpus sikkimensis, E. floribundus & Saurauia punduana*

Source: Samant & Dhar, 1997.

- Wild edible species may prove a good root stock for the commercial cultivars of the fruit crops due to their wider adaptability to climatic variations, vigour, growth and resistance to insects and pests. Hence, these may be utilized as good breeding material for the improvement of horticultural crops as well as restoration and reclamation of degraded land and revised cropping systems.
- Awareness on the sustainable harvesting of these species needs to be promoted among the mountain communities to maintain the ecosystem equilibrium.

Kaphal *(Myrica esculenta)* - An important wild edible © K. Chandra Sekar

Ficus racemosa - A wild edible with sacred values © V. S. Negi

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Alpine and sub alpine zones- important medicinal plant habitats

13 Medicinal Plants

Potential, Prospects and Challenges

The recorded evidence of herbal medicine dates back to 5000 years ago. This indicates that the medicinal plants have historically remained in great demand due to their unique curative properties. The drugs derived from plants are known to have negligible side effects as compared to their chemical counterparts (Anonymous, 2000). In spite of the tremendous progress in synthetic chemistry and biotechnology, 40% of drugs in modern pharmacopoeias are derived either as pure pharmaceutical extracts from plant or their remedies. The medicinal plants sector has a huge comparative advantage in India, particularly in Himalayan region where large numbers of species are having medicinal value and traded outside the region. However, over 90% of the species used in trade continue to be sourced from the wild, and nearly 66% of which are harvested by destructive means to meet ever-increasing pharmaceutical requirements. This has brought several plants at the verge of extinction. Therefore, there is a need to look into possibilities of conserving wild medicinal plants in their natural habitats along with developing sustainable harvest protocols for species in demand. If properly planned the medicinal plant sector can become good money spinner to all Himalayan states.

Richness and Representativeness

The Indian Himalayan Region (IHR), extending from Jammu & Kashmir in the North-West to the Arunachal Pradesh in the East, exhibits wide socio-cultural and wild faunal and floral diversity. The area is identified as a biodiversity hotspot with over 8000 species of flowering plants, 44 gymnosperms, 6000 pteridophytes, 1737 bryophytes, 1159 lichens and 6900 species of fungi; these plants groups exhibit 40, 16, 25, 33, 11 and 27% endemism, respectively (Singh and Hajra, 1996). Among others, the region is an invaluable reserve of medicinal plants. Nearly 1748 species of medicinal and therapeutic value have been enumerated from the region (Samant *et al*., 1998).

Among different biogeographic provinces nearly 643 species of medicinal plants are known from trans and northwest region (J&K and HP), 701 species in west Himalayan region (Uttarakhand), 707 species in central Himalayan region (Sikkim and Darjeeling hills), and nearly 650 species from east Himalaya (Arunachal Pradesh). Availability of medicinal plants across Himalayan states of India is depicted (Table 13.1).

Nearly 26% of known medicinal plants are native to Himalayan region while another 6% species shares their nativity with Himalayan and adjoining areas. Interestingly 69% species are non-natives representing other biogeographic regions of the world (Samant *et al*., 1998). The representative species of the Trans North Western Himalaya are *Aconitum falconeri* var. *latilobum, A. chasmanthum, Angelica glauca,Bunium persicum,Cachrys pabularia, Crocus sativus, Inula racemosa, Iris kashmiriana Narcissus tagetta & Saussurea costus,;* Western Himalaya, *Aconitum* spp., *Allium stracheyi, Didymocarpus pedicellata,Pittosporum eriocarpum & Swertia ciliata,;* Central Himalaya, *Aconitum deinorrhizum, Angelica nubigena, Codonopsis affinis, Panax pseudoginseng* and *Swertia chirayita;* and Eastern Himalaya, *Begonia rubrovenia, Coptis teeta, Crinum pretense, Mesua ferrea, Pothos cathcartii,* and *Swertia dilatata,* (Samant *et al.*, 1998).

Seventeen species of medicinal plants have been recorded in the Red Data Book of Indian Plants and 120 species are assessed and placed under various threat categories of the IUCN.

Uniqueness

Of the known medicinal plants, 62 species are endemic to IHR while another 208 species are near-endemics

Table 13.1: Floral and medicinal plant diversity of Indian Himalayan Region

States	Floral diversity (No. of species)	Medicinal plants diversity (No. of species)
Jammu & Kashmir	4252	570
Himachal Pradesh	3047	643
Uttarakhand	4700	701
Sikkim	4500	440
Arunachal Pradesh	3974	500
Meghalaya	3000	850
Manipur	2376	375
Nagaland	2431	250
Mizoram	2141	135
Tripura	1546	628
Assam	3017	105

Table 13.2: Medicinal plants being exported from India (including Himalayan species)

Name of the species	Parts used
Aconitum species (other than *heterophyllum*)	Root
Acorus calamus	Rhizome
Adhatoda zeylanica	Whole plant
Berberis aristata	Root
Cassia angustifolia	Leaf and pod
Hedychium spicatum	Rhizome
Heracleum candicans	Rhizome
Inula racemosa	Rhizome
Colchicum luteum	Rhizome and seeds
Juglans regia	Bark
Juniperus communis	Fruit
Juniperus macropoda	Fruit
Picrorhiza kurroa	Root
Plantago ovata	Seed and husk
Podophyllum hexandrum	Rhizome
Punica granatum	Flower, root and bark
Rauvolfia serpentina	Root
Rheum australe	Rhizome
Saussurea costus	Rhizome
Swertia chirayita	Whole plant
Valeriana jatamansi	Rhizome
Zingiber officinale	Rhizome

Source: Ved & Goraya, 2008.

as they are also found in neighboring countries. The notable endemic species are *A ferox, A. nubigena, Aconitum falconeri, Allium stracheyi, Angelica glauca, Archengelica himalaica, Berberis kashmiriana, Coptis teeta, Inula racemosa, Pegia nitida, Piper griffithii, Saussurea bracteata, Zalacca beccarii,* etc.; and near endemic, *Allium humile, Arnebia benthamii, Berberis aristata, Berberis lycium, Cachrys pabularia, Cinnamomum tamala, Colchicum luteum, Corydalis govaniana, Dactylorhiza hatagirea, Doronicum roylei, Fritilaria roylei, Gentiana kurroa, Jurinea macrocephala, Lilium polyphyllum, Panax pseudoginseng, R. campanulatum, Rhododendron anthopogon, Roylea cinerea, Selinum tenuifolium, T. dolichophyllum, Tanacetum tomentosum,* etc. (Samant *et al.,* 1998).

Societal Importance

Himalayan medicinal plants have been in great demand not only in indigenous health care systems but also by pharmaceutical firms. These plants are in use since Vedic period. The famous epics on medicinal plants, such as Charak Samhita (1000–800 BC) have described Himalayan region as major source of raw material for health care. There are well-established traditional health care systems based on the use of Himalayan medicinal plants. Even today, most of the effective systems of treatments such as Ayurvedic, Chinese and Tibetan largely depend on natural sources that, in majority, comprise of plants. States like J&K, Himachal Pradesh, Uttarakhand and Sikkim have already made significant strides for development of medicinal and aromatic plant (MAP) sectors. The major focus of MAP sector development in all the Himalayan states has been to facilitate economic development by enhancing and modernizing production of medicinal plants; conserve their natural habitats; safeguard local heritage and knowledge on traditional health care system; and to strengthen infrastructure, extension, market and R&D facilities for medicinal plant sector development (Sundriyal, 2005). Large quantum of medicinal plants from India, including the ones from IHR, is exported (Table 13.2). The export of Ayush and Herbals from India is presented (Table 13.3). Also, other species have high domestic consumptions (Table 13.4).

Commercial Applicability

One of the Himalayan states, Uttarakhand, has categorized medicinal plants collection from forest

An exported medicinal plant from IHR *Valeriana jatamansi* © I.D. Bhatt

Table 13.3: The extent of export of Ayush and herbals from India during 2005–06 to 2009–10 (value in each column is Rs. in crores)

Category	2005–06	2006–07	2007–08	2008–09	2009–10
Ayush	311.57	350.93	416.82	700.57	764.25
Herbals	306.30	375.60	470.12	594.87	570.76
Grand Total	617.87	726.53	862.67	1261.64	1335.01

Source: DGCIS, Pharmexcil Research (Pharmaceuticals Export Promotion Council, Ministry of Commerce, Govt. of India).

Table 13.4: Medicinal plants with high consumption in India (each >100 MT/yr)

Botanical name	Estimated consumption (MT)	Source (wild/ cultivated)
Emblica officinalis	16820	W/C
Terminalia chebula	8158	W
Ocimum spp.	3533	C
Terminalia bellirica	3424	W/C
Asparagus racemosus	3180	W/C
Aegle marmelos	2939	C/W
Adhatoda zeylanica	2701	W/C
Cyperus rotundus	2382	W
Woodfordia fruticosa	2316	W
Piper longum	1737	W/C
Aloe barbadensis	1621	C
Cedrus deodara	930	W
Swertia chirayita	711	W/C
Acorus calamus	678	C/W
Rubia cordifolia	536	W
Berberis aristata	521	W
Picrorhiza kurroa	416	W
Vitex negundo	301	W/C
Rauvolfia serpentina	290	W
Nardostachys grandiflora	286	W
Aconitum heterophyllum	210	W
Sapindus mukorossi	182	W/C
Bombax ceiba	166	W
Indigofera tinctoria	164	C
Valeriana jatamansi	123	W

Source: Ved & Goraya, 2008.

Aconitum balfourii Stapf – An important medicinal plant

in three groups, *viz*. (i) *Prohibited*: fifteen species are completely prohibited from wild collection, (ii) *Allowed for sustainable harvesting*: seventeen species allowed for sustainable harvesting, and (iii) *Open*: twelve species categorized as open for collection. In the state, collection and cultivation of medicinal plants is done side-by-side. In past five years more than 4000 ha land area has been brought under cultivation of medicinal and aromatic plants and over 22,000 farmers have been identified as registered growers. To further facilitate the process of MAP cultivation over 100 nurseries have been established to supply quality planting material with the support of National Medicinal Plant Board (NMPB) and Rashtriya Kirshi Vikas Yozna (RKVY). The state has already established three herbal Mandies at Ramnagar, Tanakpur and Rishikesh and initiatives are on to open 60 collection centers at different parts of the state with the help of Forest Department. To promote cultivation of aromatic plants 27 field distillation units have been established with 95% subsidy. The Government has also created a revolving fund worth Rs. 50 lakhs for buy-back of aromatic oil, and Rs. 2 crores for procurement of medicinal plants. Accordingly the minimum support price for 20 aromatic plant produces and 8 medicinal plants parts has been fixed. The government provides subsidies to those cultivators who have taken land on lease (for more than 3 years) for cultivation of MAPs. It has simplified transit mechanism for cultivated produce of MAPs. The State Medicinal Plants Board (SMPB) Uttarakhand is implementing the central sector schemes, while Herbal Research and Development Institute (HRDI)

has been assigned the work to implement National Mission on Medicinal Plant in the state. The State government is working to develop the state as a popular herbal destination.

The SMPB is being strengthened to take a leading role for MAP sector development. Ayush and medicinal plant information has been introduced in school curricula. It has taken initiative to establish herbal gardens with the help of Forest Department, and also planning to open Ayush Grams in each districts in PPP mode. Till date seven Medicinal Plant Conservation Areas have been established in different districts of Uttarakhand. Comparative statement on demand and supply from wild and cultivated source in Uttarakhand is indicative of progress in meeting demand from cultivated produce (Table 13.5).

Table 13.5: Industrial demand and production of MAPs in Uttarakhand state

Year	Total Demand	Collection from Wild	Cultivated Produce
2007–08	1500 MT	1600.93 MT	74.63 MT
2008–09	7500 MT	2243.94 MT	1110.47 MT
2009–10	10000 MT	1950.10 MT	739.43 MT
2010–11	10000 MT	1589.77 MT	747.00 MT

Conservation and Sustainable Use Initiative

As for other parts in the country, the NMPB and SMPBs are striving hard to develop the MAP sector across the IHR with meticulous planning, comprehensive strategy and effective implementation of multi-pronged and integrated sets of projects. It is promoting, medicinal plants sector and implementing comprehensive schemes on 'Conservation, Development and Sustainable Management on Medicinal Plants' as a central sector scheme and 'National Mission on Medicinal Plants' in mission mode. In this context, each state is eligible to develop MAP sector as per their choice. This process has really set the pace for development of medicinal plants. Besides, a large number of central and state Institutes are independently working on different R&D aspects in this sector. Various universities in IHR also undertake projects from various funding agencies to take up researches in MAP sector particularly on inventory, documentation of local health traditions, pharmacology, pharmacognosy, natural products, phytochemistry, tissue culture, cultivation of MAP and other related topics. UNDP-GEF-GOI has been implementing a scheme on mainstreaming conservation and sustainable use of medicinal plant diversity in three states. Of which, two Uttarakhand and Arunachal Pradesh represent IHR.

Challenges and Action Areas

In extension sector:

- Prioritize species as per state's climatic conditions, traditional knowledge and availability of diverse scientific institutions and industry needs. Selected high altitude species could be monopoly items for Himalayan state.
- Strengthen nursery network for production of quality planting material for demanding species to increase area under cultivation, and develop agro-techniques for new potential species, and provide technical support to farmers
- Establish quality control laboratories, value addition & value chain, and post-harvest management facilities.
- Develop rural collection centres and godowns to bulk the MAPs, insure buy-back arrangements

Burans (*Rhododendron arboreum*) – A good source of herbal drink

- Monitor trade and harvesting of MAPs from wild areas.
- Promote contractual farming with assured buy-back.

At research front:

- Develop state specific data base on medicinal plants and regularly monitor the diversity and distribution of MAPs in natural habitats.
- Promote bioprospecting of potential species
- Document traditional health care system
- Develop agro-techniques
- Develop network of medicinal plant conservation areas (MPCAs) with the help of local communities
- Strengthen enabling environment and policy back up

Other Relevant Considerations

There is a growing acceptance of Indian traditional systems of medicine across the globe that has resulted in increased demand for herbal and natural products to meet both, the healthcare needs and dietary supplements, which has opened up new opportunities for the medicinal plant based industries. At present India is contributing 8.13% of the the global demand of herbal and Ayush raw material with an accelerating growth rate of 22.44% which is much higher than the global average (6.87%). India is second largest producer of the raw material at global level.

An organized extension and conservation programme

Podophyllum hexandrum Royle – High value species © S.S. Samant

Near endemic *Fritillaria roylei* © Ravindra K. Joshi

for each state with due support from transparent policies for collection, protection and cultivation could help to harness optimal benefit from MAP sector. Centre and state governments and civil societies are required to play key role for developing medicinal plant sector to the desired level.

Conclusions

- All Himalayan states form an important repository of medicinal plants; the local governments need to work to increase production, commercialization and product development from MAP resources.
- All states in IHR need to realize full potential of MAP sector by way of developing products such as phytochemicals, neutracetautical, aromaceuticals, herbal drinks, functional foods, OTC medicines & drugs, culinary herbs and spices, cosmetics, flavors & fragrances and herbal veterinary products.
- There is a need for building capacity of of the local communities and empowering them to protect and cultivate MAPs.
- Promote constant dialogue with industry to develop MAP sector to meet international standards.
- Develop an enabling policy environment regarding management of medicinal plants with effective institutional arrangement, production and marketing, R&D support in each Himalayan state.

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Forest-dependent Hill Agriculture – West Himalaya © R.S. Rawal

14 Farming Systems and Biodiversity

Mountain specificities have played a key role to support the diversity of farming systems in the Himalayan region. Majority (58%) of the working population in this region is engaged in traditional agriculture and allied activities. The traditional farming system in the region is mainly an interdependence of land, livestock and forest. The diversity in physiography, land, and climate, etc., has resulted in much variation in the natural biodiversity and agricultural practices that provide a range of products to support livelihoods. The farmers have been maintaining thousands of crop varieties and livestock for generations as per the environmental conditions and social needs using indigenous management practices. However, according to the Central Statistical Organization (CSO), the total gross value added (GVA) output of agriculture and allied activities in the Himalayan region is just 3.5% of the GDP in the country (Table 14.1); the figure for horticulture (fruits and vegetables) is 7.1%.

Richness and Representativeness

Across IHR, the prevailing major farming systems include '*Jhum*' or shifting agriculture in Northeastern region, Alder-cardamom based agro-forestry in Sikkim, crop rotation and mixed cropping in Uttarakhand and horticulture and MAP cultivation in Himachal and Jammu and Kashmir. Plantation crop farming is another form in the region, which is characterized by large scale cultivation of a single cash crop, supported by advance technical inputs, i.e., tea plantation in Assam, West Bengal, Sikkim, Uttarakhand and Himachal Pradesh.

To elaborate diversity of farming systems within a specific area, we take an example of Himachal Pradesh. The state is well known for its unique farming systems and prevailing biodiversity. Farming provides direct employment to ~71% of the total population in the state. The agriculture sector contributes to nearly 45% of the total state domestic product.

The farming system in the state is described in four agro-climatic zones (Table 14.2). With the advent of modern techniques, the traditional farming systems are continuously been under threat due to mono-culture activities in crops in different agro-climatic zones (Kuniyal *et al.*, 2004). However, agricultural sector in the state has adopted a diversification approach by way of promoting off-season vegetables, and cash crops, like potato, ginger, soyabean, oilseeds, and pulses. The farmers focus more upon generating the cash crops for earning more revenue. A total of 47 agricultural crops are grown in the state, including vegetables and others such as tea in different agro-climatic conditions. Maximum number (42 crops) of species are cultivated in Kangra, Mandi and

Table 14.1: Contribution of agriculture and allied sectors to the gross domestic product (2005–2006) (in lakh Rs., at 1999–2000 prices)

Region	Agriculture	Fruits & Vegetables	Kitchen Garden	Straw & Stalks	Total
IHR	6,92,073	7,40,906	4,250	70,328	1,507,557
India	29,566,154	10,426,735	2,24,437	23,49,741	42567,067

Source: Mukherji, 2010.

Table 14.2: Agro-climatic zones and representative crops in Himachal Pradesh

Agro-climatic zones	Altitude (m)	Cultivated area (%) of the state	Major crops
Shivalik hill zone/ Sub tropical	350–650	40	Wheat, Maize, Paddy, Gram, Sugarcane, Mustard, Potato, Vegetables etc.
Mid hill zone/ Mild temperate climate	651–1800	37	Wheat, Maize, Barley, Black Gram, Beans, Paddy, etc. Off-Season Vegetables, Ginger, temperate vegetables like Cauliflower and root crops
High hill zone/ Humid temperate climate and alpine pastures	1801–2200	21	Wheat, Barley, Lesser Millets, Pseudo-cereals (Buckwheat and Amaranthus), Maize, Potato/seed Potato and temperate Vegetables
Cold dry zone	>2200	2	Wheat, Barley, Pseudo-cereals, Seed Potato, Peas as green and seed purpose

Source: http://hpagrisnet.gov.in

Table 14.3: Horticulture zones and fruit species diversity in Himachal Pradesh

Zone description	Altitude (m)	Rainfall (cm)	Major fruit crops
Low hills & valleys (Sub tropical)	365–914	60–100	Mango, Litchi, Guava, Loquat, Citrus, Fig, Ber, Papaya, etc.
Mid hills (Sub temperate)	915–1523	90–100	Stone Fruits, Persimmon, Pear, Pomegranate, Kiwi Fruit, etc.
High hills & valleys (Temperate)	1524–2742	90–100	Apple, Pear, Cherry, Almond, Walnut, Chestnut, etc.
Cold & dry zone (Dry temperate)	1524–3656	24–40	Apples, Prunes, Almond, Chilgoza, Pistachionut, Walnut, Hazel-nut, Hops, etc.

Source: http://hpagrisnet.gov.in/horticulture

Agriculture in hills revolves around domestic animals

Solan districts followed by Sirmaur (41), Bilaspur (41), Shimla (40), Kullu (39), Chamba and Hamirpur (38), Una (37), Kinnaur (28) and Lahaul and Spiti (21) (Sinha *et al*., 2009).

As a part of horticultural activities, farmers get good return from apple, temperate fruits, mango, citrus fruits and others. Horticultural crops grown in different horticultural zones are presented (Table 14.3).

Livestock husbandry is integral to all rural systems across the IHR. Many rural institutions and cultures revolve around domestic animals, especially among the scheduled tribes and nomadic communities. The cattle population in the IHR is 5.3% of the country and nearly 74.2% of total cattles in IHR is of the indigenous varieties.

Life-Support Values of Agro-Biodiversity

Undulating topography, variation in altitude, micro-climatic conditions, etc., in IHR offer natural advantage for crop diversification. Agricultural crop diversity, as well as genetic diversity within a single crop, is one of the key features of mountain agriculture. Diverse production from small landholdings also provides insurance against crop failures. "Baranaaja" culture, a multiple crop mix raised by mountain farmers, is a unique testimony of it.

The farming practices of each region have their own peculiarities. Starting from cold deserts, sowing of few species during one cropping season (Kharif) is practiced during the year. However, livelihoods of nomads is largely dependent on rearing of sheep and few other animals. Horticulture, floriculture and MAP cultivation along with other crops is a prominent farming practice in North West (Himachal Pradesh and Jammu & Kashmir). Whereas cultivation of Saffron is unique to J&K. Three crops in two successive years is a characteristic feature of the rain fed agriculture practiced in mid altitude zone of the Western Himalaya. The gentle slopes receiving high rainfall in Assam, West Bengal and Sikkim favour tea farming and large cardamom based agro-forestry is unique to Sikkim. The NE region is, however, known for '*Jhum*' cultivation. The traditional '*Jhum*, is the major life support system for various tribal groups in the region.

Culture and Biodiversity Linkages

The farming systems in the Himalayan region have penetrated its roots deep into the culture. In different cultures sowing and harvesting of crop is celebrated by people following their own traditions. The famous cultural function of Assam 'Bihoo' is celebrated before the start of harvesting. The indigenous communities of Sikkim and nearby area are culturally rich and consider Mt. Khangchendzonga and other mountain peaks as the abode of deities. In this part, the entire diversity of plants, animals, agroforestry systems, soil, water, air, etc. are considered sacred and culturally important. For the indigenous and traditional societies of Sikkim, agroforestry plays an important role in cultural and spiritual traditions. Hence it provides recreational and spiritual services for the culturally diverse ethnic communities of the region. "Baishakhi" the famous cultural celebration in Western part of the country is also an example of cultural celebration associated with harvesting of crops. "Harela" in Uttarakhand (west Himalaya) is celebrated before sowing of seeds during *rabi* and *kharif*. This festival, infact marks the traditional method of testing of seed viability (Shah, 1986).

Societal Importance

The proportion of the total workforce engaged in agriculture in the IHR (58%) is the same as it is for the country, but its composition differs significantly. At the national scale, less than one third of the total workers (31.7%) are actual cultivators, whereas, in the Himalayan region nearly half of the total workers fall under this category (49.9%). The scenario stands reversed for agricultural labourers who constitute more than one-fourth of total agricultural workers in the country (26.5%) and only 8.4% in the IHR. The percentage of women cultivators is significantly higher (66.6%) in the Himalayan region as compared to the national average (33%) (Rawat *et al*., 1996, 1997).

Conservation and Sustainable Use Initiatives

- Promotion of organic farming without the use of pesticides and chemical fertilizers.
- Development of rain-fed agriculture through watershed approach.
- Rainwater harvesting for irrigation, recharging the ground water and preventing erosion.
- Post-harvest management and efficient marketing system.
- Agro-processing and value addition.

Challenges

- Farming system is directly linked with water resources, soil, forest ecosystem, livestock, climate, etc. and therefore equilibrium needs to be maintained between different components for long term sustainability.
- Adaptation of the agricultural practices to changing climatic conditions in view of securing food requirements and providing balanced nutrition along with conservation of the traditional crop varieties and land races.
- Declining soil fertility due to high erosion and nutrient leaching through run-off.
- Diversion of agricultural land for human settlements.
- Climate change impacts on hill agriculture and other horticulture crops.
- Conservation of traditional varieties under modern farming system.

Conclusions

- Hill farming system is practiced in a wide range of agro-climatic conditions.
- Himalayan farming system is diversified; modern farming tends to be mono-culture, while traditional is rich in diversity.
- Climate change impacts are evident in shifting of apple cultivation and other crops to higher altitudes.
- There is a need to promote a combination of mixed cropping and multiple farming as part of sustainable farming systems in the IHR.

The Himalayan region has great diversity of cultivated crops, therefore, a supportive policy is concurrently required to encourage the farmers to maintain high crop diversity through organic farming and harness the full potential of off season and niche crops. In addition, efforts also need to be made to enhance their quality, productivity and marketability (establish infrastructure), skill building, value addition, etc.

Promotion of season cultivation – Polyhouse

Level and terraced fields- Characteristic of West Himalaya
© Ravindra K. Joshi

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Traditional systems of managing varieties of crops under "*Jhum*" in Nagaland © SCR Vishvakarma

15 Traditional Knowledge Systems

Traditional knowledge systems (TKSs) and cultural heritage play significant role in sustainable use, management and conservation of bio-resources. The Himalayan people have well established traditional knowledge (TK) of bio-resource management and conservation. This includes use and conservation of medicinal plants, forecasting of local weather using climatic indicators, natural dyes, varieties of traditional fermented foods derived from local crops, etc,. Strong TKS has helped indigenous communities to survive in difficult terrains of the Himalaya for generations. However, as elsewhere in the globe, unprecedented population growth and increasing consumerism has affected TKS in the region and the prevailing knowledge system with indigenous societies is dwindling fast. In this context, and realizing the wider implications, TK in the region needs due attention and recognition.

Richness and Representativeness

While considering prevalence of TK in IHR, this is reflected in diverse sectors. A few examples are given below:

Biodiversity conservation: Tradition of nature worship and attaching sacred value to sites, selected species of plants and animals, has helped in biodiversity conservation and its sustainable utilization. Such traditional practices occur across the region. The Himalayan region is particularly rich in sacred groves and sacred natural sites, which provide protection to representative relict patches of original forests and various rare fauna and flora.

Fermented foods and beverages: Fermented foods like *Siddu* (made from wheat flour, opium seeds & walnut) and *Sepubari* (made from black gram) in Himachal Pradesh and *Kinema* (made from soybean) in Sikkim and Darjeeling hills, and many other kinds occur in the region. These food items are integral part of life sustenance strategy of highlanders. More recently, many of these items have gained recognition in tourism industry as local speciality cuisine.

Natural dyes: Various ethnic communities, including Bhotiyas of west Himalaya are well known for their

Table 15.1: Plants used in preparing natural dyes by the Bhotiyas of Uttarakhand

S. No.	Plant species	Part used	Colour produced
1.	Khukhuyinya (*Rumex nepalensis*)	Root	Yellow
2.	Dolu (*Rheum australe*)	Root	Yellow
3.	Akhrot (*Juglans regia*)	Fruit cover	Camel
4.	Kapasi (*Corylus jacqumontii*)	Fruit cover	Camel
5.	Kingod (*Berberis* spp.)	Root	Yellow
6.	Archa (*Rheum moorcroftianum*)	Root	Yellow
7.	Bajar Bhang	Root	Brown
8.	Geranium (*Geranium nepalense*)	Root	Red

traditional expertise in processing and colouring of wool and preparing varieties of woolen garments (Table 15.1). Alone in Arunachal Pradesh, 37 plant species are traditionally used for dyeing of cloths.

Traditional therapies: Approximately two million traditional health care practitioners still use medicinal herbs for curing various ailments. A study in Uttarakhand reveals Vaidyas, the traditional herbal healers, use about 156 medicinal plant species for preparing 243 formulations for treating 73 ailments. These medicinal plants contain nearly 100 therapeutic properties. This practice, mainly acquired from generations, is now declining.

Traditional hill agriculture: IHR has a strong base of traditional hill agriculture that has sustained the local communities and helped in maintaining rich gene pool. For instance, in Central and West Himalaya well adapted traditional varieties of grains, pulses, millets, amaranths, maize and vegetable are cultivated on terraced hill slopes. Traditionally grown millets and pseudo-millets are a good source of protein, B vitamins, and minerals and beneficial fibre. However, in more recent past, the traditional agriculture is being replaced by income generating crops (Kuniyal *et al*., 2004). For example, in cold desert of Lahaul valley, 8 varieties of traditional food crops (monetary efficiency 1.96) were cultivated before 1960s. Today about 95% of the agriculture land is under hop, potato and pea for higher cash return (monetary efficiency 2.86). In spite of this change, farmers still cultivate traditional crops such as barley and buckwheat for traditional cuisine and rituals as second crops after harvest of pea. Likewise, in other parts of IHR, traditional agriculture practices contribute towards maintenance of genetic diversity.

Uniqueness

Attempt is being made to exhibit uniqueness of TK and practices with shifting cultivation (*Jhum*), in North-East region. *Jhum* is a unique form of agriculture wherein one piece of forest land is slashed and burnt, ash is mixed in the soil and land is cultivated for a period of two years, and left for fallow development. *Jhum* is prominent land use associated with socio-cultural framework of the local communities in the North-Eastern states of IHR.

Jhum practices vary from tribe to tribe. In past jhum cycle used to be >20 years; *Jhum* system of >12 years cycle is considered ecologically viable. Along with rice, several varieties of vegetables, tapioca, chillies, and amaranths are cultivated in the *Jhum* fields. Various unique traditions are associated with *Jhum* (Ramakrishnan, 1992). A unique example of *Jhum* comes from Lazami in Nagaland where farmers practice an unusually long cropping phase, and a weeding system with almost no fallow period.

Cultural Diversity and Biodiversity Linkages

In IHR, with numbers of tribes and sub-tribes, diversity prevails in cultures that include languages, social structures, spiritual traditions, farming, therapies and certain invaluable traditional knowledge systems of bio resource use, and conservation. Use of traditional cereals and pulses for preparation of traditional foods and beverages, colouring of woolen and cotton yarn with locally available natural dyes and making clothing with locally available raw material are classical examples of biodiversity linkage with culture in the region.

Societal Importance

The knowledge base of Himalayan people on use and protection of bioresource is enormous. Take an example of medicinal plant, over 1748 plants have been recorded from the region. The traditional *Vaidya* system is very strong in Uttarakhand. Likewise, *Apatani* tribes of Arunachal Pradesh have very strong knowledge of herbal medicine. About 158 MP are used by Apatanis for treatment of various ailments (Kala, 2005). *Amchis* in the trans-Himalaya (Laddak in Jammu & Kashmir, Lahaul and Spiti in Himachal Pradesh) use about 337 plant species for their traditional health care (Nandy *et al*., 2006).

Unique Case Studies

Following examples are being used to illustrate the strength of TK in the region:

- **Traditional animal husbandry:** Traditional rearing of livestock is an integral part of hill agriculture, particularly in high altitudes, for wool, meat, milk, hide, organic manure and drought and pack powers. Yak (*Poephagus grunniens*), a native of Tibet, is domesticated in parts of Jammu & Kashmir, Lahaul & Spiti district of Himachal Pradesh and high altitudes of Uttarakhand and Arunachal Pradesh. Its ability to adapt prolong sub-zero temperature in snow bound environment and its survival on coarse fodder is unique and this quality of yak is effectively utilized by traditional communities by way of developing a system of cross breeding with local cow.

Traditional *Vaidya* system in IHR © Rakshita Pathak

A Naga woman returning from "*jhum*" field with several vegetables and fuel wood

- **Traditional off-take irrigation canals *(Kuhl)***: In North Western Himalaya traditional off-take water channels (*kuhl*) are developed, managed and water is shared among right holder for ensured irrigation. Stream water and snowmelt water from hill tops is channelized upto farmers field. In Cold desert of the Lahaul valley 100% of agriculture, forestry, kitchen garden and managed grasslands are irrigated through *Kuhl* in absence of rains.

Conservation and Sustainable Use Initiatives

- The Traditional Knowledge (Protection and Management) Act implemented in 2010.
- Traditional Knowledge Digital Library of CSIR contains Database of 1200 Ayurvedic, Unani and Siddha Formulations.
- Department of Indian Systems of Medicine & Homoeopathy (ISM & H) created in 1995 and renamed Department of Ayurveda, Yoga & Naturopathy, Unani, Siddha and Homoeopathy (AYUSH) in 2003, focuses on development of education and research on these systems.
- Uttarakhand has been declared as an Herbal State and a maximum number of Ayurvedic and Homeopathic medicines depend on plant sources.
- The National Rural Health Mission (2005–2012) too seeks to revitalize local health traditions and mainstream AYUSH into the public health system.
- Department of Biotechnology, Govt. of India and other agencies fund projects on R&D in medicinal plant conservation, sustainable use and product development.

Challenges

- Younger generation is least interested about traditional knowledge and practices of resource management and sustainable utilization.
- Some parts of north eastern India, particularly in Meghalaya, the rich tradition of sacred grove is fading.

Conclusions

- Traditional knowledge and practices of hill farming has contributed in gene pool conservation and therefore needs to be promoted.
- Documentation of 'Vadiya' system of knowledge is urgently needed.
- TKSs associated with various tribal communities require to be explored, analysed and popularized.

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Conserving cold desert habitats- Hemis National Park © Subrat Sharma

16

Conservation Areas

Promoting Conservation in the Himalayan Region

The new vision of CBD (Convention on Biological Diversity) – "*Living in Harmony with Nature*" envisages that "*By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy plant and delivering benefits essential for all people*". This calls for attention from diverse stakeholders. In this context, India is committed to protect, conserve and sustainably use the country's biological resources through its constitution and wide-ranging policies, programmes and projects. These include the various acts (Forest Conservation, Wildlife Protection, Biological Diversity, etc.), action plans (National Biodiversity, Wildlife 2002–2016, River, Lakes, etc.), policies (Forest, Environment, etc.), programmes (MAB India etc.), and bodies (Indian Board of Wildlife: apex advisory body headed by the Prime Minister, which oversees and guides the implementation of various schemes for wildlife conservation; National Biodiversity Authority, State Biodiversity Boards, etc.). Among others, the Indian Himalayan Region (IHR) is one of the priority areas for ecosystem conservation in the country.

Richness and Representativeness

Three bio-geographic zones (Trans-Himalaya, Himalaya, and North-east India) represent administrative spread of the IHR, and nearly 8% of the total landscape is under legal protection through National Parks and Sanctuaries. In numbers and area coverage of PAs, the IHR shares considerably large part of PA network in India: Total PAs 22.0% (133 of 672 in India), PAs coverage 29.1% (45,774 km^2 of total 1,57,572 km^2 in India). Representation and richness of PAs in different Biogeographic Zones of IHR is given (Table 16.1). The initial conservation efforts (1935) in the country took off from the IHR only with the establishment of the Corbett National Park (second in the country for hosting more than hundred tiger population). The physiographic diversity of the IHR ranges from ~250 m to >7,000 m asl encompassing elements of subtropical to tundra type biomes. Major habitat types are forests, high altitude wetlands, and cold deserts. More than one third (9) of the declared internationally important wetlands of India (25) are located in the IHR. The foothills of IHR are habitats for three major terrestrial flagship species (tiger, elephant, and rhino) while high altitudes for snow leopard, Tibetan antelope, wild yak, and Himalayan tahr. Three Tiger Reserves, located in this region, cover 0.7% of total geographical area. Besides the tiger conservation programme, some of the designated Elephant Reserves are also located in the region, viz., Kameng in Arunachal Pradesh, Garo Hills in Meghalaya, and the Shivalik in Uttarakhand. Among others, the region is well represented in Biosphere Reserve (BR) network of India. Of the existing 18 BRs, 5 are exclusively Himalayan. Biosphere Reserves and Tiger Reserves in the Indian Himalaya are shown (Table 16.2).

Uniqueness

Most of the Himalayan landscape is part of the either Himalayan biodiversity hotspot or Indo-Burma biodiversity hotspot. The vertebrate faunal elements in the Himalaya provide a high degree of diversity and endemism at species level (Table 16.3). High endemism in fish species occurs in the Himalayan region as compared to the country (25.7% vs. 8.7%, respectively). Many of the plants are endemic to these mountain ranges (~40% of the flora) particularly in the high altitudes, and alpine/sub alpine areas. In total Himalayan flora represents 71 endemic genera. Five families are endemic to the region (*i.e.*, Tetracentraceae, Hamamelidaceae, Circaeasteraceae, Butomaceae, and Stachyuraceae), while over 90% of the species in Berberidaceae and Saxifragaceae are reported as endemic to the Himalaya. High endemism makes the Himalaya a highly significant area from the conservation and protection point of view.

Table 16.1: Richness and representativeness of PAs in IHR

Zone	Zone area (km²)	No. of NPs (area (km²)	No. of WLS (area (km²)	No. of PAs (area (km²)	% of Biozone
Trans Himalaya	184823	03 (5809)	04 (10439)	07 (16248)	8.8
Himalaya	210673	12 (7367)	65 (16066)	77 (23433)	11.1
North-East	171340	13 (2674)	36 (3419)	49 (6093)	3.6
Total	**566836**	**28 (15850)**	**105 (29924)**	**133 (45774)**	**8.1**

Source: MoEF, 2009.

The Himalayan ranges are characterized as unique ecosystems encompassing diversity of natural and socio-cultural systems. Some of the conserved landscapes (e.g., Nanda Devi Biosphere Reserve which includes Nanda Devi & Valley of Flower National parks) in the region have received global recognition as natural heritage site. One of the most spectacular wilderness areas in the Himalaya, Nanda Devi National Park is dominated by the 7,817 m high peak of Nanda Devi, India's second highest mountain which is approached through the Rishi Ganga gorge, one of the deepest in the world. Beside the iconic species (snow leopard, Himalayan maple, and Himalayan birch), several animal (red panda, wild yak, marmots, musk deer, hangul, and Himalayan Tahr) and plants species (Himalayan Yew, Rhododendrons, Cedar, Pitcher plant, etc,) are confined to the Himalayan mountains only. A large number of orchids, many representing neo-endemic taxa, occur in the eastern Himalayan region.

Traditional beliefs and practices in the region have helped in conserving various representative landscape elements as reflected by occurrence of sacred groves/landscapes in a variety of ecological situations where patches of forests and other type of landscapes (e.g., alpine meadows, high altitude lakes) are attached with sacred values. This philosophy of conservation is more visible in North-Eastern region but present in other regions too, e.g., Mawsmi in Cherrapunji, Demaazong in Sikkim, Lakes of Chhiplakot and Hemkund in Uttarakhand. An important, internationally known, environmental movement "Chipko Andolan" to save the forests began in the West Himalaya.

Tradition of Community Conserved Areas (CCAs) especially in Eastern part of IHR, is unique in the sense that these areas are declared by community themselves for promoting conservation and sustainable use of resources.

Societal Importance

Country's conservation philosophy believes that the protecting our biodiversity is a critical national priority as it is linked to local livelihoods of millions of people.

Table 16.2: Biosphere and Tiger Reserves in the Indian Himalaya

State	Biosphere Reserve		Tiger Reserve	
	Name	Area (km²)	Name	(Area, km²)
Uttarakhand	Nanda Devi	5860.69	Corbett	1318.54
Himachal Pradesh	Cold desert	7770.00	–	–
Sikkim	Khangchendjunga	2619.92	–	–
Meghalaya	Nokrek	820.00	–	–
Mizoram	–	–	Dampa	500.00
Arunachal Pradesh	Dehang-Debang	5111.5	Namdapha	1985.245
			Pakhui-Nameri	1206.00

Table 16.3: Some of the known biodiversity of the Himalayan region (representing only ~16% of India's land area) and its contribution to the biodiversity of the country

Plant groups	Percent share of Country's known Stock	Endemism (%)	Animal groups	Percent share of country's known Stock	Endemism
Angiosperms	47.0	40.0	Mammals	64.8	Na
Gymnosperms	81.4	16.0	Birds	43.0	Na
Pteridophytes	58.7	25.0	Reptiles	35.0	29%
Bryophytes	43.9	32.5	Amphibians	36.0	35%
Fungi	53.1	27.4	Fishes	17.0	35%
Lichens	59.5	11.2			

Sustainable use of our biodiversity, therefore, has both ecological and economic value. Rich biological wealth makes the Himalayan region a highly significant area from the conservation and resource planning angle and expected to bring prosperity to the people living in such areas. For example, collection of *Cordyceps* (Kira Jari) from alpine region has contributed significantly to strengthen the rural economy of the region. In the IHR, about 1,748 plant species of medicinal uses have been recorded, and contributed in the development of local traditional/indigenous knowledge (i.e.,Amchi and Vaidyas). Many modern drugs are being produced from these species. Himalayan ranges provide various ecosystem services and goods (to the people living therein or in far places of the Indian-subcontinent) by way of sustaining major supply of water, timber, fiber, oils, spices and condiments, firewood, organic manure, fodder, and hydropower. It is reckoned as "repository" and continues to remain an important centre for the origin of the crop diversity and numerous under-utilized and potential future crops (e.g., *Citrus*). Diverse types of conservation areas contribute for protection of such a rich biodiversity.

Conservation and Sustainable Use Initiatives

The Article 8 of the Convention on Biological Diversity (CBD) advocates the importance of promoting *in situ* conservation. More systematic conservation efforts in the region started as early as in 1935 with establishment of first National Park in the foothills of the Himalaya. However, more focus on establishing national parks in the Himalayan region began after 1970. Between 1970 and 1995 many of the national parks and wildlife sanctuaries were established in the entire Himalayan region. Some more recent and important national programmes targeting conservation and sustainability of Himalayan ecosystem include "National Mission on Sustaining Himalayan Ecosystem", "National Wetland Inventory and Assessment of High Altitude Himalayan Lakes", "Project Snow Leopard", "National Lake conservation Plan". Species-specific conservation programme,however, include: (i) flagship animals tiger (national animal), rhino, elephant (national heritage animal); (ii) other animals like snow leopard, pygmy hog and ghariyal; (iii) birds (great Indian bustard) and an action plan for vulture conservation is also in place; (iv) orchids, rhododendron and citrus from plant kingdom. Designation of Seven Biosphere Reserves (5 exclusive Himalayan) under "Man and Biosphere Programme" in different Bio-geographic zones of IHR has strengthened both conservation of biodiversity and local livelihoods in 23,039 km^2 of protected landscape. Community-based protection and management are also seen where local communities conserve and manage habitats of wildlife around them as a traditional system. Tribal communities of North-East region manage their forest areas through traditional norms. For example, Ronmei tribe in Manipur has preserved and regenerated 600 ha of village forest in the Loktak Lake catchment.

Challenges

While new discoveries are still being made from the IHR, endemic animals like wild yak and mountain quail have already been placed in the "critical" category of Red Data Book (IUCN, 1994). Endangered species are present in every group but more in avian fauna (Himalayan Monal Pheasant, Mountain Quail, Western Tragopan, Himalayan Bearded Baza, Tibetan Snowcock, Tibetan Blook Pheasant, Satyr's Tragopan, Blyth's Tragopan, Temmincks Tragopan, Koklass Pheasant, Black necked Crane, Rufous neckled Hornbill, etc.); and endangered reptilian species include such as widely distributed forms as Indian Rock Python, while the only endangered amphibian in the region is Himalayan Newt in Darjeeling area. Of the total, 622 threatened plants listed so far, 137 of the Himalayan plants are listed under various threat categories (Red Data Book). Of the 137 RDB species, 71 are from the Eastern, 56 from the Western part of Himalaya, and ten species are common to both these regions. Among special groups, rhododendrons are highly valued but some of these are endangered (e.g.,out of 36 species of rhododendrons occurring in Sikkim, eight have been assessed under threat). Traditional practices of resource management and conservation are breaking down on the face of social and economic changes leading to overexploitation and degradation of resources. Habitat loss and degradation of resources are major challenges posed by human activities (e.g., Land-use change, over harvesting, poaching, human-animal conflict, and pollution) and looming threats of climate change. Under such a changing scenario, it is a great challenge to redesign/redefine conservation areas, especially PAs, in such a manner to accomodate dynamism and impacts of changes on biodiversity and human livelihoods.

Conclusions

The Indian Himalayan Region (IHR) has received due attention under PA network of India and contributes significantly to total numbers and area coverage of PAs in India. These PAs and other conservation areas have helped in protection of rich, representative and unique biodiversity elements of "Himalayan Biodiversity Hotspot". However, the ongoing changes in socio-economic structure and expected threats of Climate Change, pose great challenge to existing Conservation Areas in the region both with respect to their value for biodiversity conservation and human livelihood support.

Conservation Areas benefiting human sustenance © Subrat Sharma

Understanding conservation value of sacred groves © Tarun Belwal

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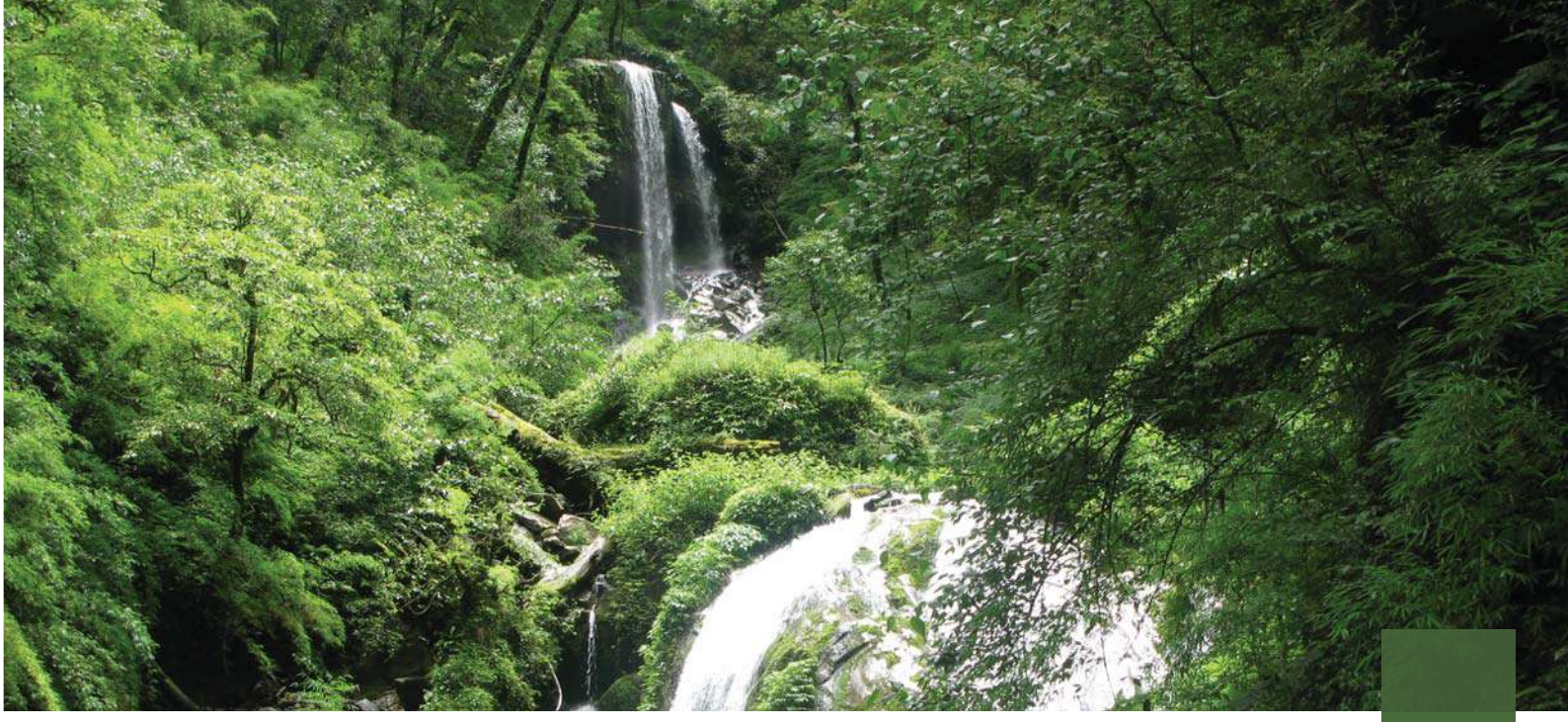


Himalayan forests- store house of goods and services © Balwant Rawat

17 Ecosystem Services

Biodiversity and Ecosystem Services Link in the Indian Himalayan Region

Biodiversity is essential for not only human survival and economic well-being but for the ecosystem function and stability as well (Costanza *et al*., 1997). It is the source of many ecosystem goods, such as food, medicine and genetic resources, and services like carbon requestation, water regulation etc. Unfortunately, despite the proven importance of biodiversity to sustain life on the earth it is rapidly declining worldwide (Millennium Ecosystem Assessment, 2003). Arguments for biodiversity conservation are often based on Ecosystem Services (ES), but it remains not very clear whether few or many species are needed to maintain ecosystem functioning and services. Ecosystem Services result from interactions between biotic and abiotic components of ecosystems and may be defined as conditions and processes through which ecosystems and species in them sustain and fulfill human life (Daily, 1997).

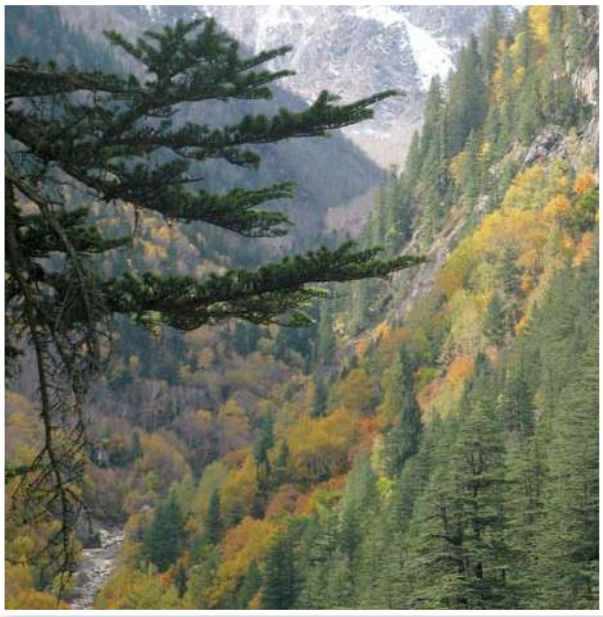
Richness and Representativeness

About 70% of the world's non-polar glaciers occur in the Himalayan region; this mass of snow and glaciated area, covering an area of 23,902 km^2, serves to 19 river basins in the Himalayan Region. Mighty rivers like Ganaga, Yamuna, Indus, and Brahmaputra arise from this region. The Indo-Gangetic plains inhabited by over 500 million people are benefited through the ES flowing through these river systems in the form of water and mineral resources and associated life-supporting processes (Singh, 2007). Bio-climatic gradient represents the distinct diversity of plants and animals, as apparent from eight major forest functional types ranging from sub-tropical to sub-alpine forests and alpine scrubs above them. Beyond timberline there exist the vast alpine meadows. The forest cover accounts for about 32.3% of the total geographical area of Indian Himalayan Region (IHR), which is higher than the proportion for the country (21% in entire country). Of this 32.3%, majority have very good cover (45.2% good forests) about one-third, consists of moderate forests (31.5%) and 29.4% is considered as open forest. These forests store enormous amount of carbon. For example, C stock in vegetation and soil pool for the state of Uttarakhand has been estimated at 531 mt (Table 17.1).

Table 17.1: Carbon stock in different forest ecosystems of Uttarakhand

Forest type	Area (km^2)	Biomass Pool (mt)	Soil Pool (mt)
Tropical conifer (Pine)	5418	33.4	61.71
Temperate conifer	6017	37.1	68.54
Temperate broad leaved	7809	119.3	111.95
Moist deciduous	3027	54.4	15.10
Dry deciduous	695	12.5	3.47
Sub Tropical (Sal)	562	10.1	2.80
Total	**23528**	**266.8**	**263.6**

Note: mt, million tons. *Source:* Singh, 2007.



Biodiversity rich conifer-mixed broad leaf forest © G.C.S. Negi

Uniqueness

- Regulating the climate in Indian subcontinent, the Himalayan ranges have a profound effect by preventing frigid, dry arctic winds blowing south into the subcontinent thus keeping south side much warmer than corresponding temperate regions in the other continents. It also forms a barrier for the monsoon winds, keeping them from traveling northwards, and causing rainfall in the south of the Himalaya.
- The Himalayan forests help in maintaining soil fertility, capture essential atmospheric moisture, and regulate river flow and reduce erosion and sedimentation downstream owing to a large "sponging effect", thus regulates the hydrological regime in the rivers flowing downstream (Bruijnzeel and Bremmer, 1989) that is desirable for hydropower and other industries. The IHR through its river connections with the adjacent lowlands and transport of water and nutrients is a principal provider of ES (provisioning service) that keeps on replenishing the productivity of major croplands.
- The Himalayan zone cover nearly 19% area and contribute to 33% of Soil Organic Carbon (SOC) reserves of the country largely due to thick forest vegetation. IHR, being a rich repository of biodiversity and biological resources of human use, contributes directly to the livelihood and sustenance of the people. In this region, over 675 wild plant species, representing 384 genera, and 140 families are used by people as food/edible, medicine, fodder, fuel and timber.
- The high altitude lakes, mountain peaks and sacred natural sites attract tourists and have a vast potential of eco-tourism, adventure tourism and religious tourism.

Societal Importance

- The most notable ES is now considered to be C sequestration by forest ecosystems, particularly on the face of global warming. The C pool in IHR forests (forest biomass + soil C) has been estimated at 5.4 billion t and these forests can sequester about 65 mt C annually in above ground biomass alone. Preliminary study has estimated the forest ES value approx. 1150 US$/ha/year, and the value of Himalayan forests with regards to C-sequestration has been estimated at Rs. 37.5 billion/yr; and the total value is Rs. 943 billion (Singh, 2007). As per the estimates (Singh, 2007), Arunachal Pradesh (Rs. 323.95 billion), Jammu & Kashmir (Rs. 118.02 billion) and Uttarakhand (Rs. 106.89 billion) are the leading states in IHR with respect to values of forests ES. Verma (2007) has estimated the total ecosystem value (TEV) of Himachal Pradesh forests at Rs. 6,46,75 /ha/yr (Table 17.2).

Case Study

Biodiversity and ES Link – A Comparison of Oak and Pine Forests in West Himalaya

- Forest diversity is the main source of livelihood of people living in western Himalaya. Out of the 64% area under forests in Uttarakhand, 12.3% is covered by Oak forests and 16.4% by Pine forests. Oak forests are characterized by high biodiversity (Shanon-Weiner index) for tree (1.3 vs. 0.18), shrub (1.6 vs. 1.3) and herb (3.3 vs. 2.6) layer as compared to Pine forests (Table 17.3).
- Oak forests recorded greater biomass (549 vs. 224 t/ha) and C stock (382 vs. 190 t/ha) as compared to Pine forests, however, the C sequestration rates of the two forest types was recorded almost same (Oak 5.6, Pine 6.2 t/ha/year) (Table 17.3).

On-Going Initiatives

- A new programme "The Economics of Ecosystems and Biodiversity (TEEB)" initiated by Union Ministry of Environment and Forests (MoEF) is one of the major efforts in India for proper accounting of ES and its role in national accounting system. State-level efforts include evaluation of ES and their accounting in state domestic product (SDP) of Himachal Pradesh.
- Towards promoting state initiatives for protection of the forests, a compensatory measure as "green dividends" or "green bonus" has been initiated by the Union Government.
- Community participation has been strengthened in forest management, e.g. Uttarakhand state where ~12,000 community managed forests cover more than 0.5 million ha of land.

Challenges

- A new "Accounting" system is required which should encompass the biodiversity value and services provided by the nature. On account of lack of Total Ecosystem Value (TEV) estimates for ESs,

Table 17.2: Annual value of ES in Himachal Pradesh under the scenario of IIFM-CSO (2005) study

S. No.	Ecosystem Services	Per ha value of forest and tree cover area in HP (Rs.)
1.	**A. Direct consumptive benefits**	
	Timber logging	221.3
	Fuelwood	762.7
	Fodder (collection)	547.0
	Grazing	2607.2
	Minor Forest Products	195.2
	Total	4333.4
	B. Direct non-consumptive benefits	
	Ecotourism	3270.0
	Total Direct Benefits (A+B)	**7603.4**
2.	**Indirect benefits**	
	Watershed benefits	498330.0
	Microclimatic factors	976.8
	Carbon stock	111102.1
	Carbon flux	653.7
	Biodiversity	27917.0
	Employment generation	168.4
	Total Indirect Benefits	**639148.0**
3.	**Total economic value of ES (TEV)**	646751.4

Source: Verma, 2007.

the current system of National Accounts reflects only the marketed value of ESs and the whole array of ecological services do not find any place in the current calculus for GDP estimate which is a gross underestimation of their contribution in the national economy. For example, the contribution of forests to India's GDP has varied from 1–1.5% over the nine year period from 1993–1994 to 2002–2003.

- It is often suggested that as long as ES are not included in market system, governments should incorporate them in their accounting systems so that the service providers have economic rewards for their conservation efforts- a concept of payment for ES (PES). There is a need to develop sound methods to monitor flow of ES.
- Structural and functional dynamics of forests and other vegetation is least captured in the ES valuation. Intangible services of forests such as recharging of groundwater, regulation of stream

Provisioning of water to millions of people (downstream) © Shalini Vidyarthi

Table 17.3: Biodiversity and ES in western Himalayan forests (a case study of Oak and Pine forests). *Values in parentheses depict diversity* (Shanon-Weiner index)

Forest biodiversity and ES parameters	Oak forests	Pine forests
Species richness		
Trees	6–8 (1.0–1.6)	2–4 (0.12–0.23)
Shrubs	6–9 (1.5–1.7)	4–7 (1.2–1.3)
Herbs	29–35 (3.2–3.3)	17–19 (2.4–2.8)
C-stock (t/ha)		
Tree layer	275	112
Soil	107	78
Total	382	190
C-sequestration (t/ha/yr)	5.52–5.64	5.99–6.44
Value of ecosystem goods collected by people (Rs./capita/year)	4917	4256
Wild edibles collected by people (Rs./capita/year)	227	138
Soil loss during monsoon season (t/ha)	0.35	1.01
Rainwater runoff during monsoon season (L/ha)	1810	2465
Soil nutrient concentration (%)	N= 0.35–036 C= 1.83–2.11	N= 0.12–0.18 C= 0.19–1.31

Source: Joshi and Negi, 2011.

flows, flood control, micro-climatic functions, biodiversity maintenance, recreational, spiritual and aesthetic values are grossly underestimated or ignored during development planning and yield poor investment decisions (Negi *et al*., 2012).

Other Relevant Considerations

It is important to develop strategies to conserve as high a proportion of the species on the planet as possible, but a balanced approach of conservation should also consider other environmental issues such as carbon sequestration, waste dissipation, hydrological balance, soil formation, health of local ecosystems, and others, not intimately connected with biodiversity (Singh, 2007).

- Verma (2007) has pointed out that the loss of a forest provisioning ES is fundamentally economic in nature, its conservation needs to be addressed in economic terms. For forests to be conserved, they need to be perceived as being more valuable than the usual, standard utilities they provide.
- Raising new plantations may not be feasible as a mitigation tool to C-stocking rather protect the young and regenerating forests and promote regeneration, as old growth forests may also not fix C efficiently.
- The unique floral and faunal wealth of the Himalaya is undergoing structural and compositional changes due to climate change. The increase in temperature may shift various species to higher elevations. The Oak forest is being invaded by Pine forests in the West Himalayan region. These climate change induced phenomenon may have adverse impact on flow of ES and need to be studied in greater details.

Conclusions

- Uniqueness of IHR produces a number of ES unmatched by any other ecosystems.
- Biodiversity and ES link is clear; thus biodiversity needs to be conserved for enhancement of ES and ensuring human well-being.

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Forest Bioresources: Important link for promoting livelihood options for local populace

Bioresource-based Products

Towards Promoting Livelihood Options

18

The Indian Himalayan mountain range encompasses a whole variety of ecological and cultural landscapes that contribute to richness of bioresources at various levels. For centuries, bioresources of both cultivated and wild origin have played vital role in the subsistence economy of the traditional communities living in the region. Among others, the forest bioresources constitute an important source of livelihood for millions of people across the Himalaya.

Richness and Representativeness

Environmental, biological, socio-cultural and economic factors prevailing in the Himalaya have resulted in the evolution of diverse agriculture ecosystems. In northeast India, a tribal dominated landscape, shifting agriculture (*jhum*) characterized by mixed cropping and linked with swine-poultry husbandry is the most extensive land use. This highly organized agriculture is based on traditional knowledge accumulated through centuries, in harmony with the environment. Shifting agriculture provides varieties of food items, preferred by the tribal people, throughout the growing season and some 8-35 crops are grown together and harvested sequentially from July to December. This system is considered relatively sustainable if the fallow period is fairly long. On the other hand, western Himalaya has a long heritage of subsistence economy, with agriculture being the core component involving over 70% of its population. All the farming systems are livestock based and form a spectrum of economic activities ranging from nomadism (practiced by *Gujjars*), transhumance (*Bhotias*) to settled agriculture. Settled agriculture, a mixed "crop livestock" farming system, predominates over a broad range of altitude (between 300 m and 2700 m). This is often organized as terraced agricultural fields on steep slopes. The crop diversity in the agriculture in this region is very high and as about 40 different species of crops are grown.

Box 18.1. Cultural practices linked to conservation of bioresources

- The bark of *Taxus baccata* and *Betula utilis* is removed using indigenous wooden tools by the Bhotiya community of the Uttarakhand which is linked to cultural-religious belief system.
- The traditional herbal healers of Uttarakhand refrain from collecting medicinal and aromatic plants before the plants have produced viable/mature seeds/ rhizomatus parts, etc. This practice helps in natural regeneration of the plant species.
- The alpine zone (locally called "Bugiyal") is one of the most fragile ecosystems and possesses cultural religious significance. Therefore, by involving a component of sacredness, protection of species and habitats is ensured.

The richness and representativeness of wild bioresources in IHR has been already depicted in previous segments (1–17).

Uniqueness

Uniqueness by provinces/areas

The unique topography and climate has paved the way for rich bioresource diversity across the IHR from north-west to north-east. The region is home to an estimated over 60 million people. With about 800 culturally distinct communities living in the region belonging to over 200 ethnic groups that form equally diverse linguistic groups, the richness in bioresource based knowledge available with them is enormous. The region supports a large variety of wild-growing plant resources for food and

Medicinal value plants with potential to become functional food

other subsistence needs of local communities inhabiting the forested areas.
The traditional communities have developed, and continue to practice, ways of living and socio-cultural belief systems based on their intimate relationship with the natural resources and environment (Box 18.1 and 18.2).

Potential and Cultural Linkages

Ecological and economic potential

There exists a great potential for enterprise development and marketing of products from medicinal and aromatic plants, horticulture, floriculture, wild edible fruits, bamboos, spices and condiments, vegetable cultivation, organic farming, etc. (Box 18.3, 18.4 and Table 18.1). Harnessing the potential of resources through value addition as useful products could meet both short and long-term subsistence, market, cultural and conservation needs (Table 18.1). However, realizing the need for establishing a transparent system of benefit sharing, such initiatives would require more attention along with the value chain development.

Cultural diversity linkages

Apart from the economic potential of bioresources, many traditional communities rely on these resources for social, cultural and religious functions. The socio-cultural belief systems have often played a significant role in controlling over-exploitation leading to conservation of potential bioresources. The cultural practices and regulations indicate the conservation and management ethics. Through the application of traditional knowledge and customs, unique and important bioresources have often been protected and maintained in many of those areas inhabited by indigenous communities.

Initiatives for Conservation and Sustainable use

National & Institutional level

- Constitution of National Medicinal Plants Board to effectively implement an integrated policy on conservation, sustainable use, cultivation, utilization, processing and marketing of medicinal and aromatic plants (Govt. of India).
- Enactment of Biological Diversity Act and Constitution of National Biodiversity Authority to conserve biodiversity, sustainable use and equitable benefits sharing (Govt. of India).
- Over last 18 years GBPIHED-Garhwal Unit (GU) has been actively involved in conservation, sustainable use, value addition, product development of potential bioresources, particularly of wild origin in Garhwal Himalaya.
- GBPIHED-GU facilitated some local NGOs, namely, Himalto, KEDAR, and Pahari in the area of value addition and product development from some potential bioresources, particularly wild edibles for income generation.

State level

- Constitution of State Bamboo Board to bring extensive area under bamboos, promoting scientific harvest and yield improvement (Uttarakhand State).

Community level initiatives

- The Jardhargaon village in Uttarakhand regenerated and protected 600-700 ha of forest and revived several varieties of agricultural crops.
- Van Panchayats like the Mukku village in Rudraprayag district of Uttarakhand has protected several thousand hectares of high altitude pasture lands and forests.

Box 18.2. Wild edible bioresources – Improvement of livelihood of rural population in West Himalaya

- The West Himalayan region supports a large variety of wild edible bioresources occurring naturally across altitudinal range and often used for subsistence needs by the local communities.
- Based on economic potential, availability in nature, nutritional and pharmaceutical properties, about 25 wild edible plant species have been screened and selected for value addition.
- GBPIHED, Garhwal Unit, is facilitating development of entrepreneurship among the stakeholders by way of technological intervention and transfer of technologies for making value added products.
- Experiences suggest, the wild bioresource based income-generating activities have significantly improved the livelihoods of the rural people and contributed to biodiversity conservation by reducing pressures on other locally valuable species.
- Realizing the significant positive impacts, some of local NGOs (i.e., Himalto, Vishwanath, Pahari, Swaraj, Kedar Ecotourism) and individuals have produced value-added products for local market under different brand names. As estimated, the net monetary benefit earned during 2010–2011 to these institutions/ individuals ranged Rs. 1.5–25.0 lakhs.

Challenges

- Indiscriminate harvesting practices have resulted in depletion of natural regeneration and local extermination of potential plant species. Therefore, in-depth information (i.e., distribution, availability, regeneration status, yield estimates and sustainable harvesting levels, etc.) is required for proper management.
- The frequent and deliberate fires in diverse forest types have disastrous effect on many of the plant species. Therefore, appropriate fire preventive measures are required in bioresource potential zones.
- With little or no access to market information and channels, marketing remains a major challenge for bioresource collectors/gatherers. Therefore, there exists an iminent need to strengthen linkages to make market information available to the gatherers.
- Knowledge dissemination on product development, processing, value-addition, post-harvest treatment, storage facility, certification, etc., can help the local people in gaining better livelihoods and income.
- The natural habitats that harbor potential bioresources are under major threat and, therefore, require urgent step to

Under explored wild edibles awaiting intervention for product development

Table 18.1: Cost–benefit analysis of wild herbal spices (as a raw material and after value addition) used in West Himalaya

Plant species	Input (Rs/kg)		Output (Rs/kg)	
	Cost of raw materials	Other expenditure (grinding/packing & labour)	Cost of local value-added products	Net return after local value addition
Allium stracheyi	210+5.7	30+2.2	470+11.6	230+6.1
Allium humile	230+7.7	40+2.9	500+13.2	230+8.3
Allium rubellium	230+6.4	40+1.8	500+15.3	230+8.3
Angelica glauca	300+16.1	40+3.2	550+22.6	210+5.1
Pleurospermum angelicoides	300+14.6	40+2.1	560+23.7	210+7.2
Rheum emodi	300+14.6	50+3.8	560+23.7	210+7.2
Carum carvi	250+14.6	40+4.7	500+23.7	210+7.2
Cinnamomum tamala	35+0.9	30+1.2	150+10.6	85+2.2

restore/rehabilitate/conserve the degraded sites with appropriate science and technology interventions and participatory approaches.

Conclusions

- Bioresources are important renewable natural resource and their sustained availability is essential to safeguard millions of dependent people.
- Today, however, bioresources of wild origin are under serious threat, many species are on the list of rare and endangered categories due to unsustainable harvesting. The potential bioresources require reliable information on status and distribution patterns, and knowledge of anthropogenic pressure.
- It is imperative to take multi-dimensional action (social, cultural, ecological, economical and institutional) on priority basis for conservation, sustainable utilization and product development following science and technology interventions.

Bamboo-based products: Potential source of income generation

Box 18.3. Natural fibre-based products – Potential source of income generation and environmental conservation

Products from plant-based fibres play important role in daily life of the rural inhabitants. This contributes significantly to the economy of the people in various ways such as clothing and products for household purposes and agricultural implements, etc. Recently GBPIHED has listed about 134 fibre yielding plants from the Indian Himalaya, of which 25 species have huge potential for promoting income generation through cottage industries on sustained basis and few of them are listed here *(Cannabis sativa, Corchorus capsularis, Hibiscus cannabinus, Triumfetta rhomboidea* and *Wikstroemia canescens*, etc.*)*.

Box 18.4. Higher Himalayan bamboo-based products

- Of the world's 1,250 species of bamboos, India is represented by about 145 species of which 9 species are found in Western Himalaya, growing naturally in diverse climatic conditions and cover about 1394 km^2 area. Two species, i.e., Ringal (*Arundinaria falcata*) and Tham (*Thamnocalamus jonsarensis*) are found in high altitude ranges (2000–3500 m asl).
- The use of higher Himalayan bamboo has a long tradition among the Rudhiya community in WH region and a wide range of local products i.e., baskets, utensils, porridge, mats, agricultural tools, etc., are made by them which involves indigenous skill and constitutes an important basis for livelihood improvement of this community.
- There is a need to improve the quality of products targeting high value markets so that bamboo artisans are able to get better benefits.

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Biotechnological Applications

Supporting Conservation of Biodiversity and Harnessing Commercial Potential

19

Biotechnological methods are being currently adopted to address various aspects of biodiversity, namely, newer and improved methods for preservation (genetic resources), evaluation of collected germplasm for specific traits and subsequent exploitation of useful/ desired traits for commercial and sustainable utilization. India is a home to over 7% and 11% of world's animal and plant biodiversity, respectively. Focusing on plants, the source of a variety of food, medicine, fibre, energy, etc., efforts have been directed towards understanding the mechanism of adaptation under harsh environment prevailing in the Himalaya. Several rare, endangered, threatened (RET) and economically important plant species have been targeted for developing propagation packages using biotechnological methods (e.g, tissue and cell culture). However, analyses of biochemical constituents, important criteria for selecting elite populations and determining appropriate pricing of farm produce, requires immediate attention. Moreover, molecular profiling would compliment in targeting the specific (useful/desired) traits of these species. Microorganisms also possess the potential of growth promotion and yield per se, and for production of useful products (antibiotics, enzymes, biofertilizers, etc.). Such activities would not only help in reduction in direct pressures on biodiversity and promote sustainable use, but also safeguard the target species and genetic diversity.

Societal Importance

Conservation of unique gene pool of rare threatened and high value plants

Indian Himalayan Region (IHR) is known for its unique biodiversity. For example, nearly 30% of the forest plants growing in the region are not found anywhere else in the world. About 125 plant species are wild relatives of cultivated plants, including cereals, legumes and nuts, constitute valuable gene-pools that can be used in future for the improvement of crops. As described in earlier segments, over 1748 plants of medicinal value and 675 species of wild edible have been reported from the region. Most of the plants are used in different traditional and modern healthcare system and are a source of income generation. A large number of these plants are harvested from the wild to fufill the raw material requirement of pharmaceuticals and locals that has put pressure on the survival of these species in the wild. As a result, a number of species have found place in the category of threatened species, therefore, conservation of such species becomes an important priority. In this context, efforts are being made to develop propagation protocol of these species using biotechnological intervention so as conservation of unique gene pool can be initiated. Propagation protocols of various species from the Himalayan region have been developed (Box 19.1) that can be used for developing large number of quality plants. For example, *in vitro* propagation using tissue culture techniques in *Habenaria edgeworthii* showed high rate of shooting percentage (95.8%). A protocol was developed for regeneration of plants of *Rhododendron maddenii* from alginate-encapsulated shoot tips in Sikkim.

Location-specific trials at farmers field by establishing demonstration centres

Towards monitoring the success of survival and growth performance of the species, it is important to conduct multilocational trials of the plants propagated via *in vitro* methods. Over the years, the Institute (GBPIHED) has established different demonstration centers for monitoring growth performance of the various threatened and high value species of the region, e.g., *Picrorhiza kurroa, Aconitum heterophyllum, Aconitum atrox, Rhododendron madenni, Rhododendron dalhousiae, Sapium sebiferum, Diplokenema butyracea, Hedychium spicatum*, *Dendrocalamus hamiltonii*, *Camellia*

Box 19.1. Propagation protocols developed through tissue culture

Diploknema butyracea, Sapium sebiferum, Bauhinia vahlii, Quercus glauca, Q. leucotrichophora, Q. semecarpifolia, Denderocalamus hamiltonii, Thamnocalamus spathiflorus, Pinus gerardiana, P. wallichiana, Cedrus deodara, Pittosporum nepaulense, Rhododendron madenii, Myrica esculenta, Fragaria indica, Hipophae rhamnoides, Arnebia benthamii, A. euchroma, Angelica glauca, A. archangelica, Heracleum candicans, Selinium wallichinum, Aconitum heterophyllum, A. violaceum, A. balfourii, Picrorhiza kurrooa, Saussurea obvallata, S. costus, Swertia chirayita, S. angustifolia, Lilium polyphyllum, Fritillaria roylei, Habenaria edgeworthii, Podophyllum hexandrum, Rhododendron spp., Rosa damascena, Rhynchostylis retusa, Vanda cerulea and Camellia sinensis.

sinensis, etc. Outcomes of these technologies were subsequently adopted by the State Forest Departments of Uttarakhand, Sikkim and Himachal Pradesh for their afforestaton programme.

Screening and characterization of useful biomolecules for the pharmaceutical industries

In order to promote sustainable utilization of high value plants phytochemical investigation on different Himalayan species was carried out. Screening of podophylotoxin in different species of *Podophyllum* showed variations in the content. Similarly, phytochemical investigation in different *Berberis* spp. suggests that lower altitude as compared to higher one is suitable for accumulation of more berberine content. Aconitine and pseudoaconitine from *Aconitum* species showed variation in the content between tissue culture and wild plants. Results of the antioxidant activity analysis in different medicinal plants and wild edibles showed their potential to combat free radical mediated diseases. For example, linear regression analysis in the *Myrica esculenta* exhibited that phenolic contents contribute 46.3 to 47.6% of radical scavenging property and 56.6% of reducing property. Similarly, flavonoids contribute 55.4% to 70.9% radical scavenging property

Table 19.1: Useful phytochemicals/biomolecules reported from different Himalayan medicinal plant species

Medicinal plant name	Active constituent	Content	Reference
Valeriana jatamansi	Total phenolic content	12.35 mg/g	Jugran *et al*., 2013
	Total flavonoid content	6.18 mg/g	Jugran *et al*., 2013
	Total tannin content	3.41 mg/g	Jugran *et al*., 2013
	Patchouli alcohol	36.61 % of Essential oil	Bhatt *et al*., 2012
	Seychellene	4.83 % of Essential oil	Bhatt *et al*., 2012
Hedychium spicatum	Phenolic content	3.80 mg/g	Rawat *et al*., 2011
	Xanthophyll	1.61 mg/100g dw	Bhatt *et al*., 2008
	α-Carotene	20.5 mg/100g dw	Bhatt *et al*., 2008
	β-Carotene	61.8 mg/100 g dw	Bhatt *et al*., 2008
Habenaria intermedia	Gallic acid	5.51 mg/g	Giri *et al*., 2012
	Hydroxybenzoic acid	7.56 mg/g	Giri *et al*., 2012
Myrica esculenta	Chlorogenic acid	5.63 mg/g	Rawat *et al*., 2011
	Gallic acid	5.03 mg/g	Rawat *et al*., 2011
	Catechin	2.72 mg/g	Rawat *et al*., 2011
Berberis asiatica	Berberine	2.4 g/100g	Andola *et al*., 2010
Berginia ciliata	bergenin	2.27g/100 g	Singh *et al*., 2007
Berginia ligulata	bergenin	2.27g/100 g	Singh *et al*., 2007
Berginia stracheyi	bergenin	2.42 g/100g	Singh *et al*., 2007
Aconitum balfuori	pseudoaconitine	0.4–0.5mg/100 g	Khetwal, 2007
Aconitum heterophyllum	aconitine	0.62–0.06 g/100g dw	Pandey *et al*., 2007
Podophyllum hexandrum	podophyllotoxin	3.57–9.53 g/100g dw	Alam *et al*., 2008, Nadeem *et al*., 2007
Picrorrhiza kurroa	Kutkin	3.4 g/100g dw	Mishra *et al*., 2011
Origanum vulgare	γ-muurolene	62.04 % of Essential oil	Pandey and Mathela, 2000

for ABTS and DPPH, respectively and 47.8% of reducing property. These data suggest their potential in nutraceuticals industries and a source of income generation. A list of medicinal plants with their useful phytochemicals and biomolecules is presented (Table 19.1).

Conservation Applicability

Advances in biotechnology have resulted in better understanding of the biology of the entire plant kingdom, providing an opportunity for their conservation as well as sustainable utilization. Among others, tissue and cell culture; DNA fingerprinting for genetic diversity assessment; marker-assisted selection and production of secondary metabolites are few examples used in the conservation and sustainable utilization of biological resources. Over the years, efforts have been made to conserve RET and economically important plants by developing propagation protocols and subsequently undertaking field trials at different locations. Genetic fidelity assessment to demonstrate true to type plants of *Denderocalamus hamiltonii*, *Habenaria edgeworthii*, etc. Similarly, molecular markers have been widely used for estimating genetic variability in a number of species and are proven powerful tools for genotypic characterization, and important to devise effective sampling strategies such as selection of diverse individuals, populations for mass multiplication as well as in breeding programmes. Based on the markers one can differentiate diverse accessions collected from different locations and suggest its appropriateness for analysis of genetic variability. For example, studies on different species of *Podophyllum* using 20 AFLP markers showed 88.01% polymorphism amongst the species and the paired relationship of intercontinental species in the *Podophyllum* group [*P. hexandrum,* and *P. sikkimensis* (Indian May apple) vs. *P. peltatum* (American May apple)]. Similarly, studies on genetic diversity of *Valeriana jatamansi* established that lower altitudinal zones in the region are suitable for the diversity of the species than higher ones and indicated that pollinator could be one of the agents for influencing the genetic diversity. Such type of studies are useful for identifying the plants with superior quality, better adaptability and wide acceptability that can be used for conservation as well as commercialization. Different species have also been investigated for studying genetic diversity and developing suitable conservation strategy for their conservation in the Himalayan region. These include, *Zingiber officinale, Andrographic paniculata, Podophyllum hexandrum, Urtica dioca, Valeriana* spp., *Glycyrrhiza uralensis, Tinospora cordifolia, Swertia angustifolia, S. chirayita, Habenaria intermedia, H. edgeworthii, Hedychium spicatum,* etc.

Commercial Applicability

Biotechnology, a key emerging technologies, has far reaching implications especially in production of useful metabolites from the bioresources, developing linkage maps and identification of QTLs (quantitative trait loci) to understand the association between markers and genes; production of genetically modified or transgenic organisms; understanding the biosynthetic pathway; developing drug delivery system, etc. Biotech industry survey 2011 revealed that the Indian biotech sector grew at 21.5% to reach Rupees 17400 crores in revenues. This state of affairs called for maximizing the application of biotechnology in commercialization of process and products for the welfare of human being. While considering commercial potential of high value plants, the biotechnology can play an important and crucial role in providing healthier and more nutritious crops, and a new platform for producing inexpensive vaccine and drugs. Besides, it has potential of creating plants that reduce the impact of weeds, insect pests, diseases and harsh environment, providing a basis not only for the reduction of hunger through more successful agriculture but also the stimulation of economic prosperity by providing higher yields of better quality crops.

Ongoing Initiatives

Among various country-level initiatives, some of the initiatives that involve Biotechnological Applications specifically in the IHR include the following:

a) Establishment of National Bioresource Development Board for effective application of biotechnological and related scientific approaches for R&D and sustainable utilization of bioresources, specially for new products and processes; and to develop a scientific plan of action for contributing to the economic prosperity through accelerated R&D using the most modern tools of biosciences.

b) Department of Biotechnology, Govt. of India has initiated Center of Excellance Programme to augment and strengthen institutional research capacity in areas of Biotechnology for expanding and developing faculty research capability and enhancing research infrastructure.

c) To develop methods for the commercial utilization of rich bioresources with their conservation and promotion State Biotechnology Programme of Uttarakhand established Centre of Excellence for Mountain Biology (CEMB). This is expected to improve the local economy as well as conserve the natural plant wealth.

d) To enhance capcity and generate awareness among the researchers and scientists an integrated programme of human resource development in biotechnology has been initiated. The Institute (GBPIHED) has initiated a Rural Biotechnology Centre for capacity enhancement of various stakeholders, especially the rural populace.

Challenges

- Awareness generation on the relevance of biotechnological applications for biodiversity conservation.
- Ensure sustainable use of bioresources using biotechnological methods.
- Lack of state-of-art laboratory for biotechnolgical research in the region.
- Mechanism based screening of herbal drug is lacking.

Conclusions

Considering the importance of Biotechnological interventions for promoting conservation and improving commercial potential of bioresources, there is an ugent need to strengthen skills and infrastructure for biotechnological researches in Indian Himalayan Region.

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