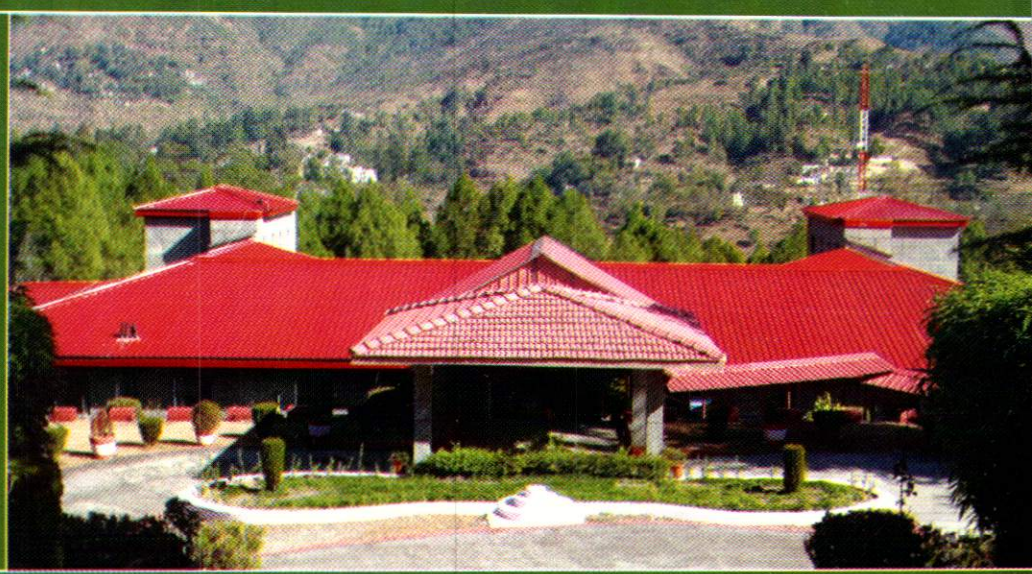
ANNUAL REPORT
2012-2013



G.B. Pant Institute of Himalayan Environment & Development
(An Autonomous Institute of Ministry of Environment and Forests, Govt. of India)
Kosi-Katarmal, Almora - 263 643, Uttarakhand, India

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CONTENTS

FOREWORD

The Institute is dedicated to serve the Indian Himalayan region (IHR) through research inputs and developmental actions in the region. The region is very sensitive to global climate change. It is called the "sentinels of change" since it responds rapidly and intensely to climatic and environmental modifications with the danger of losing essential services and menace the well being of the people depending on high altitude resources. There is growing evidence that mountains are experiencing changes in temperature higher than the global average or lower elevation regions. This elevation dependent warming has important implications for the mass balance of glaciers and associated runoff, for downstream communities and significantly affects the ecosystem and biodiversity.

At the back drop of such pronounced changes the institute has evolved with more innovative and collaborative national and international research. The institute has demonstrated a multi-scale approach, with strong interconnections between local/regional/global dimensions and trans-boundary interconnections. It has made considerable progress in quantifying the on-going and expected changes in mountain environment. The institute has also made sincere efforts to integrate across the natural sciences and social sciences with inclusion of interdisciplinary, multi-institutional approach. Its activities have demonstrated strong relevance for user needs and attempted to examine a variety of interactions among relevant systems.

During the reporting period (2012-13), the Institute has made significant progress in achieving its R&D targets. Some of the major achievements are: study on the optimizing hydrological responses in a functional land use model as an attempt towards addressing water sustainability, strengthening and maintenance of Arboreta and herbal gardens at head quarters and units, standardization of propagation protocols of over 20 multipurpose tree species and medicinal plants, assessment mapping, valuation, prioritization and conservation of medicinal plant diversity in three river valley and two watersheds in Himachal Pradesh. During the reporting period the North East unit has substantially contributed to the policy planning of Arunachal Pradesh by three policies, namely promotion of home stays in Arunachal Pradesh, promotion and management of community conserved areas in Arunachal Pradesh and Arunachal Pradesh eco-tourism policy. Inventorization and population assessment of belowground biodiversity (BGBD) particularly earthworm in a traditional village landscape of Central Himalaya was undertaken for soil fertility improvement. Several training programmes for various stakeholders have been organized through the Rural Technology Complex (RTC) at Headquarters and units in an attempt towards interaction with society and obtain their feedback and expectations. Amongst some of the regular activities completed successfully are on-site training programmes, orientation courses and exposure

MAJOR ACHIEVEMENTS

- Arboreta and Herbal Gardens were strengthened and maintained at the Headquarters, Uttarakhand; Mohal-Kullu, Doharanala and Kasol in Himachal Unit, Himachal Pradesh; and at Pangthang, Sikkim. Conventional (seed germination and vegetative) propagation protocols for over 20 multipurpose tree species and medicinal plants were developed. The seedlings were distributed to farmers for cultivation, plantation, restoration of degraded lands and development of School Campuses.
- Assessment, mapping, valuation (Conservation: nativity, endemism & threat categorization; Socio-economic utilization pattern), prioritization and conservation of medicinal plant diversity in the Chandra valley, Upper Beas Valley, Parbati Watershed, Mohal Khad Watershed and Banjar Valley in Himachal Pradesh ware done along with threat categorization and prioritization of medicinal plants on these sites.
- During the reporting year, the North East Unit had substantially contributed to policy planning with respect to biodiversity conservation of the biologically rich state of Arunachal Pradesh and promotion of livelihood of the communities by developing and further defining the three policies viz. (i) Promotion of Homestays in Arunachal Pradesh, (ii) Promotion and Management of Community Conserved Areas in Arunachal Pradesh, and (iii) Arunachal Pradesh Ecotourism Policy. The policies are being or have been developed under GOI-UNDP CCF-II project entitled "Biodiversity conservation through community based natural resource management in Arunachal Pradesh".
- Sustainable livelihood options were enhanced as an adaptive strategy to reduce vulnerability and increase resilience to climate change impact in the Central Himalaya was studied.
- Genetic diversity analysis was conducted on different high value medicinal plants, which revealed variations in polymorphism among habitats and across altitudinal gradients. Anti oxidant activity was conducted on several plant species in order to harness their potential in combating free radical induced diseases. A value chain for selling medicinal plants and flowers cultivated in farmers' field was established.
- In order to make shifting cultivation ecologically, economically and socially viable, a number of state and central policies and laws of the forest and agriculture sectors dealing with shifting cultivation and the ongoing schemes and programmes of NE states and central Government for control and regulation of shifting cultivation, were reviewed and analysed.
- Inventorization and population assessment of belowground biodiversity (BGBD) particularly earthworm in a traditional village landscape of the Central Himalaya was undertaken for soil fertility improvement was done.
- The solid waste management study in six towns (i.e., Bilaspur, Hamirpur, Mandi, Kangra, Chamba, Keylong) of Himachal Pradesh showed that biodegradable waste, on an average, made up 76% of the total waste generated, is which has a great potential for biocomposting, if kept away from medical waste.

Publications:

1. Peer Reviewed Scientific Journals		
National	-	**16**
International	-	**55**
2. *Chapters in Books/Proceedings*	-	**39**
3. Authored/Edited Books/Booklets/Bulletins/ Monographs	-	**06**
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EXECUTIVE SUMMARY

The GBPIHED with a strong commitment for sustainable development of the Indian Himalayan Region (IHR), is the only institute of its kind which addresses physical, biological, social and economic issues of the region and its people in an integrated manner. The R&D mandate of the Institute is broad and covers all the facets of environment and development. Towards achieving this, multi-disciplinary approach and integration are the guiding principles. The emphasis on interlinking of natural and social sciences is the major thrust of all the programmes of the Institute. In this effort, special attention is paid to the intricate balance between fragility of mountains, indigenous knowledge and sustainable use of natural resources. Design and implementation of R&D activities on priority environmental problems, development and demonstration of best practices, technology packages and delivery systems for improved livelihood of the people are the core issues covered under most programmes in the Institute. A conscious effort is made to ensure participation of local inhabitants for long-term acceptance and success of various programmes. Therefore, training, education and awareness of a variety of stakeholders are the essential components of all the R & D programmes. A brief summary of R&D activities of the Institute during the reporting year 2012-13 is as follows:

Watershed Processes and Management (WPM)

The theme Watershed Processes and Management (WPM) focuses to work on watershed services and management, land and water use policy, consequences of climatic change, improvement of Himalayan farming systems, relevant Indigenous knowledge systems, and domestic energy needs, etc. A project on "Optimizing Hydrological Responses in a Functional Land Use Model for Mid-elevation Himalayan Watersheds: An Attempt towards Water sustainability" was completed during the year. The study shows that the Water Supply cannot meet the full domestic and livestock demand of urban and rural areas without storage of surplus water from January to March of the same year. Water resource planning is a must in such watersheds where upstream-downstream linkages also need to be explored. In this context a new project on "Ecological, Social and Policy Implications of Changing Water Resource Scenario in the Indian Himalayan Context" was initiated during the year as a follow up of the completed project on the upper Kosi watershed. An R&D programme on "Farming Systems and Changing Climate Regime: Strengthening Food and Nutritional Security in the Himalaya", initiated in January 2013, deals with changes in farming system due to social, economic, and ecological factors and goverments policies including climate change. Average cropping area of food crops of Upper Kosi watershed in block years of 2001-2010 reveals reduction in cropping area of lentil (-62.2%), Bengal gram (-59.3%), barley (-27.5%) and paddy (-17.5%) as compared to block years of 1991-2000. The Project on "Run-off modeling and simulation of sediment load of Gangotri glacier systems" deals with measurement of daily hydrology and sediment load three times a day (i.e. at 9.00, 13.00, and 17.00 hrs.) during the period 23.06.12 to 30.09.12. Large variations (CV= 0.67) are observed in the suspended sediment load of Gangotri glacier. During the ablation season, maximum and minimum concentration of suspended sediment load is estimated as 4.08 gm/l and 0.27 gm/l respectively; average concentration of suspended sediment is estimated as 9671.51 MT/day from Gangotri glacier.

In project "Nematode diversity in the traditional agro ecosystem of Central Himalaya, their impact on soil health and crop growth", approximately fifty major genera have been identified. The identified nematodes belonged to five orders. Order Rhabditida, Tylenchida and Aphelenchida belonged to class Secernentea and orders Dorylaimida and Mononchida belonged to class Adenophorae. Project "Indigenous Knowledge: traditional health care practices in rural areas of Uttarakhand" reveals that vaidyas and village elders use about 154 medicinal plants to treat ailments, out of which about two dozen herbs had proven/reported therapeutic activities. 15 formulations of Tinospora cordifolia (giloye) have been witnessed, out of which 6 are already mentioned in literature but 9 are new. The Project "Energy use pattern in rural domestic sector of Uttarakhand State – Issues, Options & Challenges" reveals that the proportion of rural households in the state of Uttarakhand has reduced in the last decade

(2001-2011). A transformation, in the use of cooking energy in the rural areas is also evident during this decade but at a slow pace. This is evident by (i) decreasing share of fuel wood (as primary source of cooking energy) dependent households by 4% (of the total rural households) in the year 2011 than the year 2001 (67.5% of total rural households), and (ii) 8% increase in the rural households using LPG as main source of cooking energy since 2001 (29.4% vs 21.3%). In the project "Recharge area identification and estimation mean residence time for springs in one urban and one rural micro watershed in Pauri Garhwal using isotope technique, remote sensing, and GIS for implementation of artificial recharge structures", altitude effect using stable isotope technique was calculated, recharge zone identified and a geological map in 1:10,000 scale was prepared for artificial recharge.

Biodiversity Conservation and Management (BCM)

Biodiversity assessment (qualitative and quantitative), valuation (Conservation: nativity, endemism & threat categorization; Socio-economic: utilization pattern) and conservation prioritization in the Nanda Devi Biosphere Reserve, Uttarakhand, Nargu Wildlife Sanctuary, Himachal Pradesh, Kanchendzonga Biosphere Reserve, Sikkim and Tawang Kameng Biosphere Reserve, Arunachal Pradesh was done. The study provided comprehensive data sets on compositional, structural and functional aspects of biodiversity. Assessment and monitoring of the forest communities along altitudinal and disturbance gradients and climatic regimes were done. The study showed variations and changing patterns of vegetation across all the gradients. Assessment, mapping, valuation (Conservation: nativity, endemism & threat categorization; Socio-economic: utilization pattern), prioritization and conservation of medicinal plant diversity in the Chandra valley, Upper Beas Valley, Parbati Watershed, Mohal Khad Watershed and Banjar Valley in Himachal Pradesh was done. Threat categorization and prioritization of medicinal plants of these sites were done. Cultivation of Aconitum heterophyllum was promoted in Jana village, Kullu valley and Khansar village in Lahaul valley, and Withania somnifera in lower Kullu valley, Mandi Pandoh Area and Smaila and adjacent villages was promoted. Agrotechniques of the 26 high value medicinal plants were developed and disseminated among progressive farmers. Various Training Programmes and Exposure Visits were organized for creating awareness and imparting education on medicinal plants. Conventional (Seed germination and vegetative) propagation protocols for over 20 multi-purpose tree species and medicinal plants were developed. The seedlings were distributed to the farmers for cultivation, plantation, restoration of degraded lands and development of School Campuses.

From Sainj Hydro-Electric Project area, 148 species of vascular plants belonging to 72 families and 128 genera, 16 forest communities and 134 economically important plants and From Upper Beas Valley, 149 species (16 trees, 18 shrubs and 115 herbs including ferns) and 4 communities (Pinus wallichiana, Cedrus deodara, Pinus roxburghii, and Alnus nitida) were recorded. Various ecosystem services were assessed and documented. From Hadimba Mata, Kalinag, Jamadagni Rishi, Rupasna, Bhirghu Rishi and Sangchul Rishi Sacred Groves in Kullu district. A total of 133 species of vascular plants belonging to 62 families and 115 genera were recorded. One tree community i.e., Cedrus deodara was identified from Hadimba Mata, Kalinag and Jamadagni Rishi Sacred Groves. In CDBR, from 46 sites 196 species representing 51 families and 141 genera; 84 economically important plants (used for medicine (98 spp.), wild edible/food (46 spp.), fodder (27 spp.), fuel (11 spp.), timber (02 spp.), religious rites (08 spp.), Agricultural tools (07 spp.), insect repellant (02 spp.) and other species for various other purposes) and 28 other plant communities (16 shrubs and 12 herbs) were recorded. Species diversity (H′) for shrubs ranged from 0.00-3.60 and herbs, 0.98-2.65. Concentration of dominance (Cd) of shrubs ranged from 0.25-01 and herbs, 0.09-0.58. Total 29 populations of Arnebia euchroma between 3,710– 4,394m, amsl were studied in the Lahaul & Spiti and Kinnaur districts of Himachal Pradesh. The total shrub density ranged from 40-1190 Ind ha^{-1}; total herb density, 4.60-70.55 Ind m^{-2} and relative density (%) of Arnebia euchroma ranged from 0.68-41.04 % in the sampled populations. The richness of shrubs ranged from 1-6 and herbs, 4-27. Pollination Deficit Protocol experiments were conductes in 20 apple orchards (10 near natural habitats with or without the treatment of bee hives and 10 far from natural habitats with or without the treatment of bee hives of

Apis mellifera) to know the effect of bees on apple crop production. Highest population density of indigenous honey bee (Apis cerana) was recorded from the open pollinated orchards near natural habitat orchards which ranged between 5 - 7 and 4.6 – 6.9 bees/250 apple flowers of production and pollenizer varieties. Towards conservation of high value medicinal plants, propagation protocols of different plant species using conventional and in vitro approaches were developed. Phytochemical investigation on different medicinal plants was done and contents were quantified establishing the fact that different altitudinal and habitat conditions do affect the active content in the Himalayan medicinal plants.

Genetic diversity analysis was conducted on different high value medicinal plants, which revealed variations in polymorphism among habitats and across altitudinal gradients. Antioxidant activity was conducted on several plant species in order to harness their potential in combating free radical induced diseases. Value chain for selling medicinal plants and folowers cultivated in farmers field was established. Arboreta, Herbal Gardens and Medicinal Plant Nurseries were strengthened through the introduction of new accessions at Kosi-Katarmal, Almora, Uttarakhand, Mohal, Doharanala and Kasol, Himachal Pradesh and Pangthang, Sikkim. Conservation models were developed in the Govt. Schools of Uttarakhand and Himachal Pradesh. Consultation meeting was conducted for the identification and selection of traditional crops for long term studies. Various attributes of traditional agriculture in the Himalayan region particularly Uttarakhand were discussed and it was agreed that most of the traditional crops and their landraces are dwindling in the region. The traditional farmers are disinterested in continuing with these landraces. A one day Training Programme on "Biodiversity Conservation and Management in Relation to Climate Change" was organized at Govt. Senior Secondary School, Baldwara, Mandi, Himachal Pradesh on March 23, 2013. Capacity building of the 132 students and teachers representing 08 Schools and local inhabitants was done through a comprehensive lecture on Biodiversity Conservation and Management in relation to climate change; propagation techniques, practical exercise of the Participatory Rural Appraisal; and Qualitative (Rapid sampling & identification of species) and quantitative assessment (Quadrat method) of biodiversity. Pre and post training programme feedbacks were taken. The training programme showed significant improvement in the knowledge of the participants about biodiversity conservation and management and climate change. Over 800 seedlings/plantlets of medicinal and ornamental plants and multipurpose tree species were distributed to the Govt. Senior Secondary Schools and inhabitants of Kullu valley. A one day training workshop for over 30 students (Class X & XII; Biology) and teachers of five schools in Sikkim was organized. In addition to lectures, exposure to lab/nurseries, they were involved in field based vegetation survey exercise in the arboretum. Following issue prioritization exercise, participants extensively interacted on various conservation threats and possible mitigation approaches.

Environmental Assessment and Management (EAM)

The Theme of Environmental Assessment and Management (EAM) has been very successful in achieving its targets during 2012-13. The works upon which the EAM theme focused during the reporting period were mainly 12 projects out of which 7 were in-house (2 ongoing and 5 completed) and 5 were externally funded from SPL VSSC, Thiruvanthapuram, PRL Ahmedabad and DST New Delhi. In-house projects like (i) strategic environmental assessment (SEA) of hydropower projects in the Himalayan Region aim at an in-depth study of hydropower projects to develop a methodology for policy, plan and programme taking into account the Sutlej basin in Himachal Pradesh and the Alaknanda basin in Uttarakhand. Here, Remote Sensing & Geographic Information System (RS&GIS) were used as effective tools for studying these projects. The second in-house project on: (ii) climate change impacts on ecosystem services in the Indian Himalayan Region aims on climate change impacts mainly focusing on four species such as Shorea robusta, Pinus roxburghii, Quercus leucotrichophora and Quercus floribunda in the Kumaun Himalaya. Moreover, as an important part of ecosystem service, tourist recreational services have also been included in order to be studied in the background of ES especially in Himachal Pradesh state. The first three externally funded projects were mainly concerned with the climate impacts on forest ecosystems, and aerosols (solid, liquid, gas) and their

impact on climate change. These projects were: (i) indicators of climate change in context to the Himalayan forest ecosystems along an environmental gradient, (ii) aerosols climatology over the northwestern Indian Himalayan region, Himachal Pradesh, and (iii) gaseous air pollution in the background site of sprawling urban environment of Himachal Pradesh. The remaining two externally funded projects were mainly concerned with forest ecosystem services and inventorisation and monitoring of biosphere reserves concentrating basically on seeking the options for better livelihood options for the farmers and natural conservation of biosphere reserves respectively. These two externally funded projects were: (i) assessment and quantification of forest ecosystem services with special emphasis on pollination in different agro-ecosystems, and (ii) inventorization and monitoring of biosphere reserves using RS & GIS. Among the completed four projects, the first three were in-house pertaining to hydropower projects and their downslope impacts, and adverse impacts of sprawling urban environment in the form of waste as well as air pollution, while the fourth externally funded project was again on ambient air quality and its sources. The details of these projects were: (i) strategic environmental assessment (SEA) and environmental impact analysis (EIA) of hydropower projects in the western Himalayan Region (2007-2012), (ii) assessment of downstream impacts of hydroelectric projects in Arunachal Pradesh: a case of Ranganadi hydroelectric project (2011- 2012), (iii) appraisal of tourism for sustainable development– comparative analysis of Sikkim and Himachal Pradesh (2009-2012), (iv) urbanisation vis-a-vis solid waste management and air pollution in sprawling urban cities of Himachal Himalaya (2007-2012), and (v) ambient air pollution and its sources in the background sites of different hill spots in the northwestern Himalayas, Himachal Pradesh (2009-2012).

Socio-Economic Development (SED)

The Socio-economic Development (SED) programme of the Institute focuses on the technological backstopping with the skill improvement of the rural people to enable them to improve their farm based livelihoods, as also conservation & management of the available natural resources and strengthening the village institutions. During the reporting year a few projects were completed while some new ones were initiated. It was found that the mountain farming systems are under great stress as there was a sharp decline in crop varieties and races, weakening of village institutions that resulted in a net decline in common property resources, thus jeopardising livelihoods of rural communities. Advese climatic conditions, erratic monsoon, increasing wildlife threats, out migration, etc. further aggravate sustainability of the farming system, and has lead to weakening the socio-economic condition of the people. To overcome this situation, technological backstopping to smallholders, is critical for achieving sustainability in both farming systems - the shifting cultivation in North-east and upland farming systems in north-west Himalayan regions. Model-demonstrations, skill development and mass awareness greatly helped to organize farmers thus resulting in achieving desired results. The possible diversifying activities comprised promoting eco-tourism, horticulture, MAPs cultivation, floriculture, etc. that could generate better livelihoods opportunities for rural people.

The new studies undertaken in the reporting year comprise assessing ecological, economic and social viability of shifting agriculture, promotion of community based natural resource management, and linking biodiversity conservation with sustainable development in northeast India; enhancement of livelihood security through sustainable farming systems, scaling up innovative resource management practices for improved livelihoods in the Central Himalaya; and assessing economic and cultural implications of migration, and impact of pesticide application in contamination of food chain in northwest Himalaya, etc. To upgrade livelihood of Himalayan communities, a new programme was also initiated on Eco-tourism as a tool for biodiversity conservation and sustainable livelihood all across the Indian Himalayan Region. It is expected that through a focused approach for R&D, demonstration and capacity building these new programmes will have a positive impact on the livelihoods of rural communities.

Biotechnological Applications (BTA)

Large scale multiplication and field plantation of selected plant species using biotechnological and conventional protocols that were developed earlier were focussed on; two important Rhododendron

species of Sikkim, namely, *R. maddeni* and *R. dalhousiae* were field planted and monitored. Efforts continued to standardize propagation protocols for other economically important species using both conventional and in vitro methods. Successful and reproducible in vitro protocol was developed for multiplication of large cardamom (*Amomum subulatum*), a commercially important crop of the country. Estimation of bioactive compounds and molecular characterization of two species of high medicinal value, namely, *Podophyllum* sp. and *Ginkgo biloba*, from different locations of IHR are continuing. Antioxidant potential of stem barks, leaves and fruits of Olea spp. were evaluated using three different in-vitro assays (DPPH, ABTS and FRAP). Indian olive (*Olea ferruginea*) was identified as one of the potential and rich sources of natural antioxidants, and can be exploited for pharmaceutical purposes. These projects were successfully completed and based on leads and stakeholders choice new objectives were taken up in the form of separate projects. Besides initiating fresh in house projects, the members of the Group are involved in a national network externally funded (by the Department of Biotechnology) project on 'Preventing extinction and improving conservation status of threatened plants through application of biotechnological tools' in the Headquarters, Himachal and Sikkim units.

Exploration of microbial diversity with specific reference to plant growth promoting micro- organisms and mycorrhizal associations continued in different regions of the IHR, including north-east India. Besides investigations on rhizosphere communities, evaluation of medicinal properties, including antimicrobial activity in leaf extracts of *Ginkgo biloba* were carried out. Out of the three groups, the bacteria were found to be most sensitive to antimicrobial substances, followed by actinomycetes and fungi. The Microbiology laboratory is housing a Microbial culture collection; pure cultures of bacteria, actinomycetes and fungi are being maintained and regularly being accessioned by various national laboratories and institutes. A number of isolates of actinomycetes were isolated from the soil samples, collected after fire operations, at agricultural sites under shifting cultivation in northeast India. More than half of these isolates were observed in viable but non-culturable state. Some of the morphologically distinct and cultivable isolates were subjected to characterization and identification. The isolates varied in cell morphology, utilization of carbon sources, sensitivity to antibiotics, and salt tolerance. A project on characterization of pyschrotolerant fungi with particular reference to lignin degradation under mountain ecosystem is underway in an ICMR funded project.

Investigations on the possible role of mycorrhizae on gas exchange characteristics, particularly photosynthesis and water relations in three central Himalayan Quercus species (*Q. glauca*, *Q. leucotrichophora* & *Q. semecarpifolia*) has been completed. Preliminary studies indicate that amongst these species *Q. leucotrichophora* can adapt better at wider altitudinal range. Under the pond-based integrated farming system, studies are being carried out on Saprolegniasis, a common fungal infection of fishes in lakes and ponds. The study mainly involves exploration of fungal infection in fingerlings and adult fishes, and to isolate, culture, characterize and identify associated fungal species; this would help in understanding fish diseases and formulating integrated management to the farmers in the region. Initiatives on capacity building in imparting training on simple technologies to rural folks and training of MSc & PhD students continued

Knowledge Product and Capacity Building (KCB)

The traditional ecological knowledge and wisdom of the indigenous people have become a major focus of attention within the past decades. The knowledge accumulated, documented, produced/developed over a period of time in any field for human well being and natural resource management, is required to be transmitted or exchanged through capacity building efforts to empower all the stakeholders at different levels. With greater realization of the value of this knowledge base, it is considered that the knowledge needs to be an integral part of a holistic and cost-effective approach to sustainable development. It is now widely recognized that along with conventional science and technology, the traditional knowledge products are of critical importance for the over all development of the Himalayan region. It is considered to have fundamental importance in the management of local resources in the husbanding of the world's biodiversity and in providing locally valid models for sustainable living. The Himalayan mountain communities have acquired an immense knowledge of

their natural environment. Yet his accumulated knowledge is rapidly disappearing as the traditional communities are steadily becoming more culturally and biologically uniform. Knowledge base of the different traditional societies and knowledge products developed through science and technology interventions, if successfully adopted/implemented through capacity building programmes would certainly help ecologically sound, economically viable, socially acceptable and institutionally enforceable outputs.

Over a period of time the institute has put major efforts in the compilation of a knowledge system for management and utilization of natural resources, state of art methodologies/approaches, model demonstrations on various aspects of development for grassroot workers and practioners, synthesis of existing scientific and traditional knowledge for popularization of best practices for sustainable development, empowerment of local inhabitants based on various livelihood opportunities such as tourism/eco-tourism and off farm-on farm activities, popularization of bioprospecting and value addition in traditional/wild bioresources for enhancing the livelihood of the marginal communities, establishment of participatory action research, demonstration and training centres on hill specific appropriate technologies in three agro-ecological zones of the Central Himalaya, and has developed a network with various stakeholders (policy makers, professionals and practioners) in different sectors to share the knowledge products for the benefit of the user groups, promotion, cultivation and conservation of potential medicinal plants, analysis of nutritional and nutraceutical potential of wild edibles and traditional crops, development of model approach for popularizing of science-climate science education involving students and teachers of Uttarakhand, impact of tourism on ecology, economy and socio-cultural system in upper Kedar valley, and assessing of carrying capacity of lodges/hotels in different places at a 35 km distance along the Kedarnath pilgrimage site.

1. INTRODUCTION

During the year 2012-13 various R&D activities were executed by the Institute at different locations of Indian Himalaya through its HQs at Kosi-Katarmal (Almora) and four regional Units, namely, Himachal Unit (Kullu), Garhwal Unit (Srinagar-Garhwal), Sikkim Unit (Pangthang) and NE Unit (Itanagar). Over the years, the Institute has taken significant strides in identifying problems, developing region specific approaches, demonstrating their efficacy in the field and disseminating information to various stakeholders. The diverse problems thus addressed were related to ecology, resource conservation, traditional practices, livelihood opportunities, land restoration, propagation protocol development, biotechnological interventions, etc. The Institute implements its activities through core funds provided by the Ministry of Environment and Forests (MoEF), Govt. of India, and the projects financed by external funding agencies (National and International). The Institute also supports activities of various partner Institutions in different Himalayan states through Integrated Eco-development Research Programme (IERP). The Science Advisory Committees of the Institute reviews the progress of existing projects and provides guidance to develop new R&D programmes. Under the provisions of GBPIHED VISION -2015 and following the stakeholders' consultations across the region, including that of the Scientific Advisory Committee, the Institute developed a perspective plan for XIth plan period (2007-12). The identified thematic categories include the following: (1) Watershed Processes and Management (WPM); (2) Biodiversity Conservation and Management (BCM); (3) Environmental Assessment and Management (EAM); (4) Socio-economic Development (SED); (5) Biotechnological Applications (BTA) and (6) Knowledge Product and Capacity Building (KCB).

During the reporting period various activities/ projects were concluded. Summaries of these are included at appropriate places in the text. In due course detailed documents will be published and made available to the public. The progress made during the year 2012-13 on various in-house and externally funded projects under different thematic groups, a brief account of academic and other activities, along with the statement of accounts, has been presented in this report. The Institute would be most grateful to receive critical comments and suggestions for improving quantum and quality of outpits of various R&D activities.

2. MILESTONE EVENTS

National Environment Awareness Campaign - The Forest Fires in Sikkim: A Threat to the Local Sustainable Livelihood Prospects

The National Environment Awareness Campaign was focused towards addressing the awareness component on forest fires at affected sites and build up local strategic plans and actions to mitigate the hazard with an effort to support sustainable livelihood of the people concerned. The major objective of the project were to make people of the concerned area aware about the harm caused by forest fires – ecologically & economically in the Sikkim context and their impact on their sustainable livelihood prospects. Field sites at Sumbuk, Manpur, Lungchok, Geling and Rumbuk were covered during the Forest Fires where spot awareness camps were organized among school children, villagers, panchayat members as well as JFMC members. Apart from providing awareness to forest fires an exercise was done at every site on extracting information at the villagers' level of awareness towards forest fires. This project on forest fires was useful in bringing about awareness in the areas (affected by forest fires) on what to do in case of fires and preparedness before it starts. The concerned people of the field sites came to know about the negative impact on sustainable livelihood and were apprised on how conservation will help them to live a better life in the long run. It was also indicative of the degree of effect put against the livelihood aspect of the people concerned.

Biodiversity Conservation Training to Students and Teachers

A Training workshop for Students and Teachers of Sikkim schools on 'Conservation of Biodiversity' was organized at Pangthang on April 20, 2013. About 30 participants from five schools of class X and Class XII were provided a series of lectures, and a field exercise in the functional arboretum helped them understand the approaches of vegetation surveys and field problems when taking up biodiversity studies. The pre and post perception on biodiversity and climate change related issues was yet another important exercise for the participants. Besides, Environmental science exposures were provided to 22 M.Sc. (Ethnobiology) students and 05 teachers of Sikkim University on November 11, 2012 through an extensive resource lecture from HK Badola.

International Day of Biodiversity (IDB)

The International Day of Biodiversity (IBD) with a theme "Forest Biodiversity" was celebrated at the GBPIHED, HQs at Kosi-Katarmal, Almora and its four regional units on May 22, 2012 with school children and teachers of nearby schools. In the GBPIHED, HQs, the day was celebrated at Suryakunj – Nature Interpretation and Learning Center (an *ex-situ* conservation site). Over 100 students from 19 different schools participated in the programme. Institute faculty described the intricate relationship among different biodiversity components and its importance in forest biodiversity. Dr. L. M.S. Palni, Director of the Institute briefed on the importance of technological intervention and new scientific innovations on forest biodiversity but at the same time he emphasized on sustainable use of natural resources. Besides, various activities, reflecting the theme, were organized which included drawing, debate, essay writing, etc.

The International Day for Biological Diversity was also celebrated at the Sikkim Unit of the Institute. The main content of the program consisted of a topical question-answer session on biodiversity and on-the-spot drawing competition over the theme "Biodiversity: As You Know It Today". The questionnaire was in two sets of Nepali and English versions for greater reach in topic. These two main events of the day-long program were organized in the school premises in which 50 students from Class VI to XII participated. The best performers in the events were presented with certificates of proficiency as well as consolation certificates.

Special Session on ICIMOD's Future Direction towards Sustainable Mountain Development - Focus on Indian Himalaya Region

A special session was organized on ICIMOD's future direction towards sustainable mountain development - focus on Indian Himalaya Region during SMDS 2012 on 26th May, 2012, for a short (2 hr)

session at Chintan Bhawan, Gangtok Sikkim. The Special session was co-sponsored by ICIMOD jointly with the Indian Mountain Initiative (IMI) supported by GBPIHED, Sikkim Unit. A formal inauguration of the workshop was made with opening remarks by Mr. P. D. Rai Hon'ble MP from Sikkim. This was followed by the presentation from (i) ICIMOD's Strategic Framework **by** David Molden, DG, ICIMOD and (ii) Introduction to ICIMOD's Regional Programmes by Eklabya Sharma, DPO, ICIMOD, wherein he mentioned several aspects of Transboundary issues at local and global perspectives and in the process highlighted on the significance of biodiversity value and ecosystem services – the two main topics coming under discussion. During Plenary discussion, possibility was also explored for a larger network of stakeholders and gets their views on strategic framework and future direction. After the Plenary discussion on Strategic Framework and interaction a concluding remarks by B.S. Rathore, Ministry of Environment & Forests, Govt. of India was made and with the presentation of vote of thanks by Dr. G, S, Rawat, Deputy Programme Manager/ Senior Scientist, Ecosystem Services, ICIMOD was the workshop declared closed for the day.

World Environment Day

The World Environment Day was celebrated at GBPIHED-HQs at Kosi-Katarmal, Almora and all the four regional units as "A Day with Students" with a theme "Green Economy: Does it include you" on June 05, 2012. On this occasion students from various schools of the region were exposed to various laboratories of the Institute to see live demonstrations on different topics like water testing, tissue culture, bio-technology, micro-biology and remote sensing and GIS, etc. Besides, various documentaries on nature, space, biodiversity, etc. were shown to the students. Welcoming the participants, the Director of the Institute described the importance of the 'World Environment Day' and its objectives.

The Himachal Unit of the Institute also celebrated the Environment Day with the students. Various activities such as Declamation contest; Poster and Slogan Competitions and Cultural programmes related to the environmental conservation were organized. The Scientist In-charge, GBPIHED, Himachal Unit addressed the participants and stressed that plantation of broad leaved native trees should be promoted as they play an important role in environmental conservation. Sikkim Unit, at its Pangthang campus, has also organized the World Environmental Day. The day commenced with a group plantation of multipurpose trees including tissue culture raised *Rhododendron maddeni* Pangthang, in tune to strengthen green mission of the state. Scientists, technicians and staff of the institute and workers and miscellaneous persons actively participated in the plantation programme.

Similar celebrations were also held at Garhwal Unit and NE Unit of the Institute to mark the World Environment Day.

Annual Day Celebration

The Institute celebrated 125th Birth Anniversary of Pt. Govind Ballabh Pant and Annual Day function of the Institute at its HQs Kosi - Katarmal and all the four Units (Garhwal Unit – Srinagar; HP Unit - Kullu; Sikkim Unit - Pangthang; and NE Unit - Itanagar) on September 10, 2012. The function was inaugurated by the Chief Guest Prof. Vinay Pathak, Vice Chancellor, Uttarakhand Open University, Haldwani who also delivered the inaugural address. Director of the Institute delivered welcome address and briefly highlighted the Institute's R & D activities conducted through its HQs and four regional Units. The new initiatives in the research including Glaciers study; Kailash Sacred Landscape, Climate Change, etc. were emphasized. Institute's commitment for promotion and up-scaling of environment friendly and cost effective technologies in the region was highlighted.

On this occasion 18th Pt. Govind Ballabh Pant Memorial lecture entitled "Realizing Low Carbon Strategy for Inclusive Growth" was delivered by Padambhusam Dr. Kirit S. Parikh, Former Member, Planning Commission, Govt. of India, Chairman, Expert Group for Low Carbon Strategy for Inclusive Growth, Planning Commission, Govt. of India and Chairman, Integrated Research & Action for Development (IRADe), New Delhi. Presidential address delivered by Dr. T.S. Papola, ICSSR National Fellow and Honorary Professor, Institute for Studies in Industrial Development, New Delhi and Former Member, Planning Commission, Govt. of India.

Besides, Photo competition cum exhibition on different aspects of Himalayan Biodiversity and Ecology was inaugurated by Dr. T.S. Papola. The panel

of Judges for the photo competition consisted of Shri Threesh Kapoor, Shri J. Bisht and Dr. J.S. Mehta. Vote of thank was proposed by Dr. P. P. Dhyani, Senior-most Scientist of the Institute. Over 300 participants representing diverse sections of society participated in the programme.

Wild Life Week Celebration

Wildlife Week was celebrated at the HQs and its four regional units (6-7 October, 2012). The aim of the celebration was to make aware the youth on issues of Biodiversity Conservation. On this occasion, a Biodiversity exposure and interpretation campaign for students and teachers of Almora District was organized with particular emphasis on inculcating interest among the children for diversity of life in their immediate surroundings. Exposure visit to the 'Suryakunj' - Nature Interpretation and Learning Centre at Kosi-Katarmal, Almora was the main event followed by various on-spot competitions for the students. Over 100 students and 12 teachers from 11 schools participated in the programme.

Workshop on Tourism/Ecotourism Promotion in Kedar Valley

The Garhwal Unit organised a one day workshop on "Tourism/Ecotourism, Problems/Issues and Potentials in Kedar Valley" between 4-5 March 2012. Shri Mahendra Prasad Semwal was the chief guest of the programme. The Scientist Incharge welcomed the participants and gave a detailed presentation on problems, issues and management of eco-tourism in Kedar Valley. A total of 60 participants from executive member's dignitary of KEDAR (Kedar Ghati Ecotourism Development Action and Research association) Govt. departments, NGOs, women farmers, different stakeholders participated in the programme. All stakeholders discussed their views and possible ways of a developmental plan for promoting eco-tourism in the valley through a group discussion with the experts and scientists.

Governing Body Meeting

The 36th Governing Body Meeting of G.B. Pant Institute of Himalayan Environment and Development, was held on March 20, 2013 at Ministry of Environment & Forests, New Delhi. The meeting has been chaired by Shri Hem Pande, Additional Secretary, MoEF on behalf of Secteraty, MoEF, New Delhi. The meeting was attended by Shri B.M.S. Rathore, Joint Secretary, MoEF (Member); Shri Hari Har Mishra, Director IF, Representative of AS & FA (Member); Dr. B.K. Singh, Director MoEF, Representative of DG Forests (Member); Prof. V.K. Gaur (Member); Dr. R.K. Agrawal, Deputy Secretary, MoEF (Special Invitee) and Dr. L.M.S. Palni, Director, GBPIHED (Member Secretary). Dr. R. Semwal, Consultant (Mountain Division), MoEF also attended the meeting. Other Members, Secretary, DBT, New Delhi; Chief Secretary, Uttarakhand; Prof. Kanchan Chopra; Prof. Sudhir Sopory, and Prof. J.S. Singh could not attend the meeting and leave of absence was granted to them.

The Governing Body deliberated on various issues concerning R&D of the Institute and provided valuable suggestions for improvements. The Governing Body also approved the draft Annual Report and Statements of the Accounts for the year 2009-10.

Workshop on Climate Variability/Change Impact on Farming Systems and Possible Adaptation Strategies

Garhwal Unit of G.B. Pant Institute of Himalayan Environment and development organized a workshop on climate variability/change impact on farming systems and possible adaptation strategies between 20th-21st March, 2013 at Kandara village, Rudraprayag District of Uttarakhand. The workshop brought together experts and local people particularly farming communities and representatives of local NGOs, to start a dialogue on how to deal with the effects of climate change in hilly region of Garhwal Himalaya. Shri Rakesh Gairola former director of education and Smt. Shakuntala Jangwan, State president of BJP, were the chief guest and guest of honour of the programme. Scientist In charge of the Unit appraised all participants for their eagerness to share the idea and knowledge between scientists and stakeholders. About 80 participants from different backgrounds i.e. farmers, academic Institutions (HNB Garhwal University/Krishi Vigyan Kendra, Govt. line agencies, NGOS, etc.) participated in the programme. After inaugural session perceptions of the stakeholders regarding climate change impact and possible adaptation strategies adopted by the community at local level were documented through a group discussion. The workshop identified the need for capacity building

programmes for farming communities in the region, reviewed current and future plans for adapting strategies and discussed how to best implement strategies at the community level. The workshop also suggested a plan for climate resilient development and village ecosystem- based adaptation for hill communities.

Workshop on Capacity Building and Entrepreneurship Development through Rural Technology

Garhwal Unit organized a two day workshop on "Entrepreneurship Development through Sustainable Utilization and Management of Local Bio-resources in Kedar valley" during March 24-25, 2013. Sh. Madan Mohan Semwal was the chief guest of the programme. The Scientist In-charge, addressed the participants and expressed gratefulness on behalf of the institute to all the stakeholders, representatives of communities from different regions of Uttarakhand for their active participation and delivered detail presentation on the potential of natural resources, strategies for sustainable utilization and management of these resources to enhance livelihood through adopting the technologies demonstrated at the centre. A total of 70 stakeholders of different backgrounds such as farmers, students, NGOs, members of line departments of the region participated in the programme. Various issues related to sustainable utilization and management of bioresources and linking them with livelihood of the stakeholders were shared among the stakeholders during field demonstration and training.

Development of Entrepreneurship Skills among the Locals and Value Chain and Marketing of Agro-products for Livelihood Enhancement

Garhwal Unit organized a two day workshop on Entrepreneurship development through value chain and marketing of agro-products in Kedar valley during March 25-26, 2012. Sh. Surya Prasad Tiwari was the chief guest of the programme. The Scientist In charge of the Unit emphasised on value addition in local agro-produce as an option for livelihood through marketing. He depicted the previous study done in this direction to the stakeholders and also made them aware about the potential and importance of these locally produced agro-produce in local health care and its demand at the local, region, national and global markets. A total of 65 participants from different streams i.e. farmers, NGOs, govt. line, educational and Institutional were present in the programme. The participants were imparted training through on-site demonstration, power point presentation, poster presentation and field excursion. During the training period stakeholders discussed various issues related to value addition, packing and marketing outlets of the products for better returns.

Exposoure Visit to Sikkim Unit

Prof. S.P. Singh, Planning Commission, Dehradun, UK, Dr. R.S. Tolia (CHEA Chairman) and Dr. R.C. Sundriyal, Director, Herbal Research Development Institute (HRDI) Gopeshwar, Distt. Chamoli, **Uttarakhand** accompanied by Senior Officials of the Institute paid a visit to the Sikkim Unit of GBPIHED at Pangthang (Photograph 1a & b) on May 24, 2012. The Institute welcomed the visiting dignitaries by offering them Khada (traditional ceremonial scarves). Dignitaries were briefed about the Unit activities in the light of the visions and mandated objectives of the Institute, taken around all the laboratories, library and office facilities of the Unit by Dr K.K. Singh, Scientist In-Charge, of the Unit along with other Scientific/Technical/Administrative staff. They spent about an hour in the campus and had lunch organized in co-ordination with the Unit friendly contributory mess. The dignitaries highly praised the efforts of the GBPIHED-Sikkim Unit in words in the visitor's diary.

3. RESEARCH AND DEVELOPMENT PROGRAMMES

Group: Socio Economic Development (SED) & Environmental Assessment and Management (EAM)

The unique environmental setting of the Indian Himalayan Region (IHR) is varied owing to ecological, socio-economic and cultural diversity. Traditionally, the system is strongly rooted upon the concept of recycling of resources within; however, the system is undergoing rapid breakdown because of population pressure and developmental needs. In view of the above, Socio Economic Development (SED) theme of the Institute focuses on identified activities such as livelihood enhancement, sustainable tourism, entrepreneurship and self employment, indigenous knowledge, and migration and its socio-economic and cultural implications, etc. The development in the IHR so far has also involved conflict between man and nature. The exploitation of the large resource base of the hills by urban industries through mining, large scale timber extraction or hydro-electric power generation from the hill streams and rivers have resulted in both positive and negative side effects. Environmental costs of such developmental interventions, therefore, need to be integrated with traditionally practiced cost-benefit analysis. Identification of strategies for ameliorating environmental threats through scientific assessments and looking at alternate pathways for securing the ecologic and economic security of the IHR are, therefore, the back bone of the Environmental Assessment and Management (EAM) theme of the Institute, which focuses on activities such as hill specific Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA), aerosols and climate change impacts, disaster mitigation and management, and environmental management of urban areas, etc.

Group: Watershed Processes and Management (WPM) & Knowledge Products and Capacity Building (KCB)

Land and water form the backbone of the resource base on which agriculture, forestry and animal husbandry linkages depend. To meet the Millennium Development Goals for reducing hunger, combating water scarcity and achieving environmental sustainability, it is vital to seek methods for using watershed services more efficiently without compromising with the environment. In the Himalayan context, the challenges are even bigger due to complexity and fragility of the mountain ecosystem. To address some of these challenges in an integrated time bound manner, this group focuses on studies of ecosystem processes operational at watershed level including involvement of user groups and upstream-downstream linkages with a specific target of strengthening mountain specific resource management practices in a systems approach. This group also envisages activities on the enhancement of Institutional outreach based on its research products such as state-of-art methodologies/approaches, models and policy briefs, etc. Besides the above, capacity building through specifically designed modules, trainings programmes, library and IT services, which also help significantly in human resource development, are the other core areas of the R&D activities of the Institute.

Group: Biodiversity Conservation and Management (BCM) & Biotechnological Applications (BTA)

The importance of biological resources for human welfare is tremendous and beyond question since early times. With increasing human population and demand for bioresources, its sustainable and judicious use is essential for the long time survival of the people of the entire world and particularly those in the Indian Himalayan Region, which covers a total geographical area of approximately 591, 000 km^2 (18% of India) and is inhabited by about 3.7% of the total population of the country. This region harbours a variety of plant, animal and microbial populations, and is considered a "hot-spot" of biodiversity; it also caters and contributes significantly to supporting livelihood and contributing to the economic well being of the people. However, the changing world scenario stresses the need for increasing food production, pharmaceutical and other products, along with heavy industrialization, which has compelled biologists to contemplate on serious issues, like conservation of biodiversity, climate change, biotechnological interventions for improved productivity, etc. The group focuses on aspects of biodiversity conservation and management, and on applications of biotechnological methods for improving the rural economy of the Indian Himalayan Region.

Theme

WATERSHED PROCESSES & MANAGEMENT (WPM)

Himalayan watersheds support varieties of managed and natural land use types such as terraced farming, agroforestry and orchards in north west and are central to *jhum* farming in north east Himalayan regions. Besides these, natural forests, pastures, degraded lands, glacier and snowbound regions are other important land uses that regulate watershed processes. The recently accepted UN Millennium Development Goal targeted to reduce by half the proportion of people without sustainable access to safe drinking water and reduce hunger. The theme activities include problem identification, assessment and quantification of ecosystem processes through synthesis of research findings and development of practices/packages for implementation with the involvement of beneficiaries. The theme focuses to work on watershed services and management, land and water use policy, consequences of climatic change, improvement of Himalayan farming systems, relevant Indigenous knowledge systems, and domestic energy needs, etc. The main objectives of the theme are: i) Study the dynamics of the watershed processes and evaluation of ecosystem components on a watershed scale; ii) Develop ways and means of optimal uses of watershed services for improved economic and ecological viability; and iii) Evolve strategies for efficient utilization of resource through integrated watershed management.

Ecological, Social and Policy Implications of Changing Water Resource Scenario in the Indian Himalayan Context ***(2013-2017, In-house)***

Water being a fundamental constituent of environment and vital for all life forms on the planet earth, sensitivity of water resources has long-term consequences for health of mountain ecosystem and of human societies. Water stress and sustainability are functions of the available water resources and their withdrawal and consumption. Both resources and consumption are variables that depend on many factors such as ecosystem, agriculture, infrastructure, technology, demographics and economy. Additionally, the uncertainties posed by the climate change are likely to produce a drastic decline in the water supply within a few decades. Populations are growing in the region and the subsequent demands for water are increasing; a situation further complicated by the migration of people from rural to urban settings. In addition, economic development and current standards of living are increasing the demand for water. All of these issues pose challenges for water managers. The study conducted in Upper Kosi basin indicated rise in water demand from 45 to 85% in the next 18 years under different socio-economic scenarios. In most regions, supply is being outstripped by demand. Unfortunately, attempts to understand these changes in water regimes and its consequences on ecosystem properties and human societies are fragmentary due to data constraints and lack a holistic approach, particularly in the Himalayan context. Without adequate levels of financial resources and considering the ecological fragility of the region, a sensible option is to employ ecosystem-based solutions, wherever possible. This would also reduce the medium-term risks. Considering the above, it is proposed to undertake this project in a

mid-Himalayan rainfed watershed through multidisciplinary approach.

Objectives

- To identify, analyze and assess potential indicators depicting changes in water resource scenario under changing climate regime and its interaction with different ecosystem components and society at the basin scale.
- To investigate the implications of changing scenario of water resources and delineate the critical ecosystem components susceptible to change.
- To analyze the consequences of changing water regime on society, and possible adaptation measures to be employed at local and policy level.
- To develop policy options and adaptive water management action plans for addressing the challenges identified above in the context of Himalayan Mountains.

Achievements

- Inception meeting of the project was held to identify the role of the participating team members. Checklist of parameters to be studied was finalized. Literature regarding water quality map of study site as well as its adjoining areas has been collected.
- Preliminary field survey of Kosi watershed (from Khairna to Ramnagar) for selection of water sampling stations has been done.
- Mean monthly rainfall of four stations viz. Almora (1901-1968), Ranikhet (1901-1968), Kausani (1951-1977) and Ramnagar (1901-1941) of watershed are analyzed. Out of the total annual rainfall, 77% rainfall is recorded in the monsoon season. The Average maximum rainfall is recorded in Ramnagar and minimum in Almora (Fig.1).

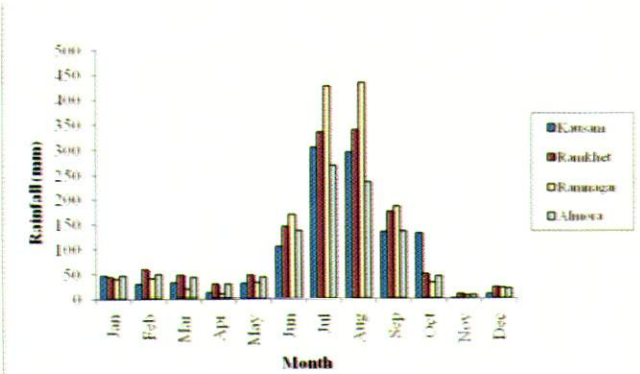


Fig.1. Mean monthly rainfall in Kosi watershed.

Farming Systems and Changing Climate Regime: Strengthening Food and Nutritional Security in the Himalaya *(2013-2017, In-house)*

The Indian Himalayan Region (IHR) is a distinct and eco-sensitive geographical region where about 70% of the population is rural and depends mainly on rainfed agriculture, horticulture and animal husbandry. Farming systems are complex; crop husbandry, animal husbandry and forests constitute interlinked production systems. Environmental, biological, socio-cultural and economic variations in the Himalaya have led to the evolution of diverse and unique farming systems, crop species and livestock, which help communities to sustain. Farming systems of the region are increasingly influenced by technological innovations, the market economy and off-farm economic avenues. Climate change and agriculture are interlinked and climate change is only one of several factors affecting food production systems. Pheno-phases of the food crops are affected by climate change. Variations in crop phases affect agriculture by influencing the timing of planting, maturity, harvesting and also the pest activity. In IHR, farmers have developed locally suitable practices to cope with the harsh environment of the hills. New crop varieties are being introduced to the system. Literature is available on the global climate change but published information on adaptive measures/practices in farming system under climate change regime from Kumaun or Garhwal regions of Uttarakhand is largely lacking. The present proposal will fill the information gap in this context.

Objectives

- To identify changes in the mountain farming systems due to infrastructure development, and social, economical and ecological factors including climate change.
- To identify (and validate) indigenous and introduced practices (and technological interventions) that would help to cope with the changing scenario.
- To develop appropriate strategies and action plans for sustainability of mountain farming system.
- To provide inputs to development planners and practitioners.

Achievements

- Preliminary analyses of rainfall and temperature data, for the two decades (1990-1999 and 2000-

Objectives

- To maintain and operate existing permanent GPS stations at Kullu (HP), Almora (UK), Nainital (UK), Srinagar (Garhwal), Pangthang (Sikkim), Zero (AP) and focusing on: Quantification of the tectonic deformation field by experimentally determining the displacements of these fixed sites (urban centres) using GPS Geodesy with high resolution.
- To further refine the strain rate field across the Himalaya, along the Kali and Gori valleys (Kumaun Himalaya) by re-occupying the 31 control points already established in previous DST project.

Achievements

- Regular upkeep & maintenance of the system and data processing of permanent station at Almora (GBPK), Nainital (GBNL), Srinagar (GBSN), Kullu (GBKL), Pangthang (GBSK) and Zero (GBZR) for reference to other campaign sites is being done.
- The precise position and velocity of these sites in ITRF08 reference frame are determined. Data of year 2010 of permanent station is used for velocity calculation. Preliminary observations shows that the velocity of IISC and HYDE is ~ 52 mm/year, and velocity of permanent station GBPK,GBNL, GBSN is about 47 mm/year , 46 mm/year and 47 mm/year, respectively as calculated from year 2010 to 2012 (Fig.4).

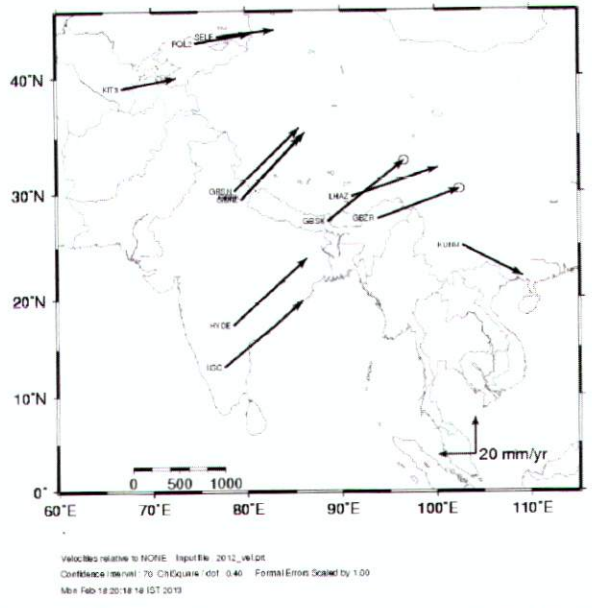


Fig.4. Velocity of permanent stations (2010-2012) and reference IGS stations in ITRF08.

- GPS field work campaign is carried out for data collection from 7 stations in Kali valley (Dharchula to Lipu Lekh) for monitoring the strain-rate accumulation in Kumaun Himalayan region for the first year. The data from these campaign sites have been recorded and rinexed; processing of data for baseline is done using GAMIT/GLOBK. GPS Campaign in remaining sites located in lesser Himalaya and Shivalik have been completed in Jan, Feb and March 2013.

Monitoring Snow and Glaciers of Himalayan Region - Phase- II ***(2010-2014,*** *Space Application Centre (ISRO), Ahmedabad)*

Himalayan glaciers contribute fresh water to the major river systems of the north India during critical summer months and make these rivers perennial. It has helped to sustain and flourish the Indian civilization along the banks of Ganga and Indus. Glaciers are highly sensitive to change in the climate. Change in mountain glaciers in the form of advance and retreat is considered a reliable indicator of climate change. In this context, this project is undertaken to monitor advance/retreat of the glaciers in Gori, Dhauli and Kali valleys of Kumaun Himalaya using satellite data and field studies. Field studies are done in the Neola and Lapa Glaciers in Dhauliganga basin. Mass Balance, glacier movement and physicochemical studies of melt water, suspended sediment and discharge measurement of the Lapa glacier was also initiated during this year.

Objectives

- To generate data base of glacier extent using moderate to high resolution satellite data of ablation period of 2010-2012 time frame and monitor the change in advance/ retreat in Dhauliganga, Goriganga and Kaliganga sub basin in Western Himalayan region.
- To carry out field studies of a specific glacier in Dhauliganga basin.

Achievements

- Field verification of glaciers and glacial lakes has been conducted in Dhauliganga and Goriganga valleys using handheld GPS (Fig.5).For mass balance and glacier movements, stakes and pits are placed in ablation and accumulation zones of Lapa glacier, respectively. Stakes are also established in the ablation zone of the Neola glacier for glacier velocity measurements.

2009), recorded at Laxmi Ashram, Kausani, provide indications of possible climatic changes in the Kosi river basin. Average monthly rainfall for the two decades indicates no marked change with totals of 1,159.4 mm and 1,157.0 mm, respectively. Very little change was observed in the number of rainy days during the two decades which slightly reduced from 119 to 116.6 days. Further, a rise in the mean monthly temperature ranging from +0.1°C (in June and September) to +1.4°C (in March) for the two decades was observed. Average monthly maximum temperatures also shows +0.7°C increase in March and decrease of -0.5°C in June.

- Kosi watershed falling in districts of Almora and Nainital is divided into various soil suborders namely Distric Udorthents, Typic Udorthents, Distric Eutrochrepts, Typic Hapludolls, Lithic Udorthents, Typic Dystrochrepts, Typic Udipsamments, Fluventic Eutrochrepts with mica schist/ quartzite/ shale/ colluvium/ alluvium soil base type.
- Average cropping area of various food crops in block years of 2001-2010 reveals 62.2% reduction in cropping area of lentil (*Lens culinaris*), 27.5% reduction in barley (*Hordeum vulgare*) and 17.5% reduction in paddy (*Oryza sativa*) as compared to block years of 1991-2000 (Fig.2 & Fig.3). Out migration of families and subsequently abandoning land without cultivation are main causes of reduction in cropping area. An increase of 28.4% in cropping area was noted for pea (*Pisum sativum*). Per hectare productivity of food crops from 1990 to 2010 reveals that productivity of paddy, wheat, pea, lentil, soya bean and potato is showing declining trends. Mustard showed no change and ragi (*Eleusine coracana*) and black gram (*Vigna mungo*) showed slightly increasing trends.

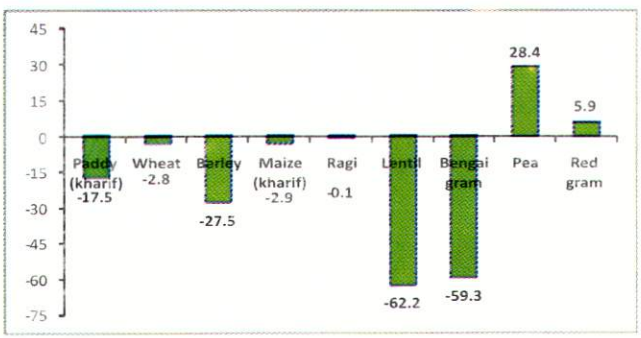


Fig.2. Changes in cropping area of food crops in block years from 1991-2001 to block years 2001-2010.

Fig.3. Farming of varieties of vegetables (garlic, onion, spinach, tomato potato etc: along with scare crows) along with wheat in Kosi watershed; in insets are coriander (A) and barley (B).

Operation of Permanent and Campaign Mode GPS Stations for Quantification of Tectonic Deformation Field in Himalayan Terrain *(2012-2017, Ministry of Earth Science, New Delhi)*

In tectonically active regions where deformation rates are large, especially in the neighborhood of active faults, hill slopes are subject to steady steepening and tend to be perpetually in a far- from equilibrium state, critically poised to slide down vast amounts of their soil cover in response to any triggering mechanism. In Himalaya, the zones along the Main Boundary Thrust (MBT) and Main Central Thrust (MCT) and the trans-Himadri thrust (TIIT) that delimits the northern boundary of the great Himalaya, are the three highly vulnerable zones prone to recurrent landslips and earthquakes. Several damaging landslides have occurred in the region. This project proposal is designed to delineate the deformation field in the Himalayan urban centers, including some notable land slip zones with high resolution, by using 6 continuously operating GPS systems at Almora, Gangtok, Nainital, Kullu, Zero and Srinagar-Garhwal. Study is also designed to constrain the deformation rate (strain) field in the Uttarakhand Himalaya based on GPS measurements to date, by reoccupying the 31 GPS campaign stations along the Gori and Kali valleys from the foothills to the trans-Himalaya.

- Maximum discharge is observed in the month of August (107.31cum/s) followed by that in July (103.6 cum/s) and September (85.0 cum/s) whereas minimum discharge is observed in the month of September (47.83cum/s) followed by that in July (64.78cum/s) and in August (69.57cum/s) during the study period (Fig.7). Relatively high runoff in July and August is due to the high melting rates caused by rise in temperature during these months. Increase in discharge is observed during mid September which shows delay in the end of the ablation season.
- Daily average suspended sediment load is also estimated for the ablation season of the reporting year. Large variations (CV= 0.67) are observed in suspended sediment load of Gangotri glacier. During the ablation season of 2012, maximum and minimum concentration of suspended sediment load is estimated as 4.08 g/l and 0.27 g/l respectively whereas average concentration of suspended sediment is estimated as 9671.51tones/day. Maximum concentration of suspended sediment is observed in the month of July, followed by that in August and September (Table-2).

Table–2. Patterns of discharge and concentration of suspended sediments load (SSL) observed during ablation season of 2012.

Month	Discharge (in cum/s)					Concentration of SSL in (gm/l)			(MT/month)
	Avg	Max	Min	Total	SD	Mean	Max	Min	Mean
July	86.31	103.60	64.78	2675.86	10.54	1.47	3.21	0.59	344378.1
August	86.59	107.31	69.57	2684.33	9.01	1.12	3.58	0.46	265728.6
September	72.40	85.00	47.83	2172.12	10.72	0.88	2.44	0.26	173994.7

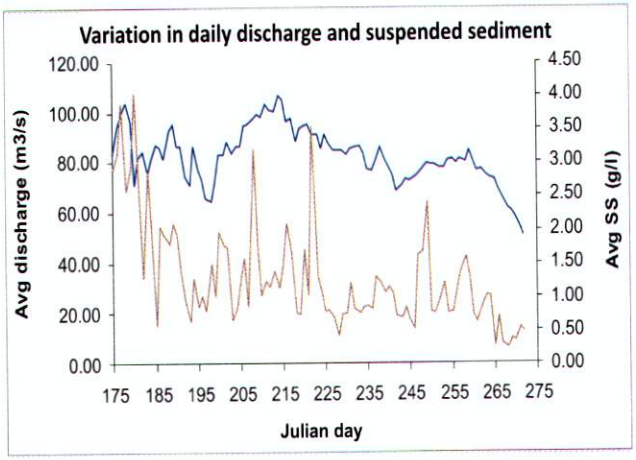


Fig.7. Variation in daily discharge and sediment concentration observed during ablation season.

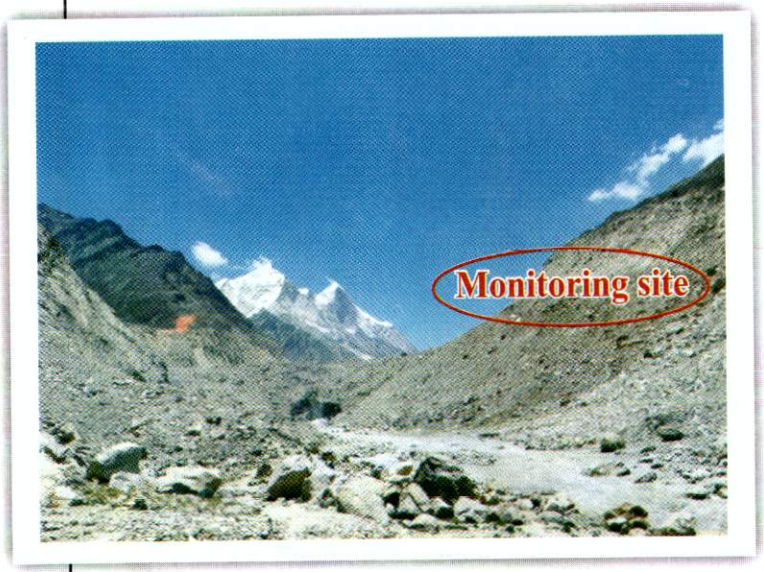


Fig.6. Monitoring site established near Gomukh, snout of the Gangotri glacier.

- Most of the glacier area of Goriganga basin is oriented towards west (34.27 %) and south-east (22.75 %), whereas in Dhauliganga basin it is in east (37.49 %) and north-east (22.97 %) orientation. Maximum area loss in Dhauliganga basin is found in east facing glaciers as 42.59 %. In Goriganga basin area loss is maximum in north-east facing glaciers (Table-1).
- Total suspend sediment of Lapa Glacier River varies from 0.11 to 1.77 g/l showing good correlation with discharge. EC values of Lapa Glacier River vary from 204 to 299µs/cm with pH value ranging from 6.77 to 7.62.

Table–1. Aspect wise loss in glacier area of Goriganga and Dhauliganga basin in 2001 to 2010 (in %)

Dhauliganga Basin

Area (Sq km.)	North	North east	East	South east	South	South West	West	North West
<1	59.54	7.23	12.23	0.00	6.32	0.00	0.00	14.67
1 to 5	0.00	15.98	10.90	5.23	16.68	3.25	47.95	0.00
5 to 10	5.61	11.27	54.70	6.39	5.87	0.00	0.00	16.16
>10	0.00	14.57	85.43	0.00	0.00	0.00	0.00	0.00
	3.16	**14.15**	**42.59**	**3.92**	**9.04**	**1.44**	**21.22**	**4.48**

Goriganga Basin

Area (Sq km.)	North	North east	East	South east	South	South West	West	North West
<1	0.00	14.48	0.00	85.52	0.00	0.00	0.00	0.00
1 to 5	25.30	26.56	0.00	0.00	8.93	25.72	0.00	13.50
5 to 10	0.00	87.56	9.04	3.40	0.00	0.00	0.00	0.00
>10	0.00	31.67	0.00	32.41	0.00	25.79	10.12	0.00
	4.57	**46.76**	**2.78**	**21.24**	**1.61**	**16.11**	**4.50**	**2.44**

Fig.5. Snout position and glacial lake of Mapang Glacier.

Run-off Modeling and Simulation of Sediment Load Gangotri Glacier Systems *(2011-2014, DST, Govt. of India, New Delhi)*

Glaciers, an important component of earth system, control the river hydrology of the mountains and the areas downstream. Himalayan glaciers are showing a decrease in snow cover and an extensive glacial retreat. Gangotri glacier which was earlier receding at a rate of 26 m/year between 1935 and 1971 has shown a gradual decline of 17m/year between 1971 and 2004 and lastly showed a recession rate of 12m/year during 2004-2005. The rapid recession and overall decrease in volume of glacier is adding to total area of erosion every year. It generates large amount of suspended sediment load, which is carried from the glacierized basin. Suspended sediment forms a part of glacier erosion. The magnitude of sediment transported by rivers has become a serious concern for the water resources planning projects. Therefore, correct estimation and prediction of sediment load carried by a river is very important. Further, the runoff generated by snow and glacier melt processes causes sediment transportation from the high altitude basins of the Himalayan region, especially from the middle and greater Himalayan ranges. Due to lack of information on hydrological processes of snow/glacier regime and availability of melt water, water resources management policies at the lower reaches of the glacier-fed rivers are often formulated without considering the impact of snow and glacier on river hydrology. The present proposal aims at addressing this important aspect of glacial hydrology.

Objectives

- To estimate the snow and glacier melt runoff using temperature index model.
- To simulate & forecast suspended sediment load and establish relationship with melt water discharge

Achievements

- The average melt water discharge from Gangotri glacier observed during ablation season of the year 2012 shows less variation (Fig.6, Table-2). Events related to high flow mostly occurred in the months of July and August confirming that these events were caused by opening up drainage network and excessive melting of snow and ice on account of rising temperature.

Summary of Completed Project / Activity

Optimizing Hydrological Responses in a Functional Land Use Model for Mid-elevation Himalayan Watersheds: An Attempt towards Water Sustainability ***(2007-2012, In-house)***

Water shortage is the main problem in rural areas of the Kosi watershed. Nearly 48% water shortage is found due to deforestation. Out of total catchment area, 228.41 km^2 was covered by forest, 129.07 km^2 by agriculture and 89.82 km^2 by barren land in hilly terrain. To solve the water problem, water harvesting structures were implemented along the river. In Urban and Rural population growth analysis, it is found that urban population is growing at a rate of 2.07% per year, whereas the rural population is growing with 0.49% per year which is affecting the water demand. As the results show water condition in watershed will become more and more crucial as population increases while water availability stays finite. Rainfall and discharge data of the river was recorded to measure available water and the availability demand analysis is carried out. Ratio of maximum and minimum discharge shows a mix trend in these four years. Double mass curve analysis shows that rainfall and runoff are strongly correlated. Water allocation is made using optimization of demand of domestic, livestock and irrigation sectors. Integrated decision support system (DSS) has been developed for optimization and forecasting domestic (Urban and Rural) water allocations in changing scenarios for forthcoming year (from 2012 to 2030). The study suggests that water supply cannot meet demand of any sector without storage of surplus water from Jan to March of the same year. Even with storage of surplus water, 100 % water demand of all sectors can be fully met till 2016. However, the urban demand can be met with this stored water. DSS is an effective tool to allocate and optimize available water to meet domestic water demand in different changing scenarios. Two months (April and May) are found as the most critical for water supply. Water Supply can't meet demand of any sector without storage of surplus water from January to March of the same year. Even with storage of surplus water, 100% water demand of all sectors can be fully met only till 2016. However, the urban demand can be met with this stored water.

Summary of Completed Project / Activity

Participatory Water Management Plan for Mid Altitude Himalayan Villages Using Optimized Water Harvesting Systems ***(2009-2012, DST, New Delhi)***

Water and overall environmental security in mid-elevation Himalayan watersheds are highly vulnerable to seasonal changes in the water regime. Understanding the year to year and season to season trend of rainfall, flow of river in past decades provides a major step towards understanding and coping with changes in seasonality of sources. There may be sufficient annual water available in a region to satisfy basic needs, if adequate conservation and storage measures are taken. Thus, water management strategies should focus on building adaptive optimized models on the basis of allocation of hydrological responses to cope with water scarcity and seasonality. This study was conducted in four villages i.e. Railakot, Manaun, Supakot and Pachchisi of Upper Kosi watershed. Water availability analysis was done by measurement of available water sources in villages in two different seasons i.e. monsoon and summer in years 2010 and 2011. The secondary data of water availability (rainfall) is used for developing three scenarios, i.e., drought year, high rainfall year and normal rainfall year. Based on this scenario, two scenarios were found in these three years. Year 2009 was normal rainfall year (annual rainfall 1100 mm) and 2010 and 2011 were above normal rainfall years (annual rainfall 1340 mm and 1555 mm respectively). A mathematical formulation of the scenario was developed and analyzed using optimization. Based on the scenario and optimization model, pilot scale testing was done in village Pachchisi. At village level, available water was more than demand of village but in two hamlets (Kafari and Chauna) water shortage was recorded in summer months. It is concluded by PRA meeting and transact walk that water management of village should be done hamlet-wise because in mountain areas hamlets of villages are situated in different altitudes and villagers can maintain and monitor their scheme easily and co-operate with each other. Construction of water tank of capacity 5.5 cu.m. and harvesting of source has been done with the active participation of villagers in Chauna hamlet. Water testing of this harvested water was also done. All parameters of this harvested water were found within desirable limits. In Village Railakot, rainwater harvesting structure and a slow sand filter was constructed for drinking water for one household. Water testing of slow sand water filter was also done. All parameters of slow sand filter were found within desirable limit. In Supakot village, plantation work and water conservation measures were executed with MNREGA scheme of the village. 70 trenches were dug and 350 broad leaf plants planted in 2 ha. area of community waste land (80% contribution of MNREGA and 20 % contribution of project, in terms of cost sharing). The post project monitoring is being done by the villagers.

Summary of Completed Project / Activity

Nematode Diversity in the Traditional Agro-ecosystem of Central Himalaya, Their Impact on Soil Health, Crop Growth *(2007-2012, In-house)*

Nematodes were isolated and identified as per standard protocol (the double maximum method) from paddy (*Oryza sativa*) and foxtail millet (*Setaria italica*) sole and intercropped plots of paddy and foxtail millet sown in the ratio 4:2, 3:3 and 2:4. All the five treatments were in triplicate under a completely randomized block design. Data was collected for four consecutive seasons. The nematodes were identified up to generic level after careful study of their interior morphology. The identified nematodes belonged to five orders, order *Rhabditida, Tylenchida* and *Aphelenchida* belonged to class *Secernentea* and orders *Dorylaimida* and *Mononchida* belonged to class *Adenophorae*.The nematodes were classified in to their trophic groups based on their feeding habits and mouth parts. They were identified as bacterivores, fungivores, herbivores, omnivores and predators. A total of approximately fifty major genera have been identified from the experimental soil and a calendar based on their presence and absence at each sampling date corresponding to a month has been prepared. Altered soil-water availability was related to potential changes in climate results in complex changes in the structure of soil food webs. The shift in the nematode composition and abundance is a useful indicator of soil condition. The cropping ratios of paddy and foxtail millet in *Kharif* season and wheat and mustard during *Rabi* season had significant effects on the temporal variability and hence stability of the various nematode functional groups across the study period. The variability in the bacterial and fungal feeding groups was the greatest. This suggested that manipulation of the resource base can have important multi-trophic effects

Summary of Completed Project / Activity

Indigenous Knowledge: Traditional Health Care Practices in Rural Areas of Uttarakhand *(2007-2012, In-house)*

In India, traditional health care practices, particularly use of medicinal herbs for healing is a practice since time immemorial. Being inexpensive, culturally familiar and readily available such practices are still in vogue in rural areas of Uttarkhand by traditional health care practitioners, locally called *vaidyas* in the absence of modern health services. Few village elders also treat some ailments at household level. In Upper Alaknanda valley majority of *vaidyas* inherited professional knowledge of healing within family (65.22% of the total). Majority of *vaidyas* had expertise of curing children (22.59% of total), followed by expertise for curing cattle, women and serious diseases. Experts for mental sickness, bone setting and common disease were more or less equal for each group about 10% of the total. About 50.62% people of 10 surveyed villages (53.67±4.05% household surveyed) admitted that *vaidya* system was easily available and inexpensive. A total of 154 herbs species were used by traditional *vaidyas* and village elders. *Vaidyas* and village elders use nearly two dozen Himalayan medicinal herbs with proven/reported therapeutic properties. 130 herbal formulations used by the traditional *vaidyas* and village elders were documented with their, composition, plant part used and use-method 15 formulations of *Tinospora cordifolia* (*Giloe*) have been witnessed; out of these 6 are already mentioned in literature but 9 are new. Phytochemistry of 67 medicinal plants (MP) used by the traditional *vaidyas* has been documented from published sources. 102 therapeutic properties and associated active principles have been documented. Antimicrobial therapeutic property was possessed by maximum number of 14 MP. Medicinal plant of different species of the same genus may have common phytochemicals such as Eugenol is found both in *Ocimum sanctum and O. americanum* and contain same insecticidal properties. Similarly two species of genus Ficus (*F. religiosa & F. racemosa*) contain common salt saponin. MPs from different families with a few common phytochemicals were also found, *viz. Ficus religiosa, Citrullus colocynthis, Achyranthis bidentata, Picrorrhiza currooa* and *Azadirachta indica* contain saponin which has antimicrobial, anticancer, cardio-protective and antistress properties. As per people's perception lack of complete knowledge of *vaidya* system, shortage of quality herbs & incorrect identification of herbs were the important reasons for an satisfactory cure of some diseases.

Summary of Completed Project / Activity

Energy Use Pattern in Rural Domestic Sector of Uttarakhand State – Issues, Options & Challenges *(2007-2012, In-house)*

The Uttarakahnd state is inhabited by a human population of 1,01,16,752 persons (Census 2011) and 69.4% of the total population of the state resides in 16,793 villages. Share of rural population to the total human population of the state has decreased in the last decade (74.3% as in 2001). There has been a significant increase in the population of districts in the plain areas of the Uttarakhand. The decadal growth of these districts is observed to be quite high and is slightly greater for the entire state than the average of the country. This study was designed to analyze patterns of domestic energy requirements with varying variables in rural settings for projection of future patterns and impact on resources, and to understand technical, institutional and financial mechanisms in rural energy demand, supply, and alternatives for planning and management. Due to diversity in the user sector, types, resources, and distribution of various energy sources, involvement of various sectors and diverse functional components therein methodology of the study was heterogeneous. Household level sampling was done in more than 13,643 rural households of 317 villages in various districts of the State. A transformation, in the use of cooking energy in the rural areas is also evident during this decade but at a slow pace. This is evident by (i) decreasing share of fuel wood (as primary source of cooking energy) dependent households by 4% (of the total rural households) in the year 2011 than the year 2001 (67.5% of total rural households), and (ii) 8% increase in the rural households using LPG as main source of cooking energy since 2001 (29.4% *vs* 21.3%). These two kitchen fuels are the prevailing main sources of cooking energy in the rural landscape of the state, however other kitchen fuels also exist. Among the other kitchen fuels cow dung cake remains the prominent source of cooking energy and 3.9% of the rural households are still using it. It is also apparent that use of most of the kitchen fuels (other than fuel wood and LPG) has decreased in the last ten years but use of charcoal and coal has increased. On comparing the major fuel combinations being used by households in different income groups it was observed that fuel combination wood + kerosene oil was used by all types of income groups. This fuel combination was used more by low income group households than the high income group. With increase in the income of the household there has been a shift to more number of fuel combinations being used having access to modern fuels like LPG, electricity etc. Second most abundantly used fuel combination Wood + KO + LPG was used maximum extent by high income group as compared to low income group. This was due to affordability of LPG by the villagers (Fig.8). Wood was only used in maximum amounts by households in the low income group and the least by high income group. With increase in the income of households shift towards use of LPG can be observed which indicates that LPG as an energy source was used in priority compared to wood with rising affordability. Other sources like dung cake, charcoal are used when household income increased particularly by those households which are agriculturists and/or rearing animals for dairy etc. and are using wood for household needs. In Uttarakhand distribution of free LPG connection to BPL families in difficult terrain was started under the government aided scheme in the year 2008. The prospect of providing free refilling was not provided to these families therefore ultimately due to high refilling cost some households were still using fuel wood for their household needs. Among the alternative fuels, non-functionality of biogas plants was more on its technical factors than social factors. Functionality analysis of bio-gas plants showed that social factors i.e. 75% of households & Economic factors i.e. 24% were reasons for functionality while their non-functionality was due to techno-environmental restrictions i.e. 77% followed by social hindrances i.e. 17%. Improvement in design (cold climate), economy (low cost), and supplementary resource requirement (Water harvesting techniques) are needed. In the last decade, use of electricity for lighting has increased while use of kerosene oil has decreased in domestic sector of the state. Use of solar energy for lighting has increased in certain districts while a few districts where there is electricity have no shown a slight increase. Use of other oil has also shown a slight increase in almost all the districts except Pithoragarh. Rural domestic sector in the mountains is a complex phenomenon and poses various types of challenges to the energy managers but also provides new frontiers for adoption and promotion of nonrenewable energy sources. Decentralized power generation and distribution are the need of the hour to reduce the loss of revenue as transmission loss and maintenance of a larger network. Biomass based electricity production is a promising sector but reguires a lot of care. Capacity building, project management & legal instruments need to be strengthened. Simple rules & regulations are needed to attract private sector in the development process of non-renewable energy.

Fig. 8. Use of Biogas for cooking energy and LPG as an alternative by a villager.

Summary of Completed Project / Activity

Recharge Area Identification and Estimation Mean Residence Time for Springs in One Urban and One Rural Microwatershed in Pauri Garhwal Using Isotope Technique, Remote Sensing, and GIS *(2009-2014, GBPIHED and NIH, Roorkee)*

Water Resource is becoming the biggest concern in Indian Himalayan Region especially during the summer. This project is an attempt to quantify the available spring water resource in two micro watersheds, one urban micro watershed (Pauri Urban Area) and the other is rural micro watershed (Dugar Gad watershed). Through this project we will also attempt to find the probable recharge area of springs falling in the study area by using the state- of- the- art technology and implement the ground water recharge structures to augment the spring discharge. Altitude effect using stable isotope technique was calculated based on the precipitation sampling in Dugar Gad micro watershed. The recharge area at an elevation above 1550 m. is calculated for a perennial spring at Dugar Gad micro watershed. Detail geological mapping was carried out for Dugar Gad micro watershed (Fig.9). The detailed geological map in the 1:10,000 scale will be used for planning of areas suitable for artificial recharge.

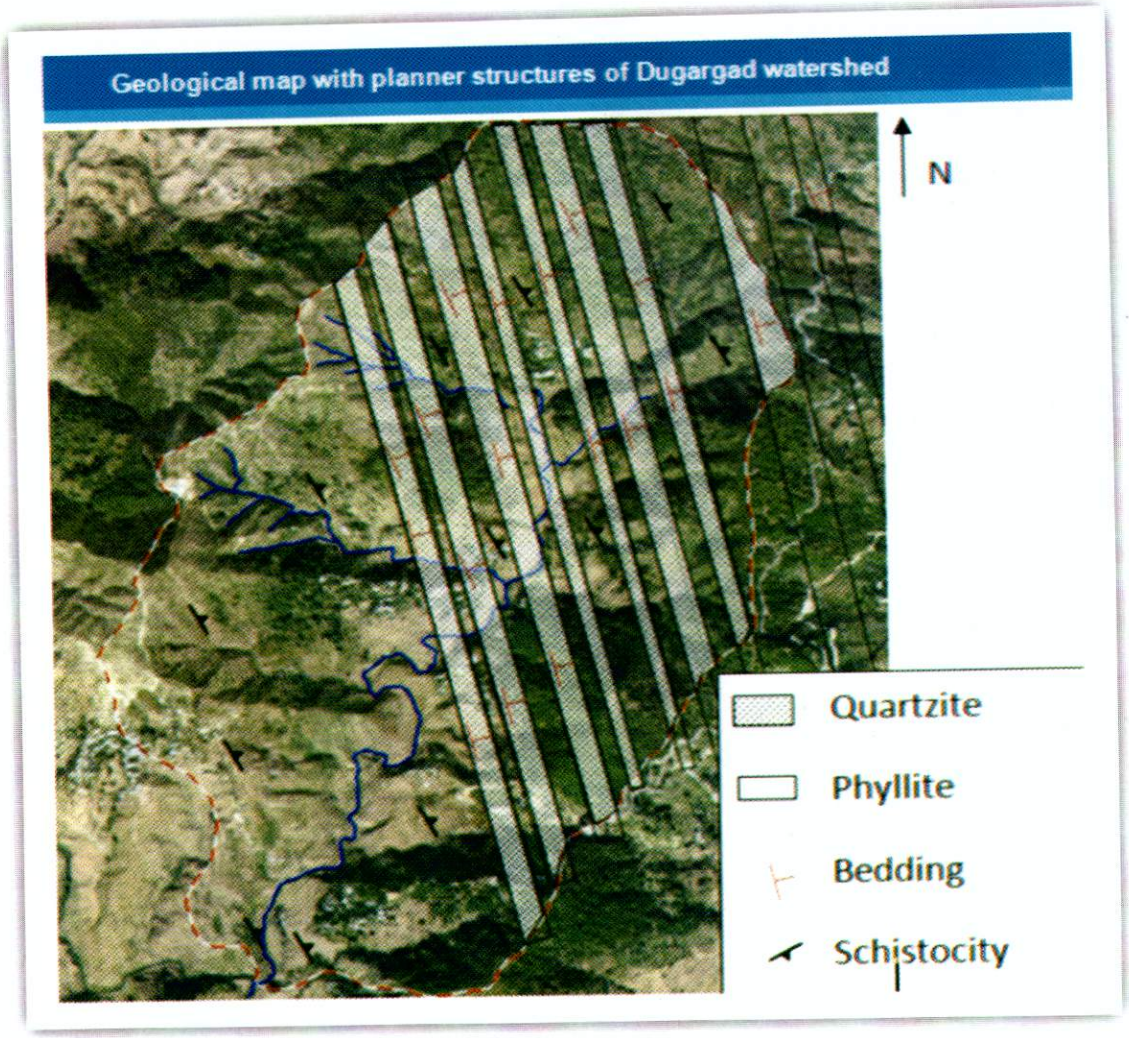


Fig.9. Detailed geological map of Dugar Gad micro watershed.

Summary of Completed Project/Acitivity

Developing Sacred Landscape Model for eco-restoration and biodiversity conservation in the central Himalayan region (2007–2012, In-house)

Continued degradation of land and biological diversity in the Indian Himalayan Region (IHR) is a serious concern in-spite of a number of R&D interventions. One of the basic reasons for ineffectiveness of such interventions could be due to non-integration of sacred/cultural and scientific values in the approach and strategy adopted for degraded land rehabilitation and biodiversity conservation. Keeping this in mind, this project was initiated in June 2007 with the following three main objectives: i) to create environmental awareness among the local people for eco-restoration and biodiversity conservation; ii) to develop a Sacred Landscape Model (consisting of a Sacred Forest Model – to value peoples' sentiments and Multipurpose Tree Model & Horticultural Tree Model – to meet peoples' requirements) for eco-restoration and biodiversity conservation by integrating scientific and sacred values; and iii) to screen/identify/recommend promising plants for rehabilitation of degraded lands based on their eco-physiological health and adaptability potential. The project was concluded successfully in June 2012. The major highlights of the project are summarized below.

1. During the project period, R&D interventions were carried out for developing and strengthening a Sacred Landscape Model (SLM) [consisting of a Sacred Forest Model (SFM), Multipurpose Tree Model (MTM), and Horticultural Tree Model (HTM)] in 14.3 ha degraded community land at 1745m elevation in Kolidhaik village (Lohaghat) of Uttarakhand.

2. A number of site development activities in terms of land rehabilitation and biodiversity conservation were carried out at the above-mentioned project sites. For plantation, 36080 pits (1.5 ft × 1.5 ft × 2 ft) for promising species and 17 contour lines (total length - 4458m; 1.5 ft width) for Napier hybrid grass were dug at the project sites. In addition, 385 trenches (6ft × 1.5 ft × 2 ft) for raising moisture content in the soil, 5 rainwater harvesting tanks (3.5 m × 2.5 m × 1.5 m) for watering of plants, 651m long eco-path (1m wide), and an umbrella-shaped rain shed near Kali temple were constructed. Barbed wire fencing (total running length -1925m) was also put up at the project sites and subsequently strengthened by bio-fencing (through thorny bushes) for the protection of plants from the stray cattle menace.

3. The project interventions have resulted in the survival of 24173 plants (67% survival) of 23 tree species at the project sites [9072 at MTM (80% survival; area- 5.6 ha), 14531 at SFM (82% survival; area- 7.7 ha) and 570 at HTM (40% survival; area- 1.0 ha)]; most of the seedlings have now attained the size of more than 3–4 m. The farmers/women of 88 families (of 6 villages) have collected almost 71.17 tonne green fodder from the project sites (i.e., 1.6 quintal/family/year). The SLM, thus developed by the Institute under this project, is being maintained and strengthened by the Van Panchayat of Kolidhaik village w.e.f. July 2012.

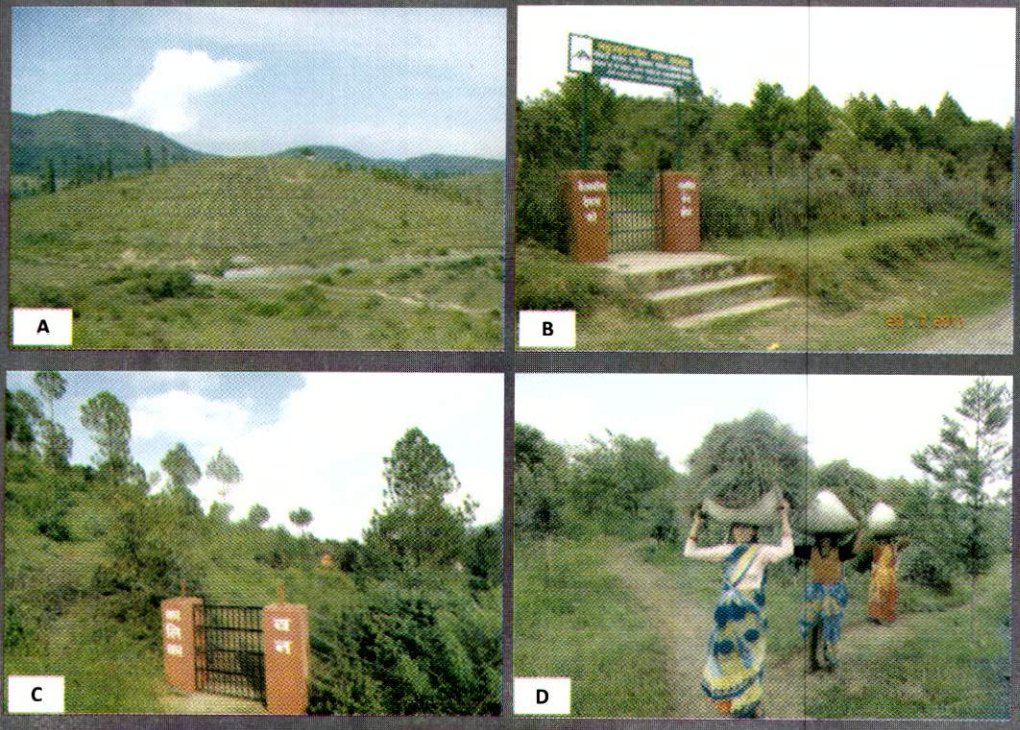


Figure 10. (A) Multipurpose Tree Model (MTM) at the project site, i.e. Kolidhaik village in Lohaghat, Uttarakhand; (B) Survival of Trees at MTM site; (C) Survival of trees at Kalika Van /Sacred Forest Model (SFM) site; (D) Collection of fodder from the project sites.

4. The data obtained on eco-physiological and leaf energy exchange characteristics of 23 promising tree species, based on the plantation at the project sites in Kolidhaik village, revealed two main categories of plants, namely under-temperature and over-temperature ones. The under-temperature plants gained sufficient amount of energy by the convection of heat and exhibited higher rate of transpiration and energy absorption, indicating their suitability for rehabilitation of degraded lands and plantation on the exposed slopes of the mountains.

5. During the project period, environmental awareness was created among diverse stakeholders including locals by organizing 10 stakeholder consultations, 7 plantation ceremonies, 6 plant distribution ceremonies, and 5 on-site training programmes on various aspects of land rehabilitation, biodiversity conservation and livelihood enhancement. These consultations/ceremonial plantations/on-site trainings were attended by more than 2200 individuals and have significantly inspired them for afforestation, degraded land rehabilitation and biodiversity conservation.

6. The R&D efforts carried out during the project period have - i) inspired the local villagers to rehabilitate the degraded community lands in and around their habitation so that their demand of fodder, fuelwood and minor timber needs could be met, and ii) helped developing a Sacred Landscape Model (SLM), which is recognized as an inspiring model for eco-restoration and biodiversity conservation. The SLM can be effective not only in the Indian central Himalayan region but also in other parts of the world, where land degradation is increasing day by day and posing serious threats to the environment and livelihood security of the local communities.

7. Another success milestone associated with the project was the plantation by way of ceremonial plantings from time to time, in which the Imam of Mosque and Hindu Pujari came to the project sites, used their religious authorities, blessed the tree seedlings, and gave inspirational discourses, highlighting Muslim and Hindu beliefs and myths about the physical and spiritual importance of trees. This is considered a graceful example of communal harmony that clearly demonstrates what kind of approaches, based on sacred/cultural and scientific values, for degraded land rehabilitation and biodiversity conservation would work, and as to how science and religion can work together for the benefit of environment and conservation/preservation of the sacred as well as cultural value.

Theme

BIODIVERSITY CONSERVATION AND MANAGEMENT (BCM)

The recognition and characterization of biodiversity depends critically on taxonomical, genetic and ecological studies. The attributes such as topographic heterogeneity, habitat productivity and structural complexity allow prediction of biodiversity. Robust data sets are urgently to develop appropriate short and long term management plans. The long-term research sites and programmes provide essential information on how biodiversity changes, and are important in distinguishing anthropogenic and natural changes. Human dependence on biodiversity and assessment of conservation and economic values of biodiversity are also critical issues. The anthropogenic activities have been identified as the critical factors for biodiversity loss and global climate change. This has necessitated the inventorization and monitoring of biodiversity at different levels and climatic regimes. Biodiversity conservation measures such as development of propagation protocols and establishment and maintenance of live repositories/ Outreach in different agro climatic zones will help in ensuring quality planting material for the promotion of conservation programmes, and enhancement of the capabilities of the stakeholders at local, regional, state and national levels to manage and disseminate information on biodiversity. Such capabilities at different levels are required for the best management of biodiversity that is critical to maintaining the air, water, soil and other conditions essential to human life. During the reporting period the studies have been conducted in tune with the above concept. Realizing the importance of biodiversity for sustainable development and environmental conservation, the Biodiversity Conservation and Management (BCM) theme envisages the following objectives: (i) To assess, valuate, prioritize, map and monitor biodiversity of the protected and unprotected areas at gene, species and ecosystem levels across the IHR for understanding the status, availability, potential and patterns; (ii) To evaluate response of Himalayan biodiversity under changing climatic conditions across the IHR; (iii) To develop packages of practices for maintenance and optimal use of sensitive biodiversity components and improvement of bio-resource based livelihood options for indigenous communities; (iv) To establish and maintain live repositories (Arboreta, Herbal Gardens, Nurseries, etc.) in different agro climatic zones across the IHR for ensuring the availability of quality planting material; (v) To sensitize diverse stakeholders and building partnerships to develop and demonstrate best practices of management and optimal use of biodiversity components

Understanding Biodiversity Patterns and Processes under Changing Resource Use and Climate Scenario in Himachal Pradesh, North Western Himalaya-Ecological and Social Implications *(2013-2017, In-house)*

The Himalayan region is recognized amongst the 34 global biodiversity hotspots. The Indian Himalayan Region (IHR) with its unique topography, climatic conditions, diverse habitats and a large altitudinal range, supports tropical, sub-tropical, temperate, sub-

alpine, alpine and tundra biomes/ecosystems. These ecosystems provide provisioning, cultural, regulating, and supporting services to the mankind as the most population of the IHR live in the rural areas. But, biodiversity of these ecosystems is depleting fast due to habitat degradation caused by various anthropogenic activities coupled with the changing environmental conditions. The Climate Change has been recognized as one amongst the most confounding factors in shaping the future of mountain ecosystems and local people. Due to the predictions that the higher altitudes and mid altitudes are likely to be more vulnerable compared to lower altitudes, there is an urgent need to understand the intensity and direction of consequent ongoing and potential impacts of changes on the composition, structure and functioning of biodiversity in these regions. Also, the biodiversity components of the temperate, sub-alpine and alpine regions are severely affected by anthropogenic activities. All these factors make the IHR most vulnerable amongst the mountain landscapes of the world. Therefore, it calls for immediate actions towards assessing status, changing patterns and processes of biodiversity components of the temperate, sub-alpine and alpine landscapes in relation to changing resource use and climate.

Objectives

- To generate robust datasets on status, changing patterns and processes of biodiversity components, as well as their conservation and socio-economic values, including nutritional (traditional crops and wild edibles) and therapeutic potential (medicinal plants) of selected landscapes.
- To evaluate and compare ecological integrity, stability and resilience of representative ecosystems and their components in the target landscapes.
- To analyze impacts of climate and resource use changes on the biodiversity components, and assess its socio-economic consequences.
- To establish Himalayan Biodiversity and Climate Change Knowledge Network (HBCC-KN) to build on existing knowledge and enhance information generation through robust globally accepted protocols, and develop management and sustainable use plans with policy briefs.

Achievements

Headquarters, Uttarakhand

- Consultation meeting was conducted for the identification and selection of traditional crops for long term studies. Various attributes of traditional agriculture in the Himalayan region particularly Uttarakhand was discussed and it was agreed that most of the traditional crops and their landraces are dwindling in the region. The traditional farmers are disinterested in continuing with these landraces. However, the group further agreed that there is an upcoming global/national market for these crop products. Based on these attributes species selection was done.
- Discussion was mainly focused on millets, pulses, fruit crops, nuts and floriculture. Prioritization was done on the basis of (i) productivity, (ii) market potential, (iii) altitudinal distribution, and (iv) known nutritional value of the crops. Based on the criteria, Pulses: Arhar, Kala bhatt and Rajma; Millets and pseudomillets (complete group); Nuts: walnut and ground nut; Fruits: Malta and Nimbu; and Floriculture (as a group) was undertaken for detailed study in the Uttarakhand region.
- Rapid survey was conducted to select the sites/habitat for biodiversity conservation. Initial survey was conducted in the Pithoragarh district and two transect (vertical and horizontal) were selected for detailed biodiversity assessment considering the wide altitudinal range, representative ecosystems – sub-tropical to high alpine, varied agriculture & cultural diversity, high levels of disturbance, etc.

Kanawar Wildlife Sanctuary, Himachal Pradesh

- Relevant literature and existing information on Kanawar Wildlife Sanctuary (Fig.11) were collected. Surveys were conducted for the qualitative assessment and economic values of floristic diversity. 258 species of vascular plants i.e., Angiosperms (76 families, 192 genera and 229 species), Gymnosperms (03 families, 6 genera and 06 species) and Pteridophytes (12 families, 17 genera and 23 species) were recorded. Among the angiosperm families, Asteraceae (13 spp.); Rosaceae (11 spp.) and Lamiaceae; (09 spp.) were species rich.
- 95 species (Angiosperms: 86; Gymnosperms: 06; and Pteridophytes: 03) with economic importance were recorded. These species were used as medicine (65 spp.), wild edibles/food (26 spp.), fodder (18 spp.), fuel (15 spp.), timber (05 spp.),

religious purposes (09 spp.), fiber (06 spp.), making agricultural tools (08 spp.) and various other thing (18 spp.) (Fig.12).

- Of the total recorded species, 86 were native to the Himalayan Region and 16 species native to the non-Himalayan region and neighboring countries together. The remaining species were non-natives. 03 species were endemic and 22 species were near endemic.

Fig.11. General View of KWLS.

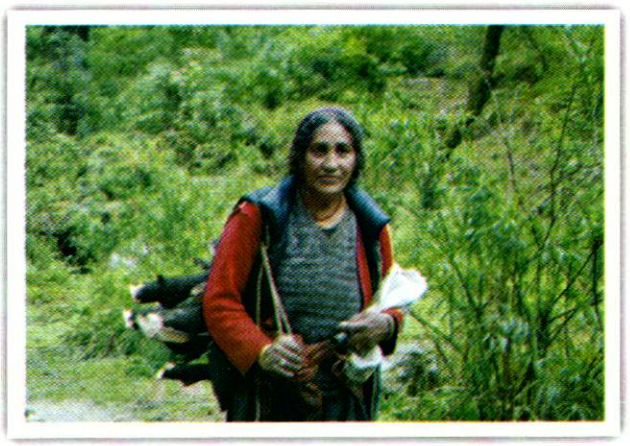


Fig.12. Local woman collecting fuel.

Kanchendzonga Biosphere Reserve, Sikkim

- For field surveys, appropriate methodologies were standardized. Socio-economic/resource survey based questionnaires and formats were designed and tested in the close peripherals of south-west of KBR. Two remote villages were surveyed for the households' socio-economics, biodiversity conservation and bioresource values, and their use practices and pattern; impacts of various factors on biodiversity, etc.
- Amongst ten most prioritized (preferred) fuel wood species, *Alnus nepalensis* and *Schima wallichii* appeared at the top for either village; however, *Castonopsis tribuloides* and *Quercus lamellosa* were other highly preferred species (Fig.13).

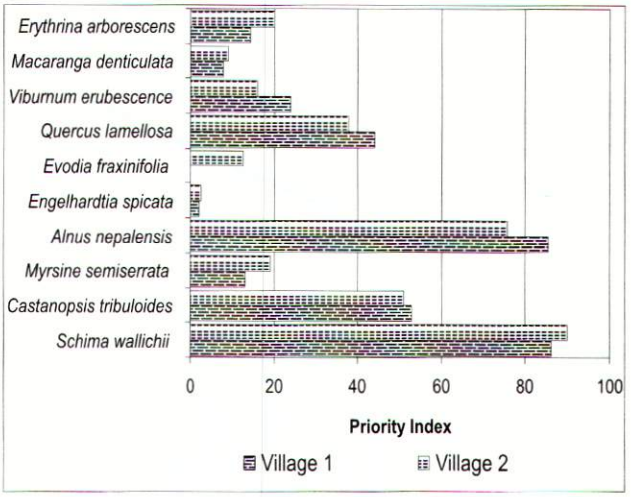


Fig.13. Top 10 most prioritized fuel wood species by villagers in Khangchendzonga Biosphere Reserve (West Sikkim).

West Kameng, Arunachal Pradesh

- The West Kameng district was visited for the selection of sites. It represents tropical semi evergreen, sub tropical broad leaved, sub-tropical pine, temperate broad leaved and sub-alpine broad leaved forests and alpine vegetation.
- The area is inhabited by a number of villages. Interaction with the inhabitants about their dependence on biodiversity was done. The inhabitants are largely dependent on biodiversity for medicine, wild edibles, fuel, fodder, timber, making agricultural tools, fibre, religious purposes, dyes and various other purposes. Over 80% of the population of the area is dependent on agriculture for their sustenance.

Study on the Impact of Sainj Hydro-Electric Project on the Great Himalayan National Park (GHNP) in General and Flora and Fauna of the Local Area in Particular ***(2012-2015,*** *Sainj Hydro-Electric Project, Himachal Pradesh Power Corporation Ltd., Sarabai)*

The State of Himachal Pradesh which forms the parts of Trans and North Western Himalayan Biogeographic Provinces, is very well known for its

typical topography, large altitudinal range, diverse habitats, representative, natural, unique and socio-economically important biodiversity. But, with the increasing human and livestock population, and developmental activities such as construction of roads, initiation of a large number of hydropower projects in biodiversity rich areas, establishment of forest based industries, etc. the pressure on the biodiversity of the State has increased many fold. This has resulted in decreased population of many ecologically and economically important species. A large number of Hydro-Electric Projects have been constructed, are under construction and proposed for construction on the rivers originating from the Himalaya. The Sainj Hydro-Electric Project (100 MW), a run of the river development on river Sainj, a tributary of river Beas in Kullu district is under construction and located at Neuly, in the periphery of Great Himalayan National Park, Sainj Valley. The adjacent areas towards the GHNP of the Sainj Hydro-Electric Project are very rich in flora and fauna. Therefore, study on the impact of Sainj Hydro-Electric Project on the Great Himalayan National Park (GHNP) in particular and flora and fauna of the local area in general has been initiated

Objectives

- To assess the flora and fauna of Sainj Hydro-Power Project area in Sainj Valley.
- To monitor the floristic diversity.
- To assess the economically important biodiversity.
- To assess status and distribution pattern of the native and endemic species.
- To assess the floristic diversity for threat categories.
- To assess the impact of Sainj Hydro-Electric Project on the flora and fauna of the Great Himalayan National Park in particular and Sainj Valley in general.
- To suggest suitable management plan for the conservation of biodiversity.

Achievements

- 21 sites between 31°45'17"N to 31°46'54"N latitudes and 77° 20' 54"E to 77°24'50" E longitudes and altitude 1,515– 2,255 m were surveyed. These sites represented in the North, East, West, South, South West, North East and North West aspects and rocky, bouldery, riverine, dry, shady, moist and shady moist habitats.
- 148 species of vascular plants belonging to 72 families and 128 genera and representing herbs (76 spp.), shrubs (31 spp.), trees (28 spp.) and ferns (13 spp.) were recorded. Dominant families were Asteraceae (15 spp.), Rosaceae (14 spp.), Lamiaceae (11 spp.), and Poaceae (07 spp.). Of the total species, 134 were used as medicinal, 66 fodder, 50 wild edibles/food, 45 fuel, 11religious, 5 fibre, 7 making agricultural tools, 7 timber, 5 dye and 9 for various purposes.
- 16 forest communities were identified. *Pinus roxburghii* community was represented in 5 sites, and *Quercus leucotrichophora* community in *2* sites. The remaining communities represented by 01 site each. Total tree density (660 Ind ha^{-1}) and total basal area (42.4 m^2 ha^{-1}) were recorded maximum in *Pinus wallichiana* community. For *Pinus wallichiana* the Density: was 380 Ind ha^{-1}, on a total basal area of 10.3 m^2 ha^{-1} and IVI 160.15. For *Cornus macrophylla-Pinus wallichiana* mixed community (Fig.14) the total tree density was 610 Ind ha^{-1} and Total Basal Area 26.23 m^2 ha^{-1}. *Cornus macrophylla* had (Density 100 Ind ha^{-1}; total basal area 18.4 m^2 ha^{-1} & IVI 116.02) and *Pinus wallichiana* (Density100 Ind ha^{-1}; total basal area 6.5 m^2 ha^{-1} & IVI 48.74) were the dominant trees. Maximum saplings and seedlings density i.e., 240 Ind ha^{-1} and 880.00 Ind ha^{-1}, respectively were recorded for *Cedrus deodara* in *Cornus macrophylla- Pinus wallichiana* mixed community. However, *Pinus roxbhughii* and *Lyonia ovalifolia* (30 Ind ha^{-1}each) showed relatively poor density.

§ Species richness (56 spp.) was maximum in *Pinus roxbhurghii* community, followed by *Pinus wallichiana* (44 spp.) community and it was lowest in *Aesculus indica* (13 spp.) communities.

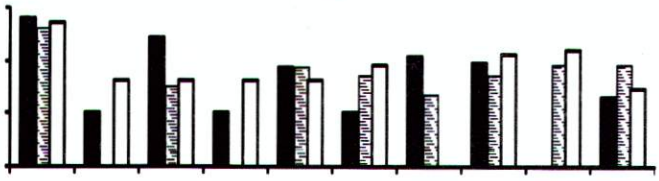


Fig.14. Population structure of *Cornus macrophylla - Pinus wallichiana* mixed community. (Abbreviations used: TD=Total density; CC=*Cornus capitata*; CM=*Cornus macrophylla*, LQ= *Lonicera quinquelocularis*; LO=*Lyonia ovalifolia*; MS=*Morus serrata*; PW=*Pinus wallichiana*; RA=*Rhododendron arboreum*; RJ=*Rhus javanica*; and TC=*Toona ciliate)*

Assessment and Quantification of Forest Ecosystem Services with Special Emphasis on Pollination in the Indian Himalayan Agro-Ecosystems *(2012-2015, Earthwatch India)*

The Himalayan region is one of the 34 Global Biodiversity hotspots. The Indian Himalayan Region (IHR) forms a major part of this hotspot. On account of its unique topography, diverse habitats and large altitudinal range (200-8,000m amsl), IHR supports representative, natural, unique and socio-economically important biodiversity. The region represents tropical, sub-tropical, temperate, sub-alpine, alpine and Tundra ecosystems/biomes. These ecosystems provide provisioning, cultural, regulating and supporting services to mankind. In the rural areas of the IHR, the mainstay of rural communities is cultivation of agricultural and horticultural crops, including vegetables for their sustenance. Farming practices are largely dependent on various ecosystem services (ES) provided by the forests interspersed in the agricultural landscape. However, changing environmental conditions are causing decline in such ecosystem services (ES). For instance, decline in pollinator services has been now identified as an important issue worldwide. It applies equally for the agro-ecosystems of IHR, which calls for a systematic study on pollinators and other forest ecosystem services in the region

Objectives

- To assess biodiversity at selected sites representing the Himalayan agro-ecosystems, including bee flora and other insect pollinators.
- To monitor phenology of selected crops with focus on the possible impact of extreme climate events.
- To assess and quantify selected forest ecosystem services flowing to the agro-ecosystems.
- To harness benefits of pollination services for sustainable livelihoods and biodiversity conservation

Achievements

- The study site i.e., Upper Beas Valley (32° 05' 51"– 32° 06' 43.8" N Latitudes and 077° 08' 08.5" – 77° 09' 56.9" E Longitudes, altitudinal range 1200-2500m) is located in Kullu district of Himachal Pradesh. Four volunteer programmes were organized jointly with Earthwatch Institute India, during June, September & November 2012 and March, 2013.
- 15 sites were surveyed and sampled and 149 species (16 trees, 18 shrubs and 115 herbs including ferns) and 4 communities (*Pinus wallichiana*, *Cedrus deodara*, *Pinus roxburghii*, and *Alnus nitida*) were recorded (Fig.15). These species and communities represented forest (7 sites), riverine (06 sites, each) and shady moist (02 sites) habitats. The total tree density of the identified communities ranged from 5.06-8.88 Ind/100 m^2, total basal area 30.12-47.47 m^2ha^{-1}, total shrub density 6.34-24.6 *Ind/100m*^{2} and total herb density 31.38-66.49 Ind/m^2. Species richness for trees, shrubs and herbs ranged from 1-8, 5-11 and 31-56, respectively. Among habitats, species richness ranged from 46-65.
- Apple, Plum and Pear trees and their branches were marked for monitoring phenological changes. Observations were recorded on leaf fall, leaf bud initiation, flower bud initiation and leaf initiation and pink flower bud initiation in the six orchards of the upper Beas Valley.
- The Participatory Rural Appraisal exercise and questionnaire survey were conducted in six villages. Information on ecosystem services (i.e., medicinal, wild edibles, fodder, fuel and timber plants, plants used for making agricultural tools, horticultural and agricultural crops, vegetables, condiments, fibers, leaf litter collection, religious and oil yielding plants, bamboo brakes, etc.) provided by agro-ecosystem to the inhabitants of villages was generated.

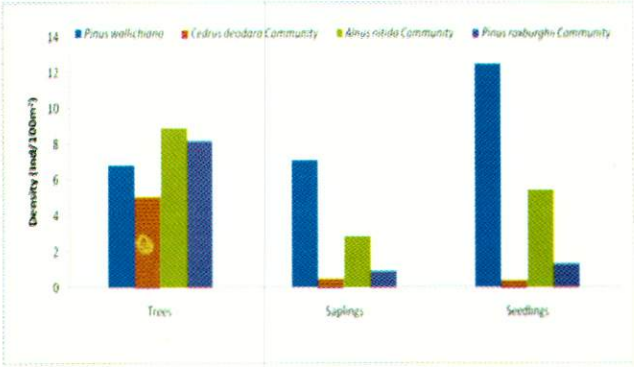


Fig.15. Community wise Total Trees, Saplings and Seedlings density.

All India Coordinated Research Project on Sacred Grove Ecosystem Service Assessment of Ecosystem Services in Sacred Groves of Himachal Pradesh, North Western Himalaya *(2012-2017, Ministry of Environment & Forest, New Delhi)*

The Himalayan region is amongst the identified Global Biodiversity Hotspots. The unique topography, diverse habitats and large altitudinal range (200-8,000m, amsl) of the Indian Himalayan Region (IHR) support tropical, sub-tropical, temperate, sub-alpine, alpine and tundra ecosystems/biomes. The major population of IHR lives in the rural areas and the inhabitants are largely dependent on various services provided by these ecosystems. In view of the rapid depletion of biodiversity, a Protected Area Network has been established across the IHR for the in situ conservation of representative Ecosystems, habitats and species. In addition, the native communities of the region practice an age old tradition of conserving trees and alpine meadows and forests near their settlements as part of their culture and religious belief. These are known as Sacred Groves and provide various ecosystem services to the inhabitants. Assessment of ecosystem services provided by the Sacred Groves has not been done. Therefore, present study has been initiated in the selected Sacred Groves of Himachal Pradesh to assess the ecosystem services flowing from these Sacred Groves

Objectives

- To assess, identify and characterize ecosystem services provided by the Sacred Forests.
- To assess and characterize the biodiversity of selected Sacred Forests for conservation.
- To assess and quantify the prominent ecosystem services/service flows (i.e., nutrients: organic carbon, NPK on the soil and leaf litter, medicinal, wild edibles, fuel and fodder plants) of Sacred Forests.
- To identify and characterize drivers impacting Ecosystem Services of Sacred Forests.
- To valuate the ecosystem services (i.e., carbon sequestration, soil nutrients, biodiversity (medicinal, wild edibles, fuel, fodder & timber, cultural, aesthetic and spiritual) of the Sacred Forests.
- To document and review the traditional and Government management practices and recommend appropriate strategy and action plan for the maintenance of selected ecosystem services in the Sacred Forests.

Achievements

- Total 17 sites were studied between 1956-2212m. Out of 17 sites, in Hidimba Mata Sacred Grove, 4 sites; Kalinag Sacred Grove, 2 sites; Jamadagni Rishi Sacred Grove, 3 sites; Bhirghu Rishi Sacred Grove, 4 sites and Sangchul Rishi Sacred Grove, 4 sites were sampled for biodiversity (Fig.16). These sites were represented by 3 habitats and 5 aspects. The slope varied from 5°- 60°. Total of 133 species of vascular plants belonging to 62 families and 115 genera were recorded. Among the identified species, 25 speci were trees, 22 shrubs and 86 herbs.
- In Hadimba Mata Sacred Grove 73 species representing 66 genera and 29 families were recorded. *Cedrus deodara* community was identified. The total tree density ranged from 280 - 330 Ind ha^{-1} and Total Basal Area, 21.01- 169.89 m^2 ha^{-1}. The soil moisture ranged from 17.27 – 23.6%, total nitrogen 1.4 – 2.24%, and organic carbon 0.75 -1.71%.
- In Kalinag Sacred Grove, 44 species representing 41 genera and 21 families were recorded. *Cedrus deodara* community was identified. The total tree density ranged from 280 – 400 Ind ha^{-1} and Total Basal Area, 27.87- 101.32 m^2 ha^{-1}. The soil moisture ranged from 12.15 – 15.48%, total nitrogen 1.68 – 2.24%, and organ ic carbon 0.55% in each the sites. The provisioning services provided medicine, wild edible, fuel, fodder and religious.

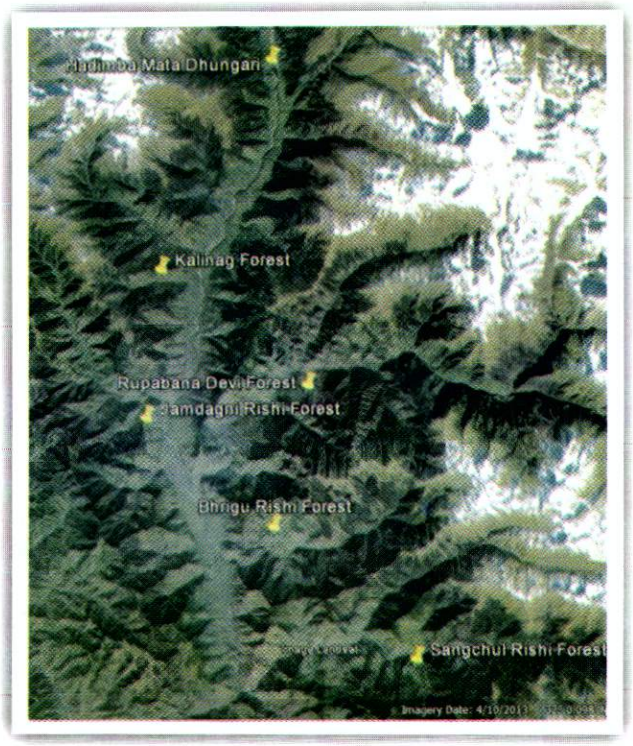


Fig.16. Location of the selected Sacred Groves.

- In Jamdagni Rishi Sacred Grove a items total of 33 species representing 30 genera and 16 families were recorded. *Cedrus deodara* community was identified. The total tree density ranged from 300 – 430 Ind ha^{-1} and Total Basal Area (TBA) 173.28 – 202.72 m^2 ha^{-1}. The soil moisture ranged from 21.93 – 31.29%, the total nitrogen 2.00 – 2.40%, and organic carbon 3.97- 7.33%.

Ecological evaluation, mapping and conservation prioritization of floristic diversity of the Spiti Valley in a Proposed Cold Desert Biosphere Reserve in Trans Himalaya ***(2011-2014,*** *Ministry of Environment & Forest, New Delhi)*

Biosphere Reserves (BRs) have been established throughout the globe to conserve the representative ecosystems. The Cold Desert Biosphere Reserve (CDBR) which covers the parts of Lahaul and Spiti district of Himachal Pradesh is one of the Biosphere Reserves of Indian Himalayan Region. It represents the potential area for the conservation of Trans Himalayan ecosystems. The Pin Valley National Park, Kibber Wildlife Sanctuary and Chander Tal Wilderness Area form the core zones in Spiti valley. The Spiti Valley of Cold Desert Biosphere Reserve is inhabited by a number of tribal villages and supports representative, unique, natural and ecologically and economically important species of Trans- Himalaya. This rich biodiversity is utilised in various forms by tribal communities for their sustenance. The available information on floristic diversity and conservation prioritization of the area is fragmentary and inadequate for developing any management plan. Therefore, the present study has been initiated to generate comprehensive data and develop a suitable management plan for the conservation of biodiversity

Objectives

- To assess the floristic diversity of the Spiti Valley in a proposed Cold Desert Biosphere Reserve.
- To study the status and distribution pattern of the native and endemic species.
- To assess the utilization pattern of floristic diversity and document indigenous knowledge and traditional practices by the tribal communities.
- To assess the floristic diversity for threat categories.
- To prioritize habitats, species and communities for conservation, and economically important species for the socio-economic development of the Tribal Communities.

Achievements

- 46 sites were sampled between 3,109-4,585m in the Spiti valley of CDBR. These sites were represented by 12 habitats and 08 aspects. The slope varied from 2-80. 196 species (5 trees, 22 shrubs & 169 herbs) belonging to 51 families and 141 genera were recorded (Table-3). *Potentilla* (7 spp.), *Astragalus* (6 spp.), *Artemisia* and *Polygoninum* (5 spp., each) and *Pedicularis* (4 spp.) were the species rich genera.
- 184 species were economically important and used as medicine (98 spp.), wild edible/food (46 spp.), fodder (27 spp.), fuel (11 spp.), timber (02 spp.), religious purposes (08 spp.), Agricultural tools (07 spp.), insect repellants (02 spp.) and other species are used for various other purposes.
- 28 plant communities were identified from 47 sites. Of these, 16 communities were represented by shrubs and 12 communities by herbs. Species diversity (H′) for shrubs ranged from 0.00-3.60 and herbs, 0.98-2.65. The highest diversity (3.60) of shrubs was recorded for *Astragalus strobiliferus* community and lowest (0.00) for *Myricaria elegans* community. The highest diversity (2.65) of herbs was recorded for *Potentilla argyrophylla-Draba olgae-Arenaria serpyllifolia-Oxytropis immersa* mixed community and lowest (0.980) for *Poa lahulensis* community.
- Concentration of dominance (Cd) of shrubs ranged from 0.25-01 and herbs, 0.09-0.58. The highest concentration of dominance (01) of shrubs was recorded for *Myricaria elegans* and lowest (0.25) for *Rosa webbiana –Ribes orientale* mixed, communities. The highest concentration of dominance (0.58) of herbs was recorded for *Poa lahulensis* and lowest (0.09) for *Potentilla argyrophylla-Draba olgae-Arenaria serpyllifolia-Oxytropis immersa* mixed, communities.
- Overall, the soil moisture content ranged from 0.45%-47.46%, total nitrogen 0.07-0.49%, organic carbon 0.08-4.84% and organic matter 0.13-8.34%.

Table-3.Taxonomic description of floristic diversity in the Spiti Valley

Taxonomic Group	Families	Genera	Species	Herbs	Shrubs	Trees
Angiosperms	44	134	188	164	20	4
Gymnosperms	2	2	3	-	2	1
Pteridophytes	5	5	5	5	-	-
Total	**51**	**141**	**196**	**169**	**22**	**5**

Conservation and Management of Pollinators for Sustainable Agriculture through an Ecosystem Approach *(2009-2014, GEF, UNEP, FAO)*

Pollination is a keystone process in both human managed and natural terrestrial ecosystems. It is critical for food production and human livelihoods, and directly links wild ecosystems with agricultural production systems. The vast majority of flowering plants only produce seeds if animal pollinators move pollen from the anthers to the stigmas of their flowers. Without this service, many interconnected species and processes functioning within an ecosystem, would collapse. Recognizing the dimensions of a "pollination crisis" and its links to biodiversity and human livelihoods, the Convention on Biological Diversity has made the conservation and sustainable use of pollinators a priority. At the Fifth Conference of Parties (COP V) in 2000, an International Initiative for the Conservation and Sustainable Use of Pollinators (also known as the International Pollinator Initiative - IPI) was established (COP decision V/5, section II)

Objectives

- To improve food security, nutrition, livelihoods through enhanced conservation and sustainable use of pollinators.
- To identify ecological practices in multiple agro-ecosystems for preventing the loss of pollination services.
- To harness benefits of wild diversity.
- To enhance conservation and sustainable use of pollinators.

Achievements

Himachal STEP Site

- Pollination Deficit Protocol experiments were conducted in 20 apple orchards (10 near to natural habitat with or without the treatment of bee hives and 10 far from natural habitat with or without the treatment of bee hives of *Apis mellifera*) to know the effect of bees on apple crop production. Highest population density of indigenous honey bee (*Apis cerana*) was recorded from the open pollinated orchards of near to natural habitat orchards which ranged between 5 - 7 and 4.6 – 6.9 bees/250 apple flowers of production and pollinizer varieties.
- Scan sampling of pollinators on both the commercial and pollinizer apple bloom cultivars of treatment orchards showed the high density of western honey bee *Apis mellifera* which ranged between 4.45 - 12.5 and 3.6 -12.44 bees /250 apple flowers in the orchards with the provisioning of bee hives of *A. mellifera*.
- PAN trap experiment was carried out to know the trend of bee population in different apple orchards. Maximum number of solitary and bumble bees were reported from near to natural habitat apple orchards as compared to distant to nature orchards.
- Total 33 species of apple pollinators were reported from the different orchards of the Himachal STEP site under the Scan, Sweep and PAN trap experiments conducted for the Pollination Deficit Protocol. Out of 33 species, 23 were solitary bees, followed by flies (06 species), Honey & Bumble bees (02 spp. Each), Butterflies (02 spp.) and Carpenter bee (01 sp.) (Fig. 17A & 17B).
- Orchards with the provisioning of bee hives were more productive both in terms of quality and quantity of apple production. Pollination Management Plan for apple crop was prepared.

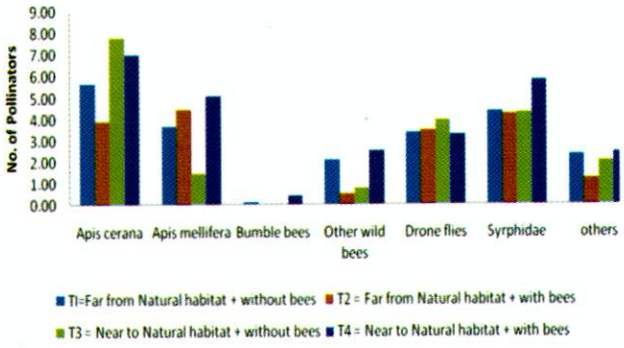


Fig.17A. Diversity of apple pollinators in open pollinated orchards.

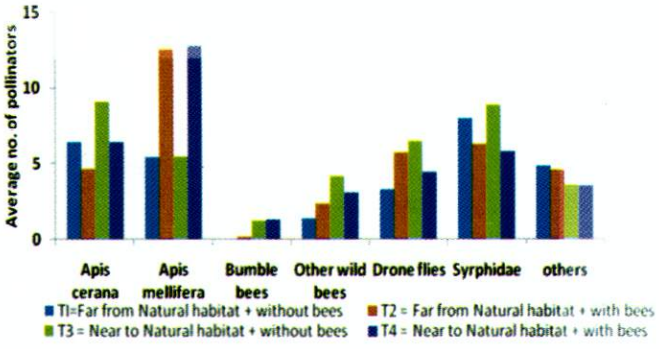


Fig.17B. Diversity of apple pollinators in provisioning of beehive orchards.

Kosi STEP Site

- Towards developing taxonomists in the area of pollination, a six day on - site training on 'Taxonomy of insect Pollinators" was conducted at Nature Interpretation and Learning Center of the Institute. Various modules on sampling, identification and characterization of the pollinators were followed by field collection of pollinators. 23 participants from 7 different institutions participated. Besides, the Institute was involved in organizing several other events for promoting conservation of pollinators. These included, state level seminar on "Past, Present & Future of Bee keeping in Uttarakhand" at Bhimtal, Nainital; training programme on management of traditional wall hives at Gangolihat, etc. Besides, various outreach materials like Pollination Flyer, Global Pollination Project Folder, Manual, Panel, Docket, Diary, etc, were prepared to promote awareness among the masses.
- Density of pollinators on different mustard sites have been evaluated and highest insect density was recorded at site Dhari (39.50) and lowest at Simnola (0.50) with highest average density of *Apis cerana* (6.00). The indigenous honey bee *Apis cerana* emerged as the most efficient pollinator across all the sites, contributing > 80% of the insect visitation (80.53 %) followed by other bees and insects (Fig.18).

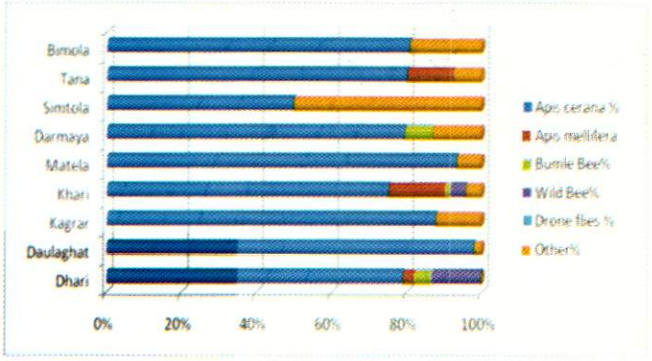


Fig.18. Relative contribution (%) of various pollinator groups across the mustard sites: 2011-12.

Sikkim STEP Site

- The status and trends of pollinators in STEP site were monitored. The density of *A. cerana* varied significantly ($p<0.01$) in 2010 and 2011, whereas for bumble-bee the variations with time frames were significant in year 2010 and 2012. The significant interaction effects (i.e., site and time) for pollinator density was revealing in year 2011 for honey bee and 2010 for bumble-bee (Table-4 & Fig.19).
- A significant positive correlation exists between flower phenology and density of *A. cerana* (r = 0.50; $p<0.01$), *Bombus* sp. (r= 0.37; $p<0.05$) and total numbers of bees (r = 0.46; $p<0.01$). A linear regression model estimated that the increased density of pollinators per 100 flowers resulted in the increase in yield of large cardamom. The model projected on an average 17–41 gm/plant yield increase of large cardamom with increasing number of bumble bee ($p<0.03$). Whereas, with increasing number of total bees a significant ($p<0.01$) increase of 21–41 gm/plant was estimated.
- Interactive & capacity building meeting was organized at Govt. Secondary School, Damthang (South Sikkim) on 06 October, 2012 to enrich the knowledge of students about conservation and management of the pollinators for sustainable agriculture in which 44 students (class 8th and 9th) and 6 teachers participated.

Table-4. Effect of sites, time frame and their interaction on major visitors of Large Cardamom in different years.

Source of variation	DF	MSS					
		A. cerana			*Bombus* sp.		
		2010	2011	2012	2010	2011	2012
Block	3	20.33	13.90	12.06	33.27	18.21	7.61
Site	2	64.70*	29.91*	35.37*	0.27	161.56*	38.88*
Time	3	86.04**	148.21**	13.13	119.09**	30.36	59.30**
Site x Time	6	20.32	21.96*	11.19	27.33**	19.32	9.99
Error	33	11.90	6.58	9.54	6.53	24.25	9.53

*MSS- Mean Sum of Square; * significant (P<0.05); ** significant (P<0.01)*

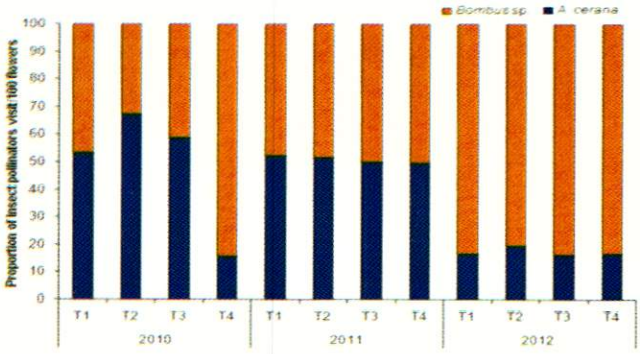


Fig.19. Proportional density of pollinators per 100 flowers of large cardamom and variations across time intervals (i.e. T1: 23–31 May; T2: 2–10 June; T3: 12–20 June; and T4: 22–30 June).

Creating a Genomics Platform for Apple Research in India ***(2010-2012, Department of Biotechnology, New Delhi)***

Apple is the most important temperate fruit crop grown mainly in Jammu and Kashmir, Himachal Pradesh and Uttarakhand. At global level more than 10,000 cultivars are known today of which only 20 are said to be commercial. India ranks tenth in world apple production; its contribution to the world apple production is only 2% as against 38% by China. Keeping in view the ever increasing demand, genetic amelioration of crop is the need of the hour. The present project envisages following two broad areas of research for genetic improvement/genomics efforts on apple: a short term program on evaluation of the elite gene pool, and a long term plan for creating molecular resources and knowledge base as a pre-requisite for undertaking genomic based approaches for genetic improvement. In the short-term plan, identification and evaluation of germplasm available in apple belt, with respect to morphological, biochemical and molecular traits will be undertaken. In the long term plan, suitable mapping population(s) will be developed using properly identified parents which will subsequently be used for development of framework molecular linkage maps. Besides, the mapping population will be evaluated in three apple producing states having different agro-climatic conditions, to generate desirable data for making it possible to take up QTL analysis for the agronomically important traits of apple. Keeping the background in view, the project is undertaken in a network mode and 5 organizations coordinated by the CCMB, Hyderabad are involved in the project

Objectives

- To identify the germplasm in Uttarakhand.
- To explore the extensive phenotyping of the cultivars.
- To generate passport data and its transmission to Jammu.
- To develop clonal propagation of cultivars.
- To maintain the mapping populations.
- To exchange the material with Kashmir University and Dr. Y.S. Parmar University.
- To analyze data and document the information.

Achievements

- Extensive survey was undertaken in the Almora, Chamoli and Uttarkashi districts of Uttarakhand and 55 apple genotypes were identified and morphological characteristics of these genotypes were collected in a standard format. Photo documentation of selected apple genotypes is being carried out at different locations (Fig.20).
- Leaf samples of 55 genotypes from Uttarakhand were sent to Jammu University and CCMB, Hyderabad. The grafted genotypes during previous year were planted at two different sites viz., Government Inter College, Majkhali and Suryakunj-Nature Interpretation Centre, GBPIHED, Almora for maintenance of mapping population.

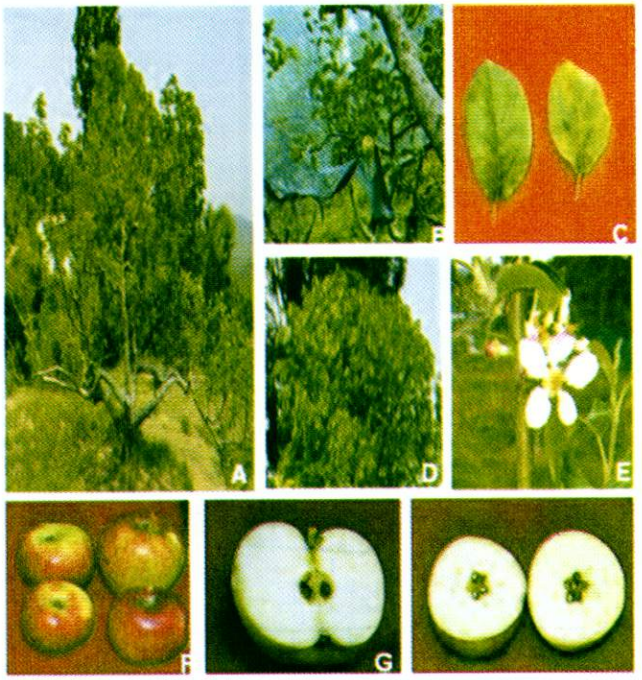


Fig.20 (A-H). Different phenotypic characters of apple genotypes; A. Tree growth habit; B. Bearing habit; C. Leaf blade (incisions of margins-upper half; D. Leaf blade (Altitude in relation to shoots); E. Flower characters (Petal arrangement and heterostyly); F. Fruit shape, ground colour, Intensity of over colour, Russeting, Russet type; G. Depth and width of stalk and eye cavity; and H. Aperture of locule.

Assessment of Ecological and Phytochemical Features and Development of Propagation Packages for Production of Elite Planting Material of Selected Himalayan Berberis Species: A Potential Source for 'Berberine' Alkaloid ***(2011-2013, Uttarakhand State Biotechnology Programme)***

Himalaya is well known for richness and uniqueness of medicinal plants. A great number of these are in use in various systems of medicine like Ayurveda, Siddha and Unani. Of the total 1748 species reported from the region, 700 species are being used by pharmaceutical companies in India in which the Himalayan medicinal plants contribute almost 50%. However, the gap between demand and supply is widening due to decreasing population size of many valuable plant species in nature. Further, indiscriminate collection and destructive harvesting of the medicinal plants from the wild have put many valuable plants in the category of critically endangered, endangered, vulnerable and even extinct. In this context, development of suitable protocols for mass production of planting materials, packages of cultivation, assurance of quality through phytochemical investigations and understanding growth responses in the wild and cultivations are some of the areas which may contribute in achieving the goal of conservation as well as sustainable development of medicinal plants. In addition, ecological assessment in natural habitat for quantifying the available wild stock and their regeneration potential will be helpful in developing management strategies for *in situ* conservation of the target species

Objectives

- To ascertain the diversity in populations (performance of species – abundance, biomass, regeneration and phenology, etc.) of selected *Berberis* species across different habitat ranges.
- To explore variations in edibility and medicinal properties (i.e., diversity of active compounds) of selected species across populations in different habitats.
- To establish relationship of value attributes (i.e., edibility and medicinal value) with plant age, phenophases and part of the plants).
- To develop conventional as well as *in vitro* propagation protocols of target species (*Berberis jaeschkeana* and *Berberis pseudoumbellata*).
- To plant and establish seedlings in the demonstration plots at different Himalayan locations

Achievements

- Towards mass multiplication of *Berberis jaescheana*, *in vitro* seed germination was attempted. Sterilized seeds were inoculated with different strengths of Murashige and Skoog (MS) medium [(i.e. MS half (MSH) and MS full (MSF)] supplemented with various concentrations of gibbereilic acid (GA_3). Results revealed that half strength MS medium supplemented with different GA_3 concentrations provided higher germination percentage as compared to full MS, and the highest germination percentage (67%) was recorded in 2mg/l GA_3 with the lowest (27%) at 1 mg/l GA_3 as well as in control (Fig. 21A & B).
- In order to understand the involvement of enzymes in germination and breaking dormancy in *Berberis jaeschkeana*, peroxidase and catalase activities in the germinated seedlings of the target species were performed. Initial results revealed a significant ($p<0.05$) positive relationship with germination percentage and peroxidase, while catalase activity showed negative relationship in *B. jaeschkeana* (Fig. 22).

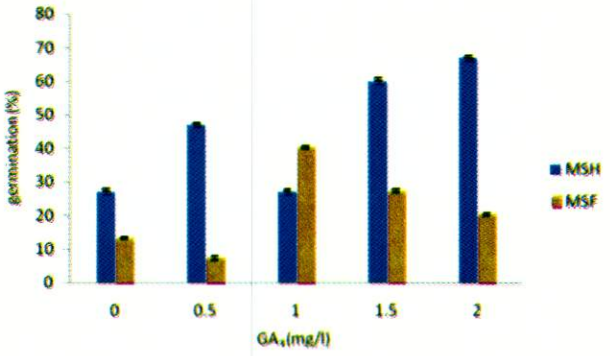


Fig.21. A. Effect of different concentrations of gibbereilic acid (GA3) on germination percentage.

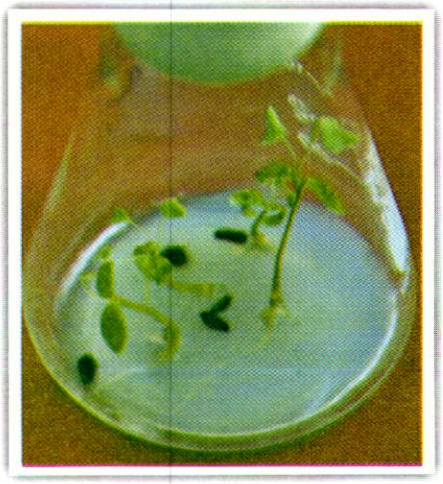


Fig.21. B. *jaeschkeana* under different MS concentrations.

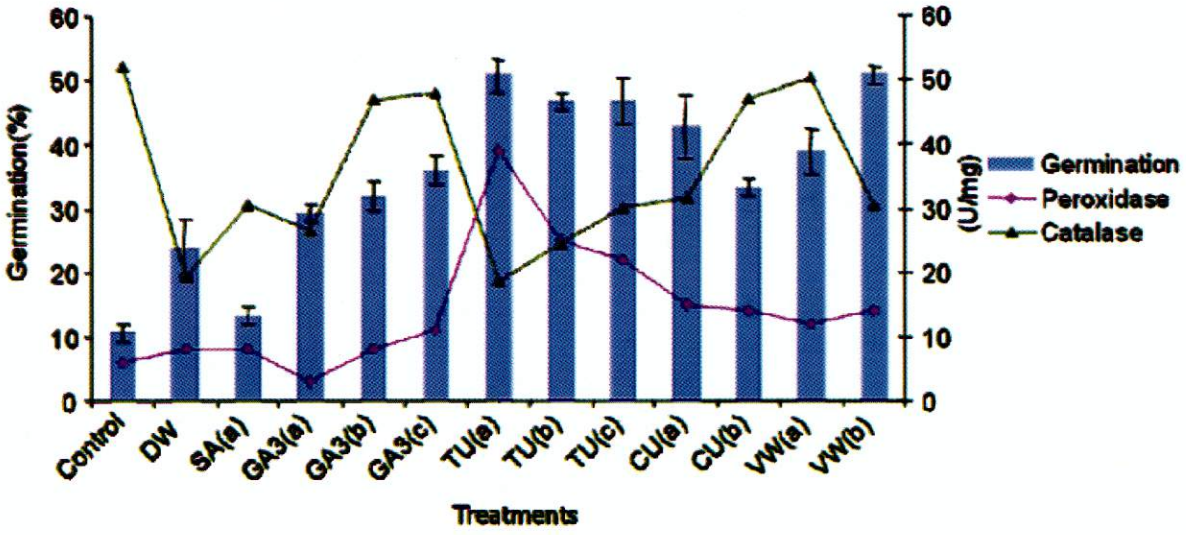


Fig.22. Effect of different treatments on germination percentage and enzymatic activity of *B. jaeschkeana* se

Summary of Completed Project / Activity

Response Assessment and Processing of Knowledge Base to Serve Long-term Management and Use of Biodiversity in the Himalaya *(2007-2012, In-house)*

Nanda Devi Biosphere Reserve, Uttarakhand

The Mountain Protected Areas (MPAs) have emerged as global priority sites and are being used as an 'early warning' system. In this context, this project attempted to define appropriate mid to long term management regimes that maintain the multiple functions of MPAs as a major challenge to the management of integrity and diversity of representative ecosystems. The study has been conducted in Nanda Devi Biosphere Reserve of Western Himalaya; Nargu Wildlife Sanctuary of North Western Himalaya and Kanchendzonga Biosphere Reserve of Central Himalaya and a proposed Tawang Kameng Biosphere Reserve in Eastern Himalaya of the Indian Himalayan Region to explore the comparative biodiversity scenarios in selected sites which can be used for wider generalization in the region. Objectives of the study were to (i) synthesize available information on biodiversity components of the reserve; (ii) investigate recruitment trends and compositional patterns of forest communities along altitudinal gradient, especially focusing three representative physiognomic types; (iii) understand use patterns of local inhabitants dependent on BR resources, especially targeting the key livelihood elements; (iv) suggest policy interventions with a view of general applicability in other BRs of the region; and (v) draw comprehensive biodiversity management plan(s) for alternative scenarios, especially building on evidences generated through the present study.

- The review of available information suggests that NDBR since its inception (1988) has attracted several researchers and nature lovers from all over the world, as a result of which the biodiversity of the reserve has been well explored during the last two decades or so. However, critical review of information also suggests certain gap areas, such as, ongoing and potential changes in the reserve's biodiversity, sensitivity indicator and related management, critical areas and habitat prioritization, use of space technology in assessment and monitoring, ecosystem services, and community compositional integrity, etc.

- The targeted sites in the study [(i.e,. Pindari-Sunderdhunga-Kafni (PSK) and Lata-Tolma-Phagti (LTP)] reflect richness, representativeness, and uniqueness values of the reserve. The PSK site of the reserve supported greater diversity of plant communities and species. However, in the context of representativeness (nativity), and uniqueness (endemism) the LTP site emerged as a more important site (native – 66.5%; endemics – 33.5%).
- Communities in both the sites, broadly exhibited progressive demographic profiles which suggested long-term persistence. However, unusually greater accumulation of seedling in PSK site with indications of successful establishment was indicative of possible changes in composition of communities in this site.
- Comparison of two time data sets, generated by using similar approach, provided evidences of change in community composition. The Community Change Sensitivity (CCS) assessment helped in identification of most sensitive communities in selected sites. For example, *Q. floribunda*, *H. salicifolia* and *A. pindrow* in PSK and *A. pindrow, A. caesium-P. cornuta* Mixed communities in LTP site.
- Changes in representative physiognomic types, based on analysis of RS data sets (1990-2005), indicated decline in total forest cover (2.8%). While Conifer dominated (2.1%) and Mixed broadleaf (3.9%) showed characteristic decline, Evergreen broadleaf exhibited an increase of 10.6% in the reserve.
- The Community Integrity (CI) scores, considering the richness, representativeness, uniqueness and threat index, highlighted the relative stability and resilience of the communities. In this respect, Mixed Silver fir-Rhododendron-Maple and Mixed deciduous communities in PSK, and *P. wallichiana* and *T. wallichiana-A. pindrow* Mixed communities in LTP site exhibited maximum community integrity thereby suggesting more stability and resilience of respective communities.

Nargu Wildlife Sanctuary (NWLS), Himachal Pradesh

- Total 702 species of vascular plants (Angiosperms: 538 spp.; Gymnosperms: 9 spp. & Pteridophytes: 55 spp.) were recorded. Of these, 58 species were trees, 105 shrubs, 475 herbs and 55 Pteridophytes. Asteraceae (67 spp.); Rosaceae (47 spp.); Lamiaceae (33 spp.); Poaceae (30 spp.); Ranunculaceae (26 spp.); Polygonaceae (24 spp.); Apiaceae (21 spp.); Scrophulariaceae (20 spp.); Fabaceae (16 spp.) and ***Caryophyllaceae, Cyperaceae*** Gentianaceae, ***Urticaceae*** (13 spp.) were the species rich families. 26 families were monotypic. 59.2% species were native to the Himalaya. 23.5% of the total and 49.8% of the native species were near endemic and 2.2% of the total and 3.8 % of the natives were endemic to the IHR.

- A total of 15 alpine communities (Shrubs: 05, Herbs: 10) were identified. Total 316 species (Shrubs: 16; Herbs: 300) were recorded from the alpine zone.
- *Juniperus recurva-Salix denticulata* mixed community had maximum density, followed by *Rhododendron anthopogon-Rhododendron campanulatum* mixed and *Rhododendron campanulatum* communities. Among the herb communities, ***Poa alpina-Bromus japonicus-Potentilla atrosanguinea-Agrostis pilosula-Sibbaldia cuneata mixed,*** **followed by** *Poa himalayanum-Agrostis munroana-Alopecurus arundinaceus-Plantago himaliaca* mixed **and** *Sibbaldia cuneata-Potentilla atrosanguinea-Nepeta laevigata-Bromus japonicus* mixed **communities, respectively showed maximum density**.
- The highest diversity of shrubs was reported in *Juniperus recurva-Salix denticulata* mixed community, followed by *Rhododendron campanulatum* and *Juniperus recurva-Cassiope fastigiata* mixed communities.

- In forest communities, pH ranged from 4.63-6.65, moisture content, 5.66-39.05%, nitrogen, 0.07-1.51%, organic matter, 2.45-9.87% and carbon, 1.42-5.73%. In alpine zone, pH ranged from 4.62-7.42, moisture content 8.40-41.06 %, nitrogen 0.11-1.05%, organic carbon 1.57-11.23% and carbon 0.91-6.51 %.
- 102 species (13 Trees; 22 Shrubs; and 67 Herbs including 2 Ferns) were identified as threatened. 09 species were identified as Critically Endangered, 16 species as Endangered; 29 species as Vulnerable and 48 species as Near Threatened. Notable Critically Endangered species are *Acer caesium, Allium wallichii, Corylus jacquemontii, Dactylorhiza hatagirea, Herminium monopyllum, Malaxis muscifera, Podophyllum hexandrum and Taxus baccata subsp. wallichiana*; and Endangered, ***Aconitum heterophyllum,*** *Allium humile, Angelica glauca, Buxus wallichiana, Calanthe plantaginea, Dioscorea deltoidea, Elaeagnus conferta, Habenaria edgeworthii, Juglans regia, Jurinella macrocephala, Morina longifolia, Pleurospermum angelicoides, Rheum moorcroftianum, Skimmia laureola, Swertia chirayita and Ulmus villosa.*
- Total 174 species were economically important. 39 species were used as fuel by the inhabitants of the 23 villages. Based on the probability of Use and Resource Index, *Quercus leucotrichophora*, *Rhododendron arboreum*, *Neolitsea pallens*, *Pinus wallichiana*, *Berberis lycium*, *Sorbaria tomentosa*, *Alnus nitida* and *Desmodium elegans* were the most preferred fuel.
- 23 species were used as fodder by the inhabitants of the 23 villages. Probability of Use (PU) was highest for *Quercus leucotrichophora* (0.70), followed by *Quercus semecarpifolia* (0.25), *Rhus javanica* (0.21) and *Bauhinia variegata* (0.14) and Resource Use Index (RUI) was highest for *Quercus leucotrichophora*, followed by *Quercus semecarpifolia* (448.20), and *Rhus javanica* (202.11).
- Long term monitoring of the prioritized species, habitats and communities for understanding the dynamics of vegetation has been suggested.

Kanchendzonga Biosphere Reserve (KBR), Sikkim

- Three major altitudinal transects in KBR were studied for woody taxa: (i) Transect 1 (1700-4200 m; west Sikkim; 24 sites, 75 species); (ii) Transect 2 (1800-4200m; north Sikkim; 15 sites, 82 species), and (iii) Transect 3 (2100-3800m; west Sikkim; 15 sites, 61 species). Ericaceae emerged as the most dominant family. Species richness significantly decreased with increasing altitude. Total basal cover decreased significantly with increasing altitude. Response assessment over 10 years period compared in the south-west KBR recorded 51 woody species, over 32 species from earlier works; with 17 species common; present study recorded greater species richness, tree density, seedlings and sapling.
- Bioresources (ethnomedicinal, edible fuel, fodder, timber species) were assessed for their use and user's preference. For south-east KBR, 118 ethnomedicinal plants curing 66 ailments and in south-west KBR, 124 plants curing 77 ailments were recorded. Study documented 77 *wild edible* plants.
- Five stakeholders' consultation workshops on '*Biodiversity Conservation and Management in KBR*' and one training in south-east KBR organized (collaboration: FEWMD, Govt of Sikkim). Study/consultations helped management in officially notifying KBR transition zone. Major policy documents, UNESCO MAB nomination doc for KBR and Sikkim Biodiversity Action Plan 2012 developed. One technical brochure (Dzongu landscape, KBR) and technical posters, (i) on *Rhododendron niveum* and (ii) Bioresource use in KBR were developed, published and widely disseminated.

- In all transects, data concludes the forests are in a regenerating stage; however, the forests in transect 1 are comparatively old. Study recommends (in KBR), (i) Eco-tourism destinations/treks

need to be reviewed for their carrying capacity; (ii) Scientific ally based modules need to be developed and implemented for strengthening community based initiatives on biodiversity and wildlife monitoring; (iii) Periodical updates on threatened plants are required for management to monitor their availability in various habitats; (iv) Cultural landscapes/unique sites need to be documented, systematically and planned for an effective management of eco-cultural tourism and livelihood options, etc.

Tawang Kameng Biosphere Reserve, Arunachal Pradesh

- Tawang Kameng Biosphere Reserve was explored. 40 species of mammals belonging to 34 genera 18 families and 8 orders were recorded. Out of these, 10 species have global conservation importance, listed either as endangered or vulnerable in the IUCN Red list of threatened species. The unique species such as *Arunachal macaque*, a species new to science and *Chinese goral*, a new addition to Indian list of mammals are known to inhabit this area.
- A total of 180 quadrats (10x10m) were laid at 6 altitudinal zones. cbh of 3000 trees was recorded. At 1800m, *Quercus* community with the dominance of *Quercus sp.* (IVI: 94.76) was recorded. Similarly, Pinus community with dominance of *Pinus wallichiana* (IVI: 121.44) at 2000m, Rhododendron community with dominance of *Rhodendron sp.* (IVI: 64.96) at 2200m, Lyonia community with dominance of *Lyonia ovalifolia* (IVI: 75.69) at 2400m, *Quercus* community with dominance of *Quercus sp.* (IVI: 46.4) at 2600m and *Illicium* community with dominance of *Illicium griffithii* (IVI: 76.75) at 2800m were recorded. The highest density was recorded at 2200m (229 ind./ ha) while the lowest at 1800m (81 ind./ ha).
- The density of trees at 2000m was 146.67 ind/ ha; 2400m (120.74 ind./ ha); 2600(110.37 ind./ ha) and 2800m (133.33 ind. / Ha). Total basal area (TBA) of tree species along the altitudinal gradients are: 14.45 ^{m2}/ ha (the highest) at 1800m; 6.71 ^{m2}/ ha at 2000m; 4.26 ^{m2}/ ha (the lowest) at 2200m; 8.71 ^{m2}/ ha at 2400m; 9.21 ^{m2}/ ha at 2600m and 9.95 m^2/ha at 2800m.
- The total numbers of species and individuals were 110 and 2221 respectively, recorded from sampled area of Yewang forest. The species richness at 1800m was 29; 2000m (11); 2200m (16); 2400 (8); 2600m (25) and 2800m (21). The highest number of individuals was 620 at 2200m and the lowest was 298 at 2600m.
- 52 medicinal plants belonging to 51 genera and 39 families were recorded. These were being used by the Monpas for treating various ailments. Most of these species are harvested from the wild with an exception to a few species such as *Pinus roxburghii, Zanthoxylum alatum, etc., which are found in human managed ecosystem.*

Summary of Completed Project / Activity

Conservation and Sustainable Utilization of Medicinal Plants in Himachal Pradesh, North Western Himalaya *(2007-2012, In-house)*

The Himalayan Region is one of the richest habitats for medicinal plants. In the region, most medicinal plants are being extracted for drugs, pharmaceutical industries and oils. Majority of these are also used in Ayurvedic, Unani, Tibetan and other traditional systems of medicine. With the increasing world demand and renewed global interest in traditional ethnopharmacy coupled with the increasing preference for natural substances in the health care system, the natural stock of medicinal plants of Indian Himalayan Region (IHR) is under tremendous pressure. The State, Himachal is being seen as a herbal state and medicinal plants as a major source of income generation. The Kullu and Lahaul & Spiti districts of the State are rich in medicinal plants. There is plenty of scope for the cultivation and conservation of medicinal plants. As such an integrated study on the conservation and sustainable utilization of the medicinal plants has not been carried out so far. Therefore, the study was conducted in Upper Banjar valley (1500-3600), Mohal Khad Watershed (1,100-3,000m); Parbati Watershed (1,000- 6,500m), and Upper Beas Valley (2,000-5,000m) in Kullu district and Chandra Valley (3,100-5,000) in Lahaul & Spiti district to: (i) assess, monitor and map the medicinal plant diversity; (ii) evaluate medicinal plant diversity; (iii) assess the medicinal plant diversity for threat categories; (iv) prioritize potential medicinal plants for conservation and socio-economic development of the inhabitants; (v) develop conventional propagation protocols and agrotechniques for the potential medicinal plants; (vi) develop strategies and promote ex-situ and in-situ conservation of medicinal plants and impart training to different stakeholders on conservation and sustainable utilization of medicinal plants. The salient achievements are as follows:

- Total 87 sites from Chandra valley, Upper Beas Valley, Upper Banjar Valley, Parbati Watershed and Mohal Khad Watershed were sampled. 476 species of medicinal plants belonging to 307 genera and 101 families were recorded. In Chandra Valley 261 species, 157 genera and 51 families; in Upper Beas Valley, 367 species, 238 genera and 88 families; in Mohal Khad Watershed, 278 species, 212 genera and 92 families; in Parbati Watershed, 402 species, 266 genera and 98 families, and in Upper Banjar Valley, 357 species, 237 genera and 96 families of medicinal plants were recorded. The diversity of medicinal plants along an altitudinal gradient and across the habitats and aspects varied considerably.
- In Parbati Watershed 244 species were native, 44 near endemic & 04 endemic; in Chandra Valley 161 species native, 19 near endemic & 02 endemic; in Upper Beas Valley 239 species native, 43 near endemic & 03 endemic; in Mohal Khad watershed 160 species native, 29 near endemic & 03 endemic and in Upper Banjar Valley 226 species native, 43 near endemic & 03 species endemic to the Himalayan region and IHR, respectively.
- From Parbati Watershed, 13 MPs were categorized as Critically Endangered, 9 Endangered, 27 Vulnerable & 26 Near Threatened; Chandra Valley, 15 MPs as Critically Endangered, 11 Endangered, 25 Vulnerable & 17 Near Threatened; Upper Beas Valley, 7 MPs as Critically Endangered, 10 Endangered, 12 Vulnerable & 17 Near Threatened; and Banjar Valley, 13 MPs as Critically Endangered, 12 Endangered, 20 Vulnerable & 14 Near Threatened.
- Population assessment and mapping of the threatened plants namely *Aconitum heterophyllum, Picrorhiza kurrooa, Dactylorhiza hatagirea, Angelica glauca, Podophyllum hexandrum, Rheum australe, Taxus baccata* subsp. *wallichiana, Withania somnifolia, Skimmia laureola, Paris polyphylla,* etc. was done. All the species showed relatively low density due to continuous overexploitation of these species.

- Cultivation of *Withania somnifera* in Tawarafae, Pandoh, Balikchowki, Thachi, Pandoh, Jhiri, Smaila and Sundernagar and *Aconitum heterophyllum* in Jana village, Kullu Valley and Lahaul valley was promoted. Over 4,00,000 seedlings of *Aconitum heterophyllum* were raised by 20 farmers in the fields at Jana village and 60,000 seedlings at Khansar village by a farmer. One farmer from Jana village developed > 2,50,000 seedlings of *Aconitum heterophyllum* and generated Rs. 3,00,000/- from the seeds and seedlings in two years under the guidance of the Institute.
- Seeds of different medicinal plants were collected and sown in the nurseries at Mohal and Kasol and herbal gardens at Mohal and Doharanala and, seed germination monitored. Over 50,000 seedlings/plantlets of different medicinal plants at Doharanala, Kasol and Mohal were developed, planted and also distributed to different farmers and other stakeholders of the state.
- Agrotechniques developed for the 26 commercially viable species were disseminated to the stakeholders of Himachal Pradesh for the promoting cultivation of medicinal plants. However, in particular the farmers were trained in agrotechniques of *Aconitum heterophyllum, Picrorhiza kurrooa, Angelica glauca, Podophyllum hexandrum* and *Withania somnifera* for large scale cultivation.
- Training Programmes (02) on *"Medicinal plants cultivation and conservation in Himachal Pradesh"* was organized and > 155 participants representing Line Departments, NGOs, NABARD, Fruit Grower's Association, and Gram Panchayats were trained for medicinal plants cultivation. Three Consultation Meetings on *"Conservation and mass scale cultivation of medicinal plants"* with the farmers of Jibhi, Khangsar and Ropa villages of Kullu, Lahaul-Spiti and Mandi districts of Himachal Pradesh, respectively focusing on mass cultivation of *Aconitum heterophyllum, Withania somnifera, Inula racemosa, Picrorhiza kurrooa, Saussurea costus and Angelica glauca* were organized.
- Over 25 Exposures Visits of the Herbal Gardens and Medicinal Plants Nurseries for over 6,000 stakeholders representing different Departments and Organizations were organized. The stakeholders were trained on various aspects of medicinal plants.

Summary of Completed Project / Activity

Up-scaling Applicability of *Ex-situ* Mechanisms for Conservation and Utilization of High Value Plant Species – Focusing on Promotion of Conservation Education & Capacity Buildings *(2007-2012, In-house)*

Conservation and optimal use of high value species has emerged as one of the priority agenda of research and development realizing the fact that it can serve the basic needs of human beings together with maintaining the biodiversity. Indian Himalayan Region occupies a significant position in the world as far as biodiversity is concerned. The propagation protocols need to be further put to test their efficacy and up scale the applicability in the field conditions through promotion of conservation education and capacity building in the IHR. In the Himalayan context, this activity assumes greater significance in view of the rapid loss of biodiversity. Capacity building of the stakeholders on conservation education through field demonstrations was executed. The work therefore integrates Conservation Education and promotion of ex-situ mechanisms of conservation and use to up-scale the applicability for effective utilization of high value species. Therefore, the project was initiated to: apply the ex-situ conservation techniques for developing appropriate technologies of mass multiplication and storage of germplasm for conservation and effective utilization; demonstrate and upscale the applicability of existing protocols in selected sites and meet the demand of planting material by different stakeholders; ensure the quality planting material through phytochemical and genetic investigation of target species; understand the growth responses of the target species in wild as well as cultivated land; develop a centre for on-site training and extension programmes for various stakeholder groups and also as a place for nature interpretation; inculcate among students excitement of understanding and working on different aspects of biodiversity conservation and encourage them to pursue higher studies in biodiversity conservation. The major outcomes of the study are as follows:

Headquarters, Uttarakhand

- Towards promoting the potential of wild edibles, nutritional and antioxidant properties have been studied. Results revealed relationship among Altitude, Antioxidant Assays, Total Phenolics, Flavonoids and Phenolic compounds. For example, significant negative correlation of catechin ($r=-0.778$; $P<0.05$) with altitude was found in *Myrica esculenta* fruits; total phenolic and flavonoid contents has significant ($p<0.05$) positive impact on antioxidant activity. Linear regression analysis showed that phenolic contents contribute 46.3 to 47.6% of radical scavenging property ($r^2 = 0.463$ for DPPH and $r^2 = 0.476$ for ABTS) and 56.6% of reducing property ($r^2=0.566$). Similarly, flavonoids contribute 55.4% to 70.9% radical scavenging property ($r^2 = 0.554$ for ABTS and $r^2 = 0.709$ for DPPH) and 47.8% of reducing property ($r^2 = 0.478$).
- Phytochemical investigation on high value medicinal plants showed that altitude, habitat, season and plant parts are the major factors influencing the active content. For example, berberine content in different *Berberis* species showed increasing trends with decreasing altitude. Similarly, summer season showed significantly ($P<0.01$) higher berberine content as compared to the rainy and winter season. Root parts in *Valeriana jatamansi* revealed high Valerinic acid as compared to aerial parts.
- Towards developing conservation strategies through evaluating genetic diversity in different Himalayan medicinal plants using ISSR markers revealed variation among populations. For example, of the 101 ISSR loci tested, 71.29% were polymorphic in Valeriana jatamansi. The genetic diversity was high at the population level, but low within individual study populations. Analysis of molecular variance (AMOVA) indicated that 0.4% of the genetic diversity among the

study populations was attributed to geographical location while 99.6% was attributed to differences in their habitats.

- In order to disseminate the technology to various stakeholders in ToT mode and to promote outreach through Conservation Education, orientation courses and training workshops were conducted every year at different schools of Uttarakhand. During the project period, a total of 254 teachers and 944 students belonging to 228 schools of Uttarakhand were made aware of the different aspects of biodiversity. Besides, the existing ex situ conservation site was upgraded in Nature Interpretation and Learning Center where facility for the staying of participants and organizing of meetings was developed.

Himachal Unit, Himachal Pradesh

- Arboretum and Herbal Gardens were strengthened and maintained. In the Arboretum over 183 seedlings/plantlets of 20 species of ecological, economical and ornamental importance were planted. Maximum survival was shown by *Adhatoda vasica, Pistacia integerrima* and *Pittosporum eriocarpum* (100%), followed by *Cornus capitata* (95%), *Pinus gerardiana* (94%), *Pyrus pashia* (89%), *Artemisia vestita* (80%), *Roylea cinerea* (75%), *Alangium salvifolium* (73%), *Buxus wallichiana* (70%), *Ginkgo biloba* (60%), *Rabdosia rugosa* (58%), *Prinsepia utilis* (50%), *Zanthoxylum armatum* (45%) and *Asparagus filicinus* (20%).
- Seed germination protocols for *Pittosporum eriocarpum, Carpinus viminea, Pinus gerardiana, Buxus wallichiana, Cornus macrophylla,* etc. were developed. I *Corylus jacquemontii under* polyhouse condition treatments of GA_3 showed maximum germination (GA_3 100µM, 100%; GA_3 150µM, 95.24% and GA_3 50µM, 90.48%), followed by KNO_3 100mM, Thiourea 150µM (80.95%, each). In *Buxus wallichiana under* polyhouse condition maximum germination was shown by the treatments of GA_3 100µM and IAA 100µM, 82.22%, each, followed by Thiourea 150µM and $NaHClO_3$ 15 mins 77.78%, each.
- Vegetative propagation protocols for *Cinnamomum tamala, Platanus orientalis* and *Ulmus wallichiana were* developed. Different hormonal treatments i.e., IAA, IBA, NAA and Bavistin were given. In *Cinnamomum tamala* the treatments with NAA 50µM exhibited maximum rooting (27%), followed by NAA 100µM and IBA 50µM (23%, each)
- Seedlings of *Pittosporum eriocarpum, Quercus leucotrichophora, Quercus glauca, Melia azaderach, Grevillea robusta, Salix babylonica, Ulmus wallichiana, Platanus orientalis, etc., medicinal plants* and ornamental species were planted and established at 10 Government Senior Secondary Schools of Kullu, Mandi and Bilaspur districts of Himachal Pradesh.
- Five One Day Training Programmes on "Weather Monitoring, Climate Change and Biodiversity Conservation and Management" was organized at Govt. Senior Senior Secondary Schools of Kullu, Mandi and Bilaspur districts and GBPIHED, Himachal Unit, Mohal-Kullu, Himachal Pradesh for over 800 teachers, students, farmers and Mahila Mandals. The pre and post feedbacks of participants showed significant improvement in their knowledge base.
- Over 700 participants representing students, teachers of the Schools (200) and Universities (250), farmers (120), Forest officials (50), NGOs of Himachal Pradesh, professors and students of Sholapur University, Maharashtra (50) and farmers of the Nanda Devi Biosphere Reserve (50) attended a traing and were trained in propagation, cultivation and plantation techniques at Mohal-Kullu.

Sikkim Unit, Sikkim

- Gene Bank demo maintained/modified; use of bamboos, innovatively, to check the soil/manure loss due to rains was standardized. Arboretum was strengthened. Over 179 accessions

(propagules) were made. On stakeholders' requests, >6000 saplings of about 12 MPTs were distributed to villagers. Field transplantation and survival/growth monitoring for over a dozen MPTs. Was done Tree phenology was monitored for >2 dozen species in the arboretum.

- Propagation, mass-multiplication, domestication and field survival/growth was assessed for many multipurpose trees (*Juglans regia, Machilus edulis, Michelia excelsa, Pandanus nepalensis, Spondias axillaries, etc*) and herbs (*Hedychium spicatum, Heracleum wallichii, Rubia cordifolia*, etc).
- In *H. wallichii*, 12 substrates were used for assessing seedling emergence and growth; *Sand +FYM+ Humus (1:1:1) appeared as the most appropriate medium (94% emergence).* Significant variability in seed germination (33 to 71%: lower umbel; 31 to 87%: middle umbel and 51 to 87%: upper umbel) was recorded. In *S. chirayita*, 6 populations were tested for seed germination after 30 months of storage; 3 populations exhibiting about 25% (>100% initially), offered fair chances of storing seeds for longer periods; species were standardized *for ex-situ* cultivation and an open bed is recommended considering profit, productivity and economy.
- In *Michelia excels*, growth seedlings' of significantly (between $p<0.05$ and $p<0.001$) differed with age (1 to 4 year). Stem height very significantly correlated with collar diameter, root diameter and root length ($p>0.001$; $r=0.905$, 0.911 and 0.687, respectively). Stem basal diameter appeared as an important trait to assess seedling quality.
- In *Pandanus nepalensis*, 13 chemical treatments of NaHClO3 (60min, followed by 30min) pre-soaking significantly stimulated maximum seedling emergence. For *Spondias axillaris*, propagation technology was developed using 10 chemical treatments. Seedling emergence greatly improved on treating seeds with H_2O_2-6% (32%; $P<0.05$), followed by GA_3 (250 µM; 25%; $P<0.05$) and $NaHClO_3$ (60 min; 25%; $P<0.05$), over control (17%).
- In *Juglans regia*, study did not fully advocate that the seed size may be effective for seedling growth; direct sowing in 3 nursery and 3 natural habitats was assessed for seedling emergence, which was significantly ($P<0.05$) highest (58%) in net shade followed by poly house (55%).
- Besides, over six training workshops for students and teachers and six capacity building workshops, *Biodiversity Conservation and Livelihood Options*, for different stakeholders were organized. MoA was signed with NABARD and four long trainings were organized targeting Farmers' Clubs of Sikkim. Two technical Dissemination materials (Poster), (i) one on *Bergenia ciliata* (Pakhan Bhed) and (ii) on *Pandanus nepalensis* (Screw pine or Tarika) were published and widely disseminated.

Summary of Completed Project / Activity

Changes in Vegetation Diversity and Plant Response in Nanda Devi Biosphere Reserve over the Last Two Decades *(2011-12, CSIR, New Delhi)*

Among global mountain systems, the Himalaya is known for its representativeness, richness and unique biodiversity elements. The diversity of representative ecosystem elements and their sensitivity to human and/or climate-induced perturbations, and more importantly, the socio-economic marginality and lack of livelihood opportunities in the region make it an important candidate for immediate action with respect to maintenance of biological diversity and sustainable flow of benefits to the society. The action, thus desired, for maintenance of biodiversity and strong research based information backup. In this context, the Mountain Biosphere Reserves (MBRs) have been identified among the most suitable areas for long-term Research & Development activities across the world. The globally selected MBRs for case studies include the Nanda Devi Biosphere Reserve (NDBR) in the Indian Himalayan Region (IHR) as a potential site from Asia-Pacific Region. Considering this recognition of NDBR, the present study identified this BR as the extensive study site with a focus towards; (i) assessment of diversity in vegetation and other land use patterns in NDBR using standard phytosociological approaches and application of RS/GIS; (ii) change detection (temporal/spatial) of vegetation at community and species level (dominant/co-dominant); (iii) identification of sensitive/vulnerable areas and communities considering patterns of natural recruitment; and (iv) development of future scenarios and prediction maps to propose long tern alternative management plans for NDBR. The outcomes of the study are as follows:

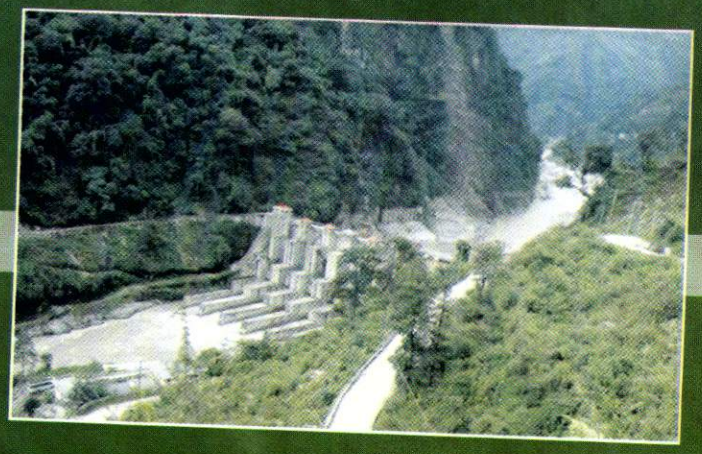
- The buffer zone of NDBR was explored for the compositional patterns across altitudinal range (2000-3900 m asl) covering temperate to sub-alpine forest communities. A total of 19 communities and 451 species belonging to 94 families were recorded. Of these, greater proportion (70.51%; 318 spp.) was of herbs, followed by 17.71% (80 spp.) of shrubs and 11.8% (53 spp.) of trees.
- The compositional features revealed that the mean tree density (260 - 1211 ind ha^{-1}) was comparable with the reported values (320-1670 ind ha^{-1}) in low to high altitude forests of west Himalaya. The range of sapling density (40-951 ind ha^{-1}) in study sites approached the lower range of values (40-6667 ind ha^{-1}) reported in the region. However, the seedling density range (470-8170 ind ha^{-1}) in the present study was considerably higher than the earlier reports for high altitude forests. The shrub density (1226-25575 ind ha^{-1}) was within the range reported for the region (871-29114 ind ha^{-1}) and herb density (3980-93600 ind 100 m^{-2}) was comparable with earlier reported range (4980-84480 ind ha^{-1}).
- The soil parameters showed variations across sites and communities. The soil pH varied from 6.57 (*Hippophae salicifolia*) to 7.04 (Mixed Silver fir-Rhododendron-Maple). Total soil organic carbon ranged from 3.38 (*Alnus nepalensis*) to 4.69 % (*Betula utilis*). Soil organic matter, however, varied between 5.83 to 8.08 % and followed the same trend as for organic carbon. The total nitrogen was minimum in *H. salicifolia* community (0.40 %) and maximum in *B. utilis* community (0.91 %). The C/N ratio for communities ranged from 5.15 to 8.68 %., with a highest value for *H. salicifolia* followed by *Q. floribunda* and Mixed Oak deciduous communities.
- The temporal changes in vegetation composition between two time observations revealed; (i) significant increase in species richness in seedling (paired mean 8.91 to 11.27; $p<0.01$) and sapling layers (paired mean 8.91 to 11.45; $p<0.05$) over the last two decades; (ii) at community level, maximum increase in species richness in seedling layer was recorded in *Quercus floribunda* and Mixed-deciduous communities (8 species in each; $p<0.05$); in sapling layer, *Q. semecarpifolia* community (6 species; $p<0.05$) followed by *Q. floribunda* community (5 species; ($p<0.05$); (iii) no significant changes in diversity patterns were revealing at any tree strata over the last two decades. In general, increase in species diversity of seedling (paired mean 2.07 to 2.10), and sapling (paired mean 2.02 to 2.25) was recorded. In case of tree layer the diversity has slightly declined (paired mean 2.60 to 2.55). At community level, Mixed Silver fir-Oak showed significant increase of diversity in sapling layer ($p<0.05$).
- The results based on Landsat-TM (2005) data, showed that over 65% area of NDBR is snowbound followed by forest vegetation (11.1%), alpine meadows (10.9%), alpine scrubs (6.4%) and agriculture land (crop land) 0.1%. While considering the overall vegetation cover in the reserve, a total decline of 51.3 Km^2 (2.8 %) was registered between 1990 and 2005. Most of the vegetation cover classes revealed negative change over 15 years time interval, with a maximum decrease of 39.6 Km^2 (5.6 %) in case of alpine meadows followed by alpine scrubs (15.8 Km^2; 3.9 %). Among delineated three forest physiognomic types in the reserve, Conifer dominated (8.1 Km^2; 2.1 %) and Mixed broadleaf forests (4.8 Km^2; 3.9 %) showed decline. However, a noticeable increase was revealing for Evergreen broadleaf forests (17.4 Km^2; 10.6 %).

Summary of Completed Project / Activity

Genetic and Phytochemical Diversity in *Hedychium spicatum* and *Roscoea procera* in West Himalaya *(2011-2012, CSIR, New Delhi)*

Himalaya is well known for richness and uniqueness of medicinal plants. Evidences have suggested a growing demand for these plants and consequently a pressure on their wild populations. However, poor scientific objectivity in available information of medicinal plants in the region is often stated as one of the major impediments in defining conservation priorities and ensuring sustainable utilization of the group. Keeping this in view, two species of family Zingiberaceae, *Hedychium spicatum* and *Roscoea procera* were selected for detailed investigation from west Himalaya with a focus to: (i) investigate the phytochemical variation and antioxidant activity among plants from different populations in Uttarakhand; (ii) examine the seasonal changes of different phytochemical constituents; and (iii) assessment of genetic diversity using DNA based molecular markers. The salient achievements of the project a given below:

- Among the selected populations (sixteen populations, each), total phenolic content was found maximum (4.75 mg GAE/g dw) in Chaubatiya in case of *H. spicatum* and 3.58 mg GAE/g dw in Mussoorie-I for *R. procera*. The total flavonoid content in Gaggar was (7.57 mg QE/g dw) in *H. spicatum* and 5.52 mg (Suwakholi) in *R. procera*.
- Populations growing in open grassy land showed comparatively higher total phenolic content (4.06 mg/g), gallic acid (28.23 mg/100 g) and ρ-coumaric acid (1.11 mg/100 g in *H. spicatum* populations. Likewise, in case of *R. procera* oak-mixed forest was found best for total phenolic content (3.04 mg/g) and gallic acid (86.01 mg/100 g); open grassy land for total flavonoid content (4.95 mg/g) and antioxidant.
- Total phenolics, gallic acid and ρ-coumeric acid were found optimum in the month of October (fruiting stage); November month for total antioxidant activity; and December for total flavonoid content in *H. spicatum*. In *R. procera*, total phenolic content, gallic acid and antioxidant activity were found maximum in the month of November; total flavonoids and catechin in the month of October. Physiological maturity of both the target species varied between 4 months (*R. procera*) to 7 months (*H. spicatum*).
- Genetic diversity analysis using inter-simple sequence repeat markers (ISSR) revealed that Suakholi, Gaggar, Ramgarh and Murnaula in case of *H. spicatum* and Surkanda, Pandukholi and Suakholi populations of *R. procera harbour maximum diversity thereby deserving higher priority for in situ conservation*. Genetic differentiation in both the species indicated that majority of the variation was distributed within the populations. In case of *H. spicatum* 89% and *R. procera* 94% variation was observed through the Analysis of Molecular Variance (AMOVA).



Theme

Environmental Assessment and Management (EAM)

The growing populations and their continuously increasing demands together have led over-exploitation of natural resources. As a result, these resources are now scarce and degrading. Low availability but high demands of the resources have posed high anthropogenic pressure beyond their carrying capacity. Consequently, a variety of environmental disorders and pollutions have resulted. The day-to-day upcoming developmental activities need a fresh re-look in an integrated manner with a view to sustainable development. The theme– Environmental Assessment and Management (EAM) therefore addresses, monitors, assesses and analyzes physical, biological and cultural components of environment, concerned with the developmental activities/ interventions/ projects/ policies/ plans in the Indian Himalayan Region (IHR). The theme aims to assess and analyze impacts, set priorities, identify gaps, develop early mitigating approach and to find new technology to achieve a goal of sustainable development. Forests, ecosystem services and conservation have always been among the core issues in the mountain agenda. IHR is likely to be adversely affected due to land use/land cover change for practicing a variety of economic activities for livelihood options and upcoming threats of climate change, its adaptation, rescilience and mitigation. The shrinking of forest resources, its functioning and ecosystem services (ES) are of utmost importance to address. The conversion of forest land for developmental activities like hydropower projects, infrastructural development, alternative land uses, etc. and loss in ES need to be assessed for compensation / rehabilitation packages based on net present value of forests. Mitigating and minimizing adverse impacts due to developmental activities and maximizing their positive impacts would improve ecosystem services and would help stakeholders in becoming self reliant. The environmental issues like strategic environmental assessment of hydropower projects, and climate change and ES have been the primary focus to improve better livelihood options. The adverse impacts due to developmental activities and sprawling urban land uses such as aerosols (particulate, gaseous, liquid) and their impact on temperature rise have been covered under the R&D activities of the theme. The EAM theme therefore envisages planning and management options for the sustainable ecological and economic development of the IHR. The objectives of the theme are: (i) Assessment and monitoring of physical, biological and socio-economic environmental attributes related to various developmental interventions/policies/plans in the Indian Himalayan Region (IHR), and (ii) Development/formulation/ suggestion of appropriate management plans ensuring ecological and economic sustainability

Strategic Environmental Assessment (SEA) of Hydropower Projects in the Himalayan Region *(2012-2017, In-house)*

Hydropower projects, in general, have been in controversy among the people, environmentalists and social activists due to environmental as well as economic concerns. This happens mainly due to lack of attention paid towards this side by project proponents and/or absence of some concrete policy. Lot of

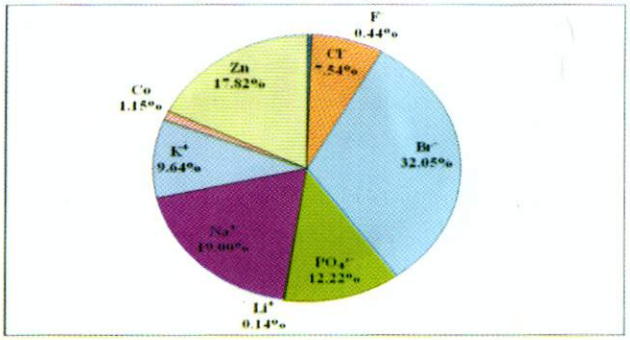


Fig.23. Ionic components of water samples in the adjacent areas of the Satluj basin.

Climate Change Impacts on Ecosystem Services in the Indian Himalayan Region *(2012-2017, In-house)*

Climate change (CC) is a major challenge facing our planet, Earth, today. Forest types and vegetation patterns (distribution, timing of life cycle phases, structure of forests, etc.) across the globe are affected by the climate. Inter-governmental Panel on Climate Change (2001) concluded that even with global warming of 1-2 °C, most ecosystems and landscapes will be impacted through changes in species composition, productivity and biodiversity. Phenology of the keystone species may change which will have impacts on forest structure and composition, and adversely influence the ecosystem services (ES) with implications on various sectors, such as, forestry, agriculture, livestock husbandry, NTFPs, etc. thereby affecting livelihood options. Also, wasteland is emerging fast due to increasing biotic pressure on forests. Similarly, cultural services and eco-tourism value of the natural landscapes are also negatively impacted. This project seeks to integrate all these aspects to improve understanding of the impacts of CC on mountain ecosystems of the Indian Himalayan Region (IHR) and to cope up with the changing situation

Objectives

- To study early indicators of CC on forest vegetation through phenological studies in the region.
- To assess the changes in structure and functions of forest ecosystems vis-à-vis impact on ES (quantification and valuation) accrued.
- To assess CC impacts on recreational / aesthetic services of the landscape and appraisal of management options like institutional arrangements and policy measures.
- To develop, refine and demonstrate models for rehabilitation of community waste / degraded lands as an adaptation to CC and to improve ES.
- To prepare regional planning for suitable forest types to encounter CC impacts and enhance ES.

Achievements

- Based on available literature and review of the past work, four representative forest communities (viz., *Shorea robusta, Pinus roxburghii, Quercus leucotrichophora and Quercus floribunda*) along an altitudinal gradient of 500 – 2000 m asl have been selected in the Kumaun Himalaya to carry out studies on different structural and functional parameters of these forests (Fig.24).
- Matured trees of dominant tree species have been marked across the four forest sites to record periodical data on phenophases (viz., leafing, flowering, fruiting, leafdrop and leaf life-span).
- The recent tourist inflow statistics of Himachal Pradesh were compiled and analyzed for indirect assessment of level of services. The high influx of tourists to the state, which was 16.15 million during year 2012, provides an indirect estimate of consumers of the recreational services that are associated with tourism (Fig.25). The tourist statistics also suggest a consistent growth in inflow which in addition to impacts of improved mobility, increasing per capita income and promotional policies, also owes partly to climate change.
- Recording of community perception on climate change impacts and adaptation measures has been initiated in the Kumaun Himalaya.

Fig.24. *Pinus roxburghii* forest selected for phenological studies in Baldiyakhan (Nainital).

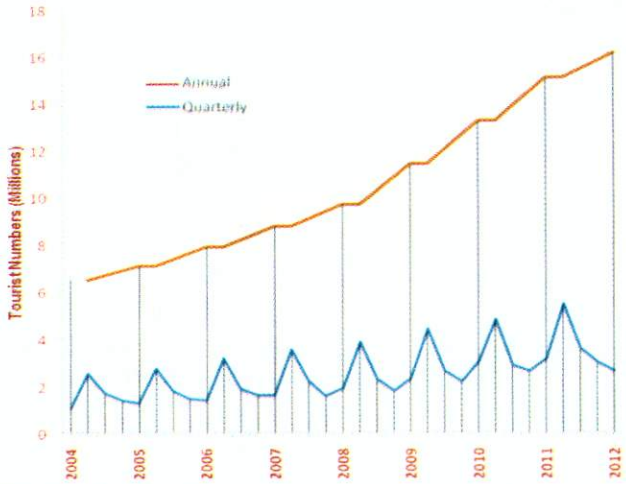


Fig.25. Trends of Tourist Influx in Himachal Pradesh. (Source: H.P. Tourism, Govt. of Himachal Pradesh)

Indicators of climate change in the context of Himalayan forest ecosystems along an environmental gradient *(2012-2015, DST, New Delhi)*

The mountains are the most sensitive ecosystems keeping in mind global climate change (CC) scenario. These ecosystems, with their great vertical dimensions, represent gradients of temperature, precipitation, and solar radiation, and form unique conditions to detect and analyze impacts of CC. The plant species and community distribution range, and their phenology is predicted to experience varying level of shifts across these gradients, and thereby act as potential indicators of CC. Among global mountains, the Himalayan region is the most prominent on account of its horizontal and vertical extent and is rich in endemic species with restricted distribution. Life support values (ecosystem goods and services) of this hotspot are highly vulnerable under the changing climate scenario. Systematic studies are therefore required to objectively define intensity of impacts, develop mitigation and adaptation strategies with regard to forest ecosystem management against the emerging reality of climate change. This project therefore takes into account these aspects across dominant forest communities in the Kumaun Himalaya

Objectives

- To assess phenological behaviour of major forest forming trees as influenced by climate change.
- *To determine the effect of climate change on* species recruitment pattern in forest communities.
- To develop satellite based indicators to deduce landscape level changes, for filling data gaps in the past, and to study climate induced variability at the level of plant communities.

Achievements

- Representative forest communities (viz., *Shorea robusta, Pinus roxburghii* and *Quercus* spp.) along an altitudinal gradient of 500 – 2000 m asl were selected in the Kumaun Himalaya to carry out studies on certain structural and functional features (Fig.26). A total of eight sites (north-west and south-east aspect) have been selected for phenological studies across these forest types.
- Mature trees of dominant tree species have been marked across the four forest sites to record periodical data on phenophases (viz., leafing, flowering, fruiting, leafdrop and leaf life-span). In the sal forest, leaf drop initiation was recorded in 40% trees of *S. robusta* by mid-March. In 18% trees, peak leaf drop had taken place and 24% individuals had initiated new leafing. Similar phenological records were made for *Mallotus philippinensis, Pinus roxburghii, Myrica esculenta, Quercus leucotrichophora, Rhododendron arboreum, Q. floribunda* and *Machilus duthei.*
- Leaf area and leaf mass of the dominant tree species have been calculated at the mature leaf stage. Leaf mass (dry weight per leaf in grams) at mature leaf stage was maximum for S. robusta (31.0) followed by *M. philippinensis* (17.9), *Q. leucotrichophora* (17.4), *M. duthei (11.3), R. arboretum (9.7), M. esculenta (8.5) and P. roxburghii (1.4).*

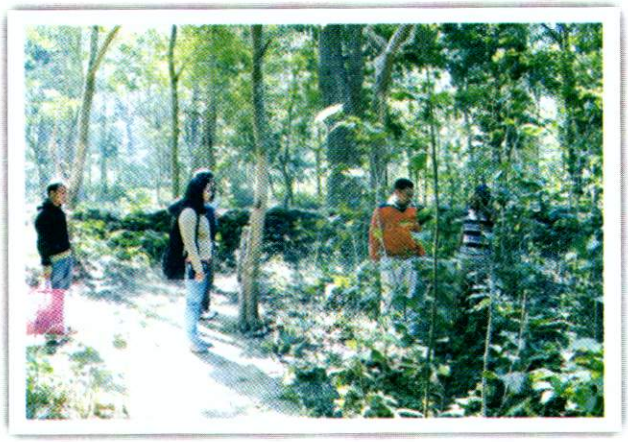


Fig.26. Selection of permanent plot for phenological observations in S. robusta forest in foothills of the Kumaun Himalaya.

Aerosol Climatology over the Northwestern Indian Himalayan Region, Himachal Pradesh *(2006-2014, ISRO-SPL, Thiruvananthapuram)*

Climate change is one of the most important issues in our planet and aerosols play an important role in bringing about the changes in climatic conditions. With the increasing man-made activities, there is an increase in the concentration of aerosols in the atmosphere, which changes the Earth's Radiation budget and hence in a long-run its climate. Optical properties of the aerosol like scattering and absorption cause cooling and heating effect in the atmosphere. Aerosols are so important that these not only affect the living organisms including human beings, but also the climate of a region. The aerosols both- the anthropogenic and natural are responsible for attenuation of solar radiation while passing through the atmosphere and thus cause solar dimming. The amount of attenuation depends upon the optical properties of aerosols. Columnar aerosol optical depth defines the extinction in the solar radiation reaching the Earth's surface. The Ångstrom parameters like Ångstrom exponent 'α' is associated with the fine size aerosols, whereas turbidity coefficient 'β' is associated with the coarse size aerosols. With the increasing concentration of aerosols up to a certain limit there is a decrease in the rainfall. The deposition of the black carbon aerosols on the glaciers on one end increases the light absorption, whereas on the other decreases snow albedo resulting in melting of the glaciers.

Objectives

- To obtain aerosol optical depth (AOD) at ultra-violet, visible and near infrared spectrums (380-1025 nm) using Multi-wavelength Radiometer (MWR).
- To obtain black carbon (BC) aerosol concentrations using Aethalometer.
- To determine the impact of aerosols on climate change in the Himalayan region.

Achievements

- Aerosol optical depth at 500nm was found to be increasing based on a study conducted during 2006-2012 (Fig.27a). Due to increase in the anthropogenic activities, the AOD increase in shorter wavelengths was higher than that in the longer wavelengths.
- When AOD observation from forenoon (FN) to afternoon (AN) was made, it was found that due to increase in convective processes with increasing solar flux, afternoon AOD values were higher compared to those in the forenoon. So attenuation in the solar flux during the afternoon period is higher than that in the forenoon. The solar flux due to the atmospheric aerosols is attenuated by 47.1% at 500 nm and 46.69% at all other wavelengths from forenoon to afternoon (Fig.27b).
- Positive correlation coefficient r =0.29 was noticed between AOD and temperature. This showed positive indications in temperature rise with the increase in AOD (Fig. 27c).
- During the observation period (2006-2012), the instantaneous aerosol Radiative Forcing at the top of the atmosphere, the surface and the atmosphere was -11.45 ± 5.80 Wm^{-2}, -35.83 ± 14.34 Wm^{-2} and $+24.39 \pm 10.94$ Wm^{-2} respectively (Fig. 27d).

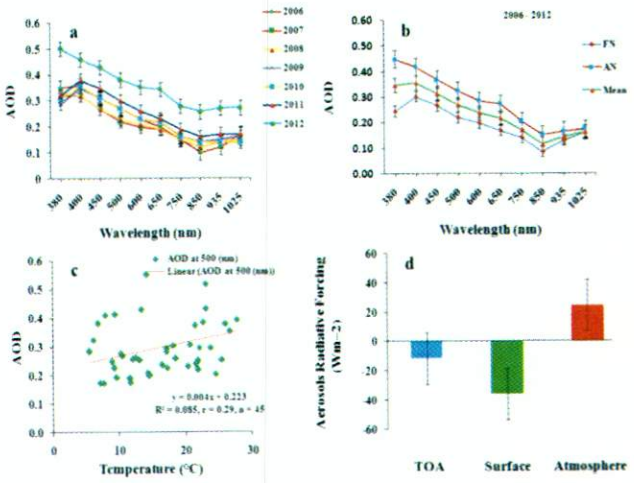


Fig.27 Aerosols and Radiative Forcing at Mohal during 2006 to 2012: (a) AOD at ten wavelengths, (b) FN, AN and mean AOD at ten wavelengths, (c) correlation between AOD and temperature (2008 to 2012), and (d) Aerosol Radiative forcing.

Gaseous Air Pollution in the Background Site of Sprawling Urban Environment of Himachal Pradesh *(2008-2014, ISRO-PRL, Ahmedabad)*

Surface ozone (O_3) is one of the important trace gases keeping in mind its dual role as an oxidant as well as a greenhouse gas. Around 90% of the ozone concentration lies in the stratosphere while the remaining 10% in the troposphere close to the Earth's

surface. Elevated levels of surface ozone can be phytotoxic as well as cytotoxic. Even though it is a trace constituent, ozone plays an important role in the atmospheric environment through radiative and chemical process. O_3, increase in its tropospheric concentration as a greenhouse gas, contributes significantly to local and global warming effects. Ozone is the primary constituent of photo-oxidative smog and is considered to be an indicator of the overall burden of the atmospheric pollutants. NO_x plays a critical role in the photochemical formation of ozone and has been found to be a limiting factor in the atmosphere. This emission is mainly in the form of NO which is later oxidized to NO_2 by different photochemical reactions (as 95% of the NO_x is emitted as NO). NO_x reacts in the presence of VOCs and sunlight to form O_3 and other secondary pollutants. It is therefore important to observe surface ozone and NO_x concentrations in the Himalayan ecosystem which is topographically very fragile and ecologically very delicate. Atmospheric ozone plays an important role in the physio-chemical processes of the troposphere but it also has strong oxidant properties, which at certain levels may damage humans, animals and vegetation.

Objectives

- To measure important concentration of gaseous pollutants such as surface ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) due to anthropogenic sources (such as vehicular congestion, and biomass burning) as well as natural sources (dust storms, etc.) to establish background values in the Himalayan region.
- To observe local meteorological parameters and relate these with gaseous pollutants, and analyze them in the background of long range transport sources.
- To suggest some feasible mitigating measures for implementing at policy level.

Achievements

- Figure 28a & b show the slope obtained from the regression analysis of OX versus NO_x plot representing the NO_x dependent local OX contribution. The intercept presents the NO_x-independent regional contribution. During daytime, regional OX concentrations have more impact in our region (33.15 ppbv) than night-time regional OX concentration. During daytime, there is also local OX contribution (0.465 ppbv) but during night-time local OX contribution (0.012 ppbv) which is negligible.
- The amplitude and duration of the peaks in ozone vary with seasons. Day-time ozone and night-time NO_x peaks are noticed during summer and autumn months. During diurnal variation, ozone showed daytime high and night-time low concentration, whereas NO_x concentration showed bimodal peaks in a day, first in morning and second in evening.
- NO_x concentration shows an inverse relationship with O_3. The daytime O_3 peak is broader and its values are higher from April to June with a seasonal mean value 61.2 ± 8.5 ppbv in the summer months. The rainy season was characterized by low O_3 concentration 23.9 ± 2.4 ppbv and showed relatively short duration of the peak. Autumn months also show high diurnal value 51.9 ± 9.5 ppbv but less broader peak than summer (Fig.28c). While higher NO_x values appear in the autumn 21.2 ± 5.2 ppbv followed by winter 14.3±9.5 ppbv) and lower values appear in the rainy season 5.2±5.0 ppbv (Fig.28d).
- On an average, O_3 on high insolation days was 41.7 ± 13.8 ppbv, while on low insolation days its concentration was 33.3 ± 9.76 ppbv. The largest ozone build-up was in May (14.7 ppbv) and June (13.3 ppbv) and lowest build-up value was in July (1.0 ppbv).

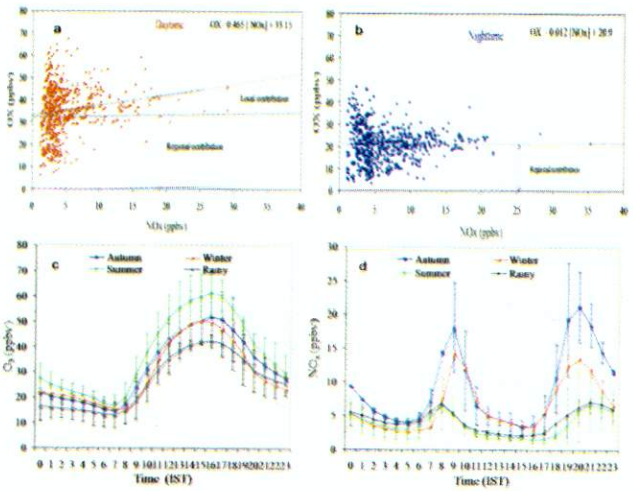


Fig.28. Variation of mean value OX concentration with NO_x concentration: (a) daytime, and (b) nighttime and diurnal seasonal variation of : (c) surface ozone and (d) NO_x at Mohal.

Assessment and quantification of forest ecosystem services with special emphasis on pollination in the Indian Himalayan agro-ecosystems *(2012-2015, Earth Watch Institute, India)*

Forest ecosystems are one of the important ecosystems on the Earth and provide many services that sustain agro-ecosystems. Scientifically ecosystem services are defined by various authors but one of the most accepted definition is 'the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life'. Ecosystem services are now largely recognized, categorized and quantified globally. Ecosystem services provide multiple benefits for human societies. For example, a forest ecosystem may provide timber, fruits, and other forest products, which represent its direct use values. A good and healthy forest ecosystem provides different ecosystem services (e.g., water conservation, carbon sequestration, erosion and flood control, and recreation), which are generally characterized with its indirect use values. The Indian Himalayan region contributes to national economy through providing various ecosystem services from forest and other ecosystems. There is a need to assess multiple services provided by these ecosystems, so that forest ecosystems can be managed and conserved on the basis of sustainable and long-term use. It is also important to reflect monetary value of different ecosystem services, e.g., provisioning, supporting, regulating and cultural services of the forest ecosystems across the two selected study sites – Uttarakhand and Himachal Pradesh. In Uttarakhand, the upper Kosi watershed has been selected for this project in Almora district while the upper Kullu valley in Himachal pradesh. In this project, special emphasis has been given to pollination services of the forests which provide habitats to the pollinators

Objectives

- To assess bee flora and other insect pollinator biodiversity at the selected sites representing Himalayan agro-ecosystems.
- To monitor the phenology of the selected bee flora with focus on flowering and fruiting.
- To quantify selected forest ecosystem services flowing to the agro-ecosystems.
- To harness benefits of pollination services for sustainable livelihoods and biodiversity conservation.

Achievements

- Phyto-sociological studies were carried out during post-monsoon season in Pine forests across three study sites (in upper Kosi watershed) for estimation of biodiversity, biomass productivity and carbon stock in above ground (tree, shrub and herb layers) and below ground (soil). A total of 90 species (1 tree, 10 shrubs and 79 herbs) were recorded across the three sites. Shanon-Weiner and Simpson's diversity indices for Pine forests for Bimola site revealed highest diversity (H' = 3.22), while for Manan site it was the lowest (H' = 2.52). Mean Pine tree density across the three sites was 516 ind./ha, mean shrub density was 86 ind./ha and mean herb density was 18101 ind./ha.
- Total above ground biomass (tree, herb and shrub layer) during post rainy season across the three sites selected for Pine forests in upper Kosi watershed was recorded as 110.10 t/ha for Manan, 104.8 t/ha for Bimola and 59.06 t/ha for Manau (Fig.29).
- Soil organic carbon (%) in soils during post-monsoon season across the three sites of Pine forests of the upper Kosi watershed have shown 2.32±0.41 to 3.14±0.21 for Manan, 1.21±0.13 to 1.65±0.46 for Manau and 0.60±0.08 to 1.26 ± 0.23 for Bimola (Fig. 30 & 31).

Table-6. Diversity indices for herb layer of Pine forests across the three sites in the upper Kosi watershed.

Site	No. of herb species	Shanon-weiner index (H')	Species richness	Species evenness	Concentration of dominance (Cd)	Simpson's diversity index (D)
Bimola	43	3.22	15.00	1.97	0.05	0.94
Manao	31	2.61	10.37	1.75	0.11	0.88
Manan	34	2.52	9.53	1.64	0.12	0.87

Fig.29. Marking CBH for girth increment of Pine trees in the study sites.

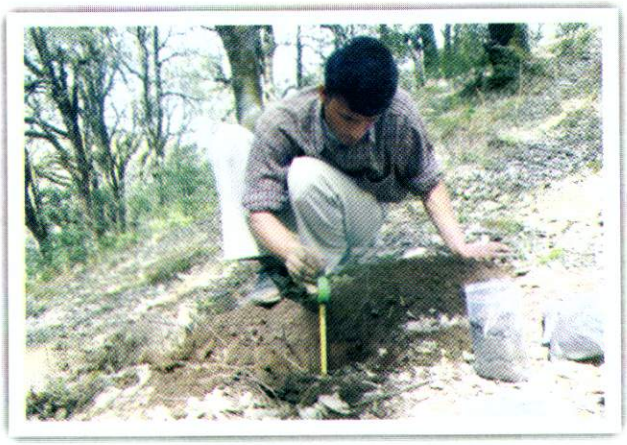


Fig.30. Collection of soil samples from a Pine forest of the study sites.

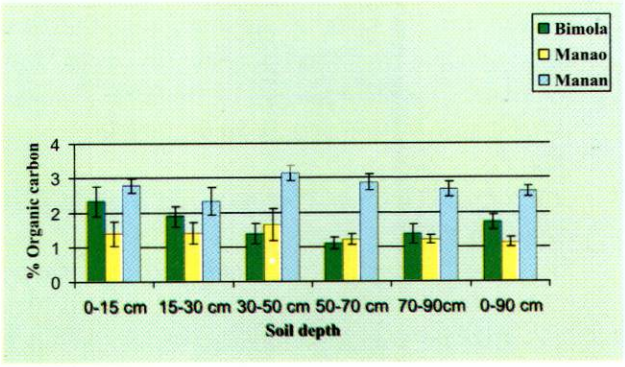


Fig.31. Soil organic carbon across the three sites of Pine forests in the upper Kosi watershed.

Inventorization and Monitoring of Biosphere Reserves in India using Remote Sensing and GIS technology: Focus on Cold Desert Biosphere Reserve *(2010-2013, Ministry of Environment & Forests, New Delhi)*

Biosphere Reserve indicates the special category of protected areas of land or coastal environment wherein people are an integral component of the system. Biosphere Reserves are selected as representative examples of the world's ecosystems. Cold Desert Biosphere Reserve (CDBR) is one of them which is unique in terms of its topography, climate, vegetation and culture. Notification of the cold desert area of Lahaul and Spiti district as Biosphere Reserve is a major achievement towards the conservation of unique and fragile cold desert ecosystem. CDBR is located in the Lahaul and Spiti district of Himachal Pradesh, which lies between latitude 31°44'N to 32°59'N and longitude 77°21'E to 78°34'E, and altitudinal range of 3300-6600 m. The Lahaul and Spiti district occupies an area of 12,210 km^2 and is a unique socio-physical unit of Himachal Pradesh. CDBR basically includes the whole of the Spiti valley and parts of the Lahaul valley. CDBR is a high altitude cold desert and the weather in the valley is quite extreme with varying conditions from bright sunshine to sudden snowfall in the high peaks and passes. It is characterized by an extremely low temperature and less precipitation. Each BR comprises of three zones, i.e., core, buffer and transition. Core zone in CDBR includes Chandertal Wildlife Sanctuary, Pin Valley National Park and Kibber Wildlife Sanctuary

Objectives

- To create natural resources and social database using latest remote sensing (RS) images of existing Biosphere Reserves in India with a focus to prepare land use and land cover maps.
- To study the temporal changes in land use dynamics (at five year intervals starting from 1990 or date of notification) as an impact of Biosphere Reserve management.
- To make recommendations for effective management of Biosphere Reserves focusing on redefining zones/boundaries.
- To develop and test RS/GIS based approaches for assessment and valuation of ecosystem services in a selected Biosphere Reserve of the Himalayan region.

Achievements

- CDBR covers a total area of approximately 7,770 km^2, out of which the core zone occupies 36.02%, buffer zone 49.46% and transition zone 14.52% (Fig.32). One national park and two sanctuaries fall within the CDBR.
- The total area of glaciers in CDBR is about 886.08 km^2, which makes 11.4% of the total area of the BR. The Bada Shigri glacier, located in the CDBR, is the largest glacier in Himachal Pradesh covering an area of about 173.75 km^2. The total length of drainage in CDBR is about 14,939.87 km and it has an eighth order river basin. The streams of lower order mostly dominate the basin with 79% of the first order and 0.005% of the eighth order streams. The total number of human settlements identified in CDBR was 719, while the total number of

monasteries and *chortens* (small deity points) were 163. Total length of road network in CDBR is 1199.02 km. Largest length of major road (82.06%), pack track (48.10%) and footpath (33.26%) fall under the transition zone.

- The total area of agricultural land in all the villages of CDBR is 17.4 km^2. As limited land area and season is available here for cultivation, suitable high yielding crop varieties as well as poly-house technology for off-season vegetables could be one of the steps to improve the livelihood options.

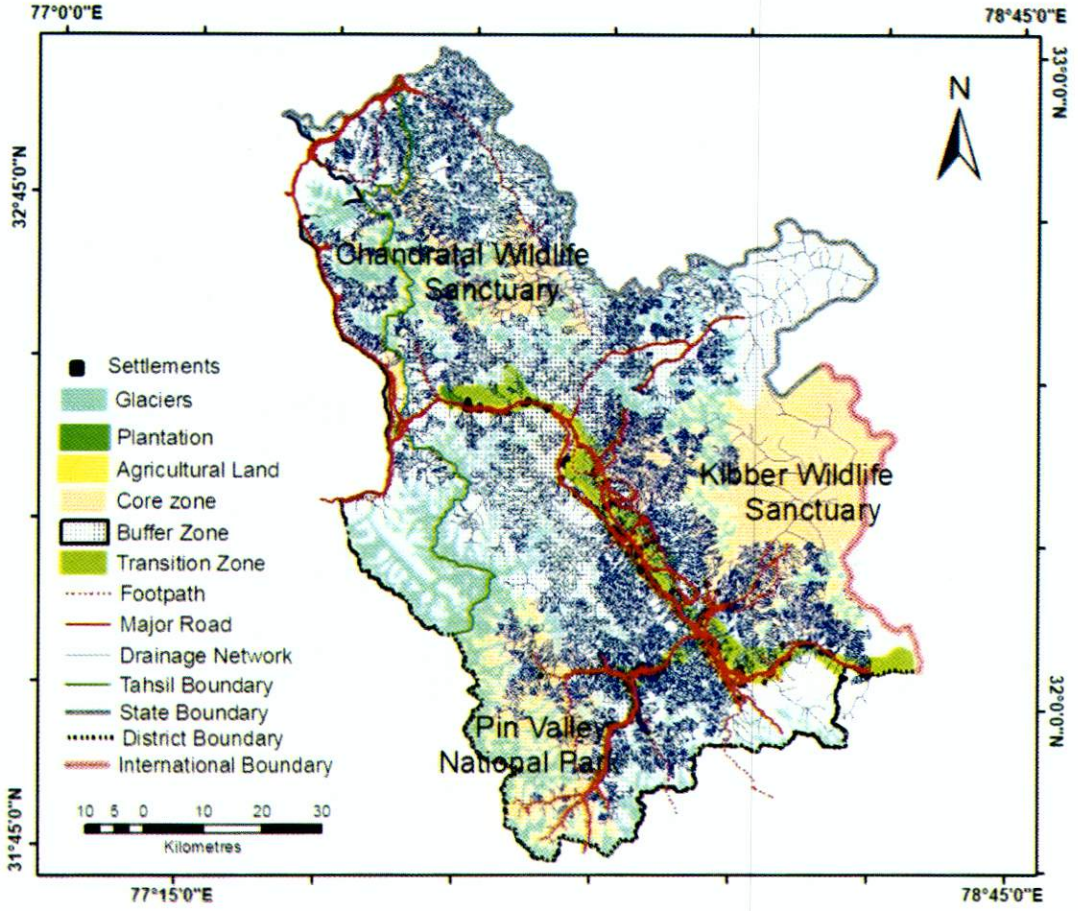


Fig.32. Land use and land cover characteristics in CDBR.
(Based on 1:50,000 Survey of India topographical maps)

Summary of Completed Project / Activity

Strategic Environmental Assessment (SEA) and Environmental Impact Analysis (EIA) of Hydropower Projects in the Western Himalayan Region ***(2007-2012, In-house)***

- The Indian Himalayan Region (IHR) is blessed with perennial rivers and huge water resources. According to Central Electricity Authority (Government of India); exploitable hydropower potential stands to be around 1,50,000 MW, out of which about 70% of this identified potential lies in the IHR only. The region directly provides life-support base to millions of people on this mountain and more than that in plains. Naturally, any large-scale development may cause some negative impacts on the environment such as larger size and large-scale hydropower developments. EIA, as a decision making tool, applies to the assessment of the environmental impacts of developmental activities and this includes the river valley projects. However, despite existing EIA framework, environmental impacts of the hydropower projects have been experienced.
- A case study conducted at River Satluj Basin revealed that more than 28 large (>25 MW), 7 small (>2 to < 25 MW) and 2 micro (<2 MW) hydropower projects with installed capacity of 9728 MW are likely to develop under HPSEB and private investors. During the field survey, it was observed that out of 37 HEPs; 15 are proposed, 10 under construction, and 12 under operational stage (Fig.33). It is assessed that settlement River Satluj still has to face air-pollution problem.
- The case studies conducted for the Kashang **Integrated** (243 MW), Karchham Wangtu (1000 MW) and Rampur (412 MW) projects show that local residents were not satisfied with the existing mechanism of public hearing. The majority of public demands put forward during the public hearing were not fulfilled by project proponents. Besides, a large number and large size of the projects are opposed by the respondents. Respondents of this region are not satisfied with overall environmental management in the peripheries and catchment areas made by the project proponents.
- Morphometric analysis of River Satluj revealed that a real aspect of drainage (A) catchment was 2945 (km^2), whereas stream length (N) was calculated 165 km. Drainage Density (D) was 0.56 km/km^2. The stream frequency was obtained 0.29 streams/km^2. Stream order (N_u) was found to be 1877 km, mean Bifurcation Ratio (R_b) 5.213, Stream Length Ratio (R_l) 0.478 and the mean stream length ratio was 1.29.
- In the Alaknanda basin, geographical locations of 38 hydropower projects were identified. Out of these HEPs identified, there were 24 large (>25 MW), 9 small (>2 to < 25 MW) and 5 micro (<2 MW) hydropower projects (Fig.34). During field survey, it was observed that 24 projects were proposed, 8 were under construction and 6 were extant.
- The morphometric analysis of the Alaknanda river basin showed five stream orders where within the 1st one (u), there were 159 streams (N_u) 530 km in length (L_u). Within the 2nd order, 33 streams (N_u) 124 km in length (L_u). Within the 3rd order, 8 (N_u) 16 km in length (L_u) and within 4th order their length was 2 (N_u) 4 km. River flow is diverted by tunnel from the dam to then power house site which results renders the Satluj basin geologically weak.
- The study area has a poor stream network because it depends upon the value of stream frequency. The low value of drainage network indicates it is poor, while high relatively indicates denser in the catchment area. These results indicate that the particular area is not suitable for a large number of HEPs. Further, a low network of drainage is not good for future HEPs due to lack of water availability.

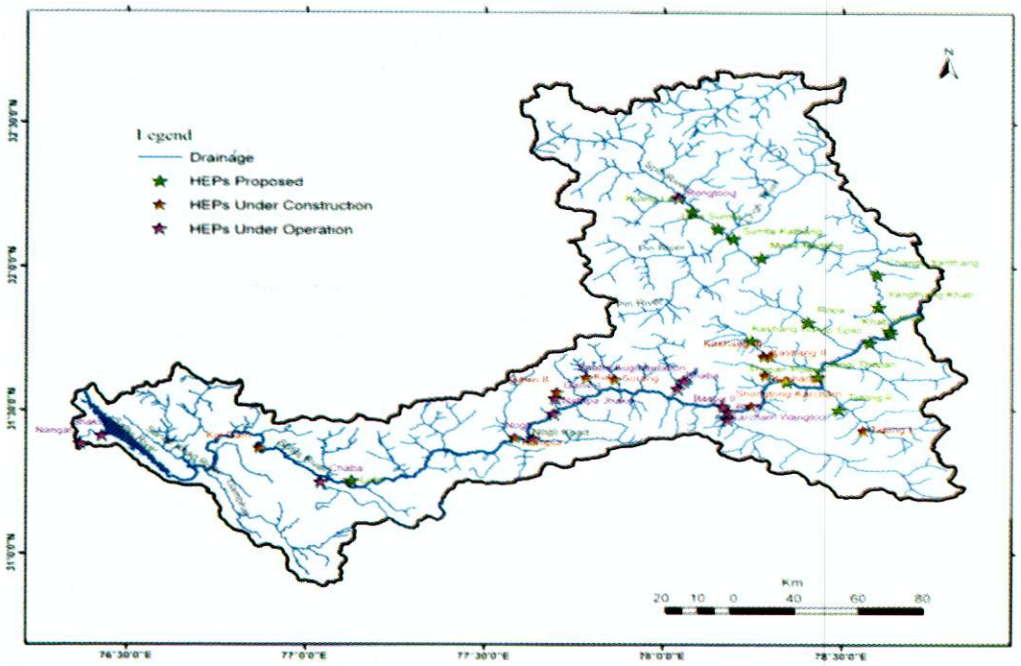


Fig.33. Hydroelectric Project in the River Satluj.

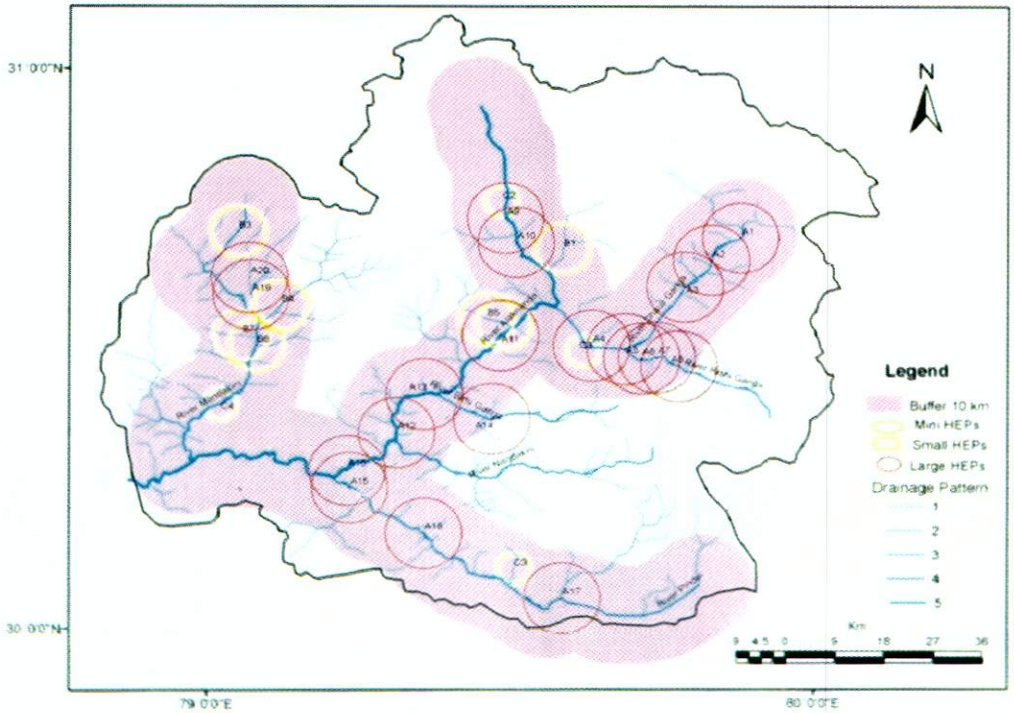


Fig.34. Hydroelectric Project in the River Alaknanda.

Summary of Completed Project / Activity

Assessment of downstream Impacts of Hydroelectric Projects in Arunachal Pradesh: A Case of Ranganadi Hydroelectric Project (*2011- 2012, In-house*)

- Downstream impacts of hydropower projects in Arunachal Pradesh and other northeastern states have become major environmental issues with the development of hydropower projects. Keeping in mind the same, the main aim of this activity was to evaluate the actual post-development impacts especially in the downstream of this hydropower project. In this context, Rangnadi HEP (405 MW) was taken into account which has been in operation since 2002 in Arunachal Pradesh (Fig.35). Ranganadi HEP uses water from River Ranganadi to generate electricity and its outflow is diverted into the adjacent River Dikrong. These two river streams join here and the influence of this hydroelectric project continues. The study was therefore focused within the influence of these two rivers covering the aspects such as water quality, land cover changes, livelihood issues, etc. primarily in the downstream areas of the project.
- As far as major findings of the project during this short-term were concerned, these were mainly the occurrences of flash floods and erratic river discharges, drying up of river beds or fragmented flow at places, water quality problems, damage to fish population, and destabilization of river bed due to increased sedimentation (Fig.36 &37). As far as the water quality parameters were concerned, these were within the permissible limits. However, water quality parameters showed negative change when water samples were taken from the downstream of the rivers.
- The land use and land cover change study showed around 85% of the total area remained unchanged in land use pattern. There is a significant increase in shifting (*jhum*) cultivation area (**total increase of around 350 ha**) in the study area (**i.e. watershed**). There was no significant change in dense forest cover but moderate dense forest was found to be changed to open forest area which was found increasing. Minor changes (**2.6%**) in were found river water body and river sand areas.

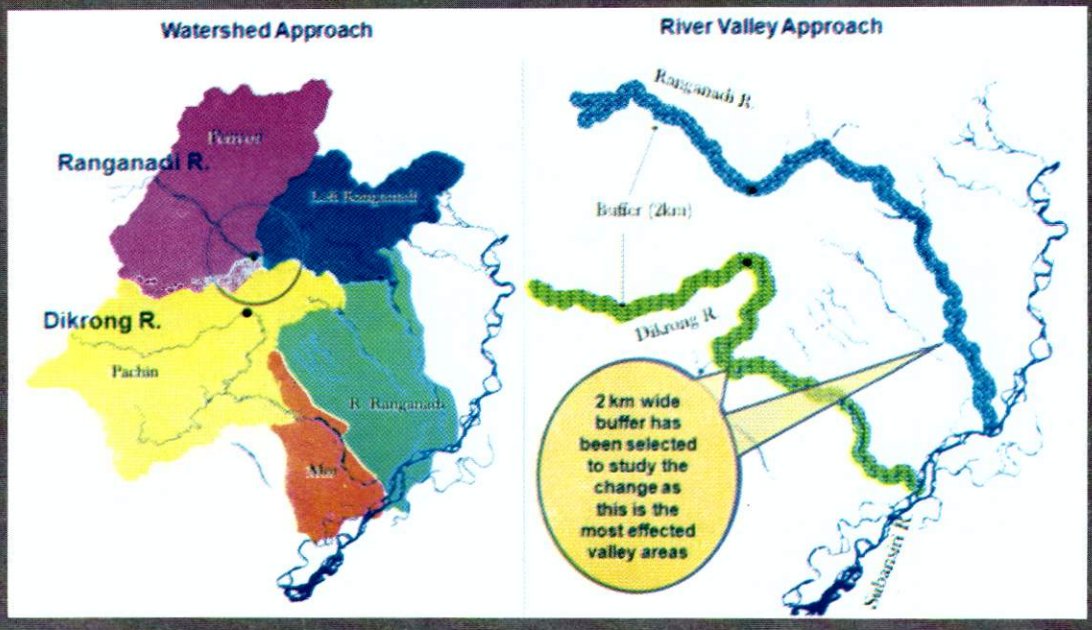


Fig.35. Methodological approach adopted for impact study.

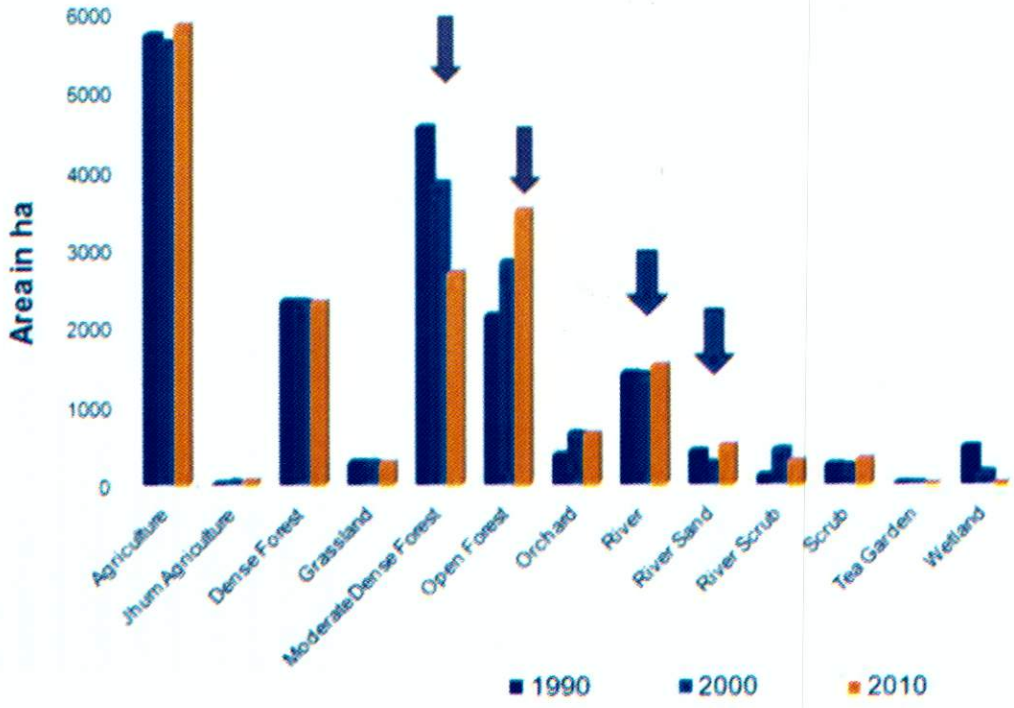


Fig.36. Land use change over a period of 20 years in the downstream of the Dam of Rangnadi HEP (405 MW).

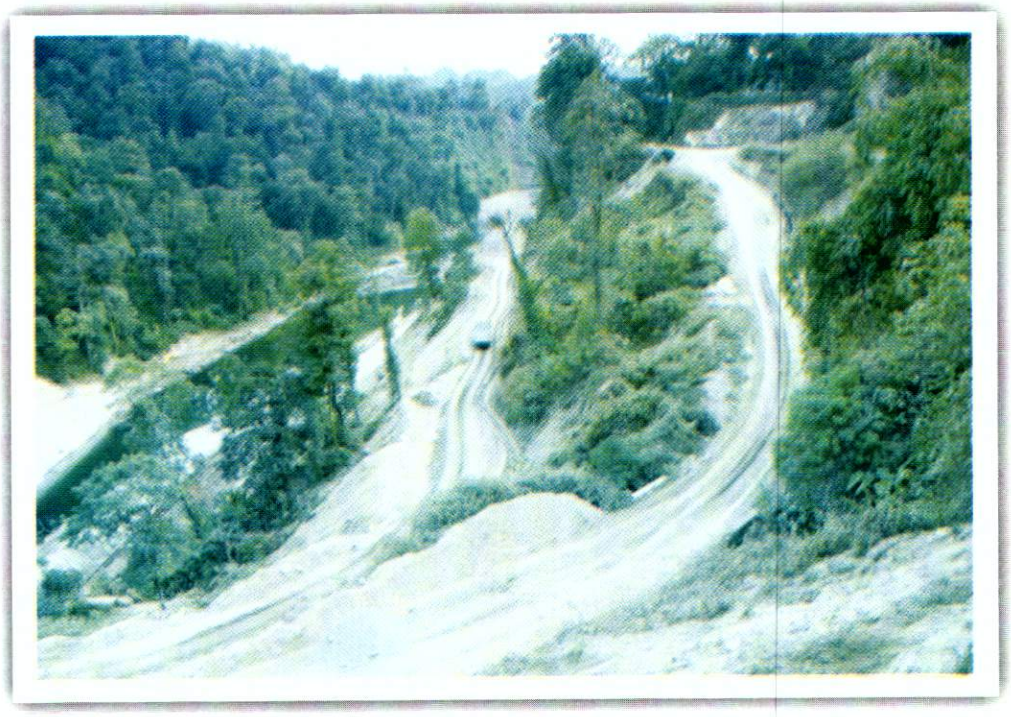


Fig.37. A fragmented flow view in the downslope of Rangnadi HEP (405 MW) in Arunachal Pradesh.

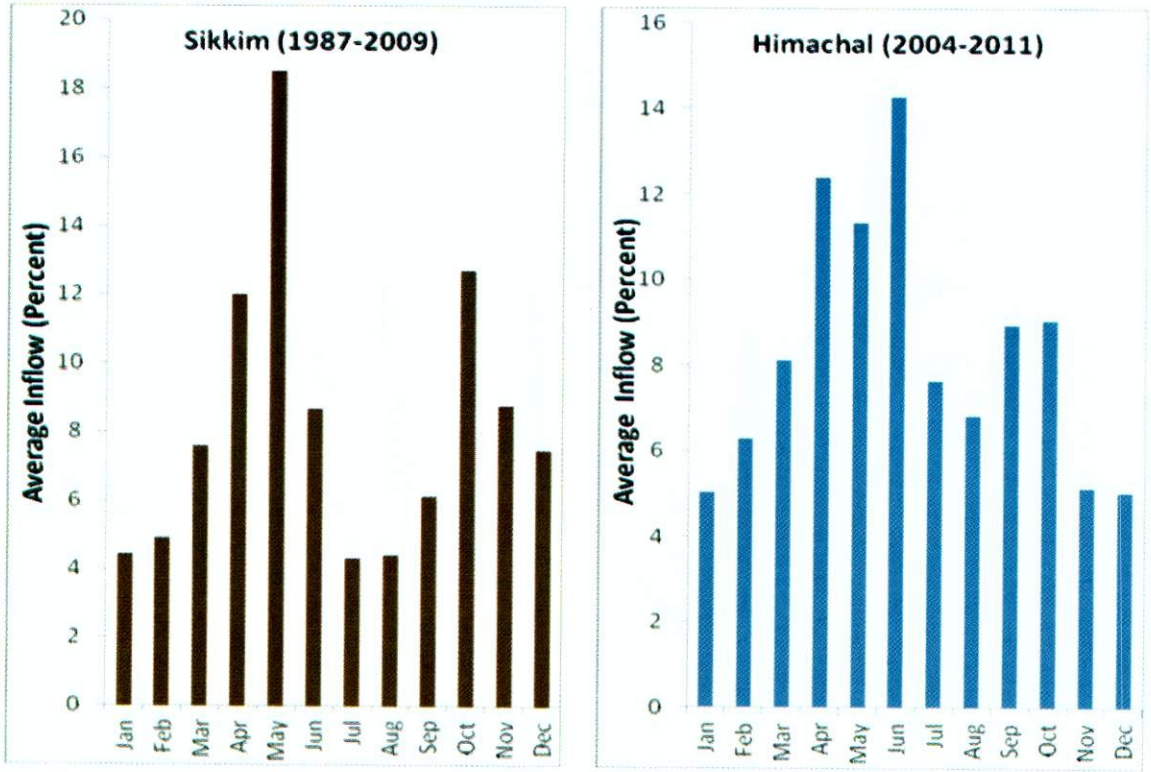


Fig.38. Profile of average monthly inflow of tourists to Sikkim and Himachal Pradesh

Summary of Completed Project / Activity

Urbanisation vis-a-vis Solid Waste Management and Air pollution in sprawling urban cities of Himachal Himalaya (*2007-2012, In-house*)

- Anthropogenic activities in the urban areas are increasing day-by-day. This has resulted in a variety of environmental problems among which solid waste problem and air quality deterioration stood to be the notable ones which are affecting the health and hygiene of the residents. The issue of solid waste management (SWM) is significant because the management authorities can deal only partially with the waste problem due to inadequate infrastructure and financial strength. Overall, it is observed that the biodegradable waste (76%) is of main concern in the urban towns of Himachal Pradesh. The awareness levels among the public in the hill towns and the strategies in hand among the managing authorities seem to be inadequate.
- With continuous increase in population in the Himalayan states the soild waste problem has exhibited an increasing trend.
- According to Census 2011, there are 68.84% rural and 31.16% urban populations in the total of India, while in Himachal Pradesh these populations comprise of 89.96% and 10.04% respectively. The urban population growth is relatively higher than that of the rural, as a result of which solid waste problem is bound to become more serious in the urban localities. The solid waste problem is likely to aggravate in the coming future if the present rate of growth in terms of native and **tourist p**opulations continue to increase and timely mitigating measures are not taken up (Table-7).
- As far as air pollution is concerned, it has risen due to increased vehicular movement, biomass burning and forest fires. It is found that the concentration of Total Suspended Particulate Matter (TSP) and Particulate Matter below 10 μ (PM_{10}) have crossed the National Ambient Air Quality

Standards (NAQS) many times at all the selected for the towns present study except Keylong (Fig.39). The ambient air quality of low altitude sites was observed to b more polluted as compared to the higher altitude sites like Chamba and Keylong. The particulate pollutants at all the six sites were greatly influenced by both the sources; local as well as long range transport sources. The results of long range transport sources suggest that a majority of these pollutants at all the towns were generally transported from arid and semi-arid regions like the Sahara, Middle-East Countries and Thar and also from the highly populated areas of the Indo-Gangetic and Punjab Plains.

- It is observed that the lower altitude sites like Bilaspur, Kangra, Mandi and Hamirpur have been noticed to have high concentration of ions while the higher altitude sites like Chamba and Keylong had a low concentration. It may have happened due to high anthropogenic activities at lower altitude sites compared to higher altitude sites. The transportation of aerosols from the highly populated Indo-Gangetic plain and from semi-arid and arid desert regions like the Sahara, Middle-East and Thar under present study may also have contributed to the increase in the concentration of ions at the lower altitude towns.
- The high load of particulate pollutants in the ambient air has been a matter of great concern for these sprawling urban and semi-urban localities of the topographically fragile and ecologically delicate regions of the Himalaya. Air pollution is, directly and indirectly, linked to the health of living organisms and our environment. As a result, there is a need to make the residents aware regarding the future consequences of polluted air and to provide guidelines to the local government about the application of pollution free technologies.

§ Most of the management authorities in urban towns yet need to have policies, plans and programmes along with adequate infrastructure to deal with similar environmental problems. If these fast growing problems are not tackled within time, it may directly or indirectly, create, many other dreadful and incurable health hazards for the visitors and the communities attached to the region. There is an ample scope for proper urban planning to deal with the existing environmental problems and to minimize these in a sustainable manner. To minimise these environmental problems, coordination and active cooperation among local residents, management authorities, research institutions and local government is of at most significance.

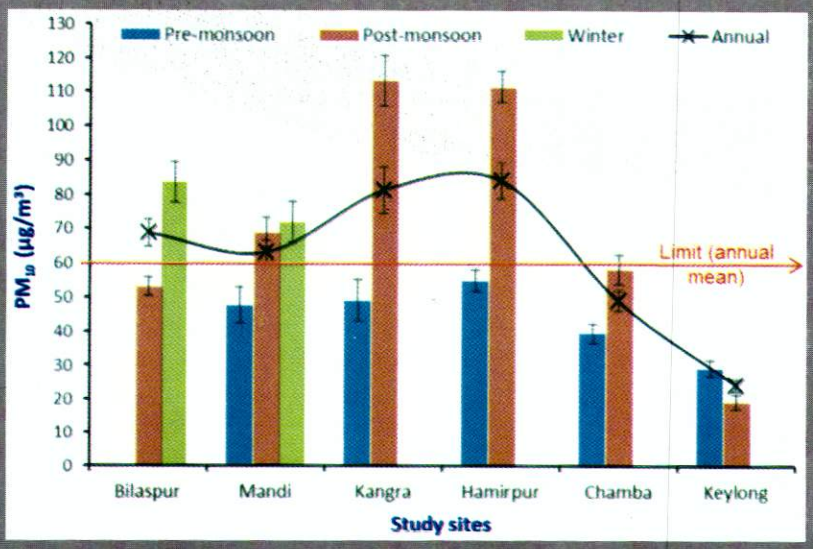


Fig.39. Seasonal and annual concentration of PM_{10} in hill towns of Himachal Pradesh.

Summary of Completed Project / Activity

Appraisal of Tourism for Sustainable Management – Comparative Analyses of Sikkim and Himachal Pradesh *(2009-2012, In-house)*

- The study presented a comparative view of Sikkim (May 2009 to December 2010) and Himachal state (September 2011 to June 2012) to understand the status of tourism as trend-patterns, impacts, economic relevance and sustainability (Fig.38). Sikkim and Himachal are both markets for domestic tourism. The foreign tourists comprise nearly 3.5% and 7% of the total annual tourist inflow in Sikkim and Himachal Pradesh respectively. The main variants that exist in these states are commercial urban tourism, nature tourism, adventure tourism, monastic and religious tourism, and rural-cultural tourism.
- The analyses of monthly profile of tourist inflow suggest that tourism in both the states is seasonal. The season I or summer season (April to June) is the main influx period accounting for nearly 46-47% of the total annual inflow in both the states. In Sikkim, May is the month of maximum inflow (18.52%), while in Himachal maximum inflow month is June (14.41%). Of the total annual inflow, the season II or autumn season (September-November) contributes to 26% in Sikkim and nearly 24.5% in Himachal. The quarterly analyses show a switch in the lean period i.e. January-March to July-September in Sikkim and January-March to October-December in Himachal, suggesting expansion of summer season up to March or increasing popularity of winter tourism as a result of new government policies, improved access due to infrastructural growth and/or general improvements of tourism prospects due to climate change.
- The linear mapping of annual inflow statistics in different segments of time brackets, and general review of the inflow trajectory on patterns of Tourist Area Life Cycle (TALC) model, suggest no signs of exhaustion, saturation and maturing out. The continuous growth of inflow with increasing trend of annual growth, suggests that tourism in both the places is under the developmental stage. Hence it has an excess capacity and sanguine prospects for future growth. Based on data sets for the periods 1980 to 2010 and 2004 to 2011, the projections for tourist inflow for year 2020 suggest inflow volumes up to 1.69 million in Sikkim and 43 million in Himachal Pradesh respectively. Tourists' inflow at these volumes would certainly enhance the income and employment opportunities and infrastructural growth. At the same time this inflow would adversely affect its future potential through trespassing of physical, social and ecological carrying capacity of the destinations.
- The observations have shown negative impacts of tourism, such as, cluttered settlements, traffic jams, waste problem, etc. in urban pockets and abandoning of agriculture, loss of agribiodiversity, diversion of agricultural lands for touristic developments in the rural areas. Alienation of locals, in-migration of outsiders, subsequent change in demographic composition, shifting control over natural resources, and weakening of local institutions are the major associated threats. In Himachal Pradesh, drug tourism in rural pockets is also developing which is affecting the young generation and the rural culture. In Sikkim state, this study also shows negative impacts of tourism in terms of pressure on forest resources, high altitude sensitive habitats, infrastructure and demand and supply. Yoga, meditation and health tourism, is a new development in attracting a good clientele. Analyses of earnings during tourism seasons suggests that in five month periods of seasons, tourism in Gangtok (Sikkim) makes an aggregate contribution of nearly 63% and four months summer period in Dharamshala (Himachal) around 49% towards the earnings of local business community.
- Tourism is spurning good money in terms of revenue from entry fees and permits, earnings of local business community providing business and job opportunities for the locals and outsiders. Yet, the study of nature tourism pockets in Sikkim, suggests that the inhabitant community from the vicinity areas are not benefitting much from tourism. The need, therefore, is to secure their benefits through the rights in travel operations, provision of soft loans for vehicles, and other concessions.

Table-7. Population, area and solid waste generation (household and total) in hill towns of Himachal Pradesh.

Towns	Estimated population (2008)[a]	Area (km^2)	HH waste (capita^{-1} day^{-1} in gm)	Total HH waste (day^{-1} in tonnes)	Share of HH waste in total waste (%)	Total waste (capita^{-1} day^{-1} in gm)	Total waste (day^{-1} in tonnes)
Bilaspur	13473	10.62	..	2.6±0.28	29.0	668	9.0
Kangra	9420	3.12	199±37	1.9±0.34	47.0	425	4.0
Mandi	27831	4.26	236±16	6.6±0.44	48.6	485	13.5
Hamirpur	17481	5.24	182±32	3.2±0.56	24.5	744	13.0
Chamba	20038	4.33	172±22	3.4±0.44	43.0	399	8.0
Keylong[b]	2031	2.47	180±8	0.4±0.02	45.7	394	0.8

[a]*survey was conducted in 2007 -08, and estimation of waste generation based on population for the year 2008 was estimated according to the decadal growth in town populations*
HH = Households
[b] *= sampling could not be done in winter season due to heavy snowfall in Keylong*
± *= Standard Deviation (SD)*

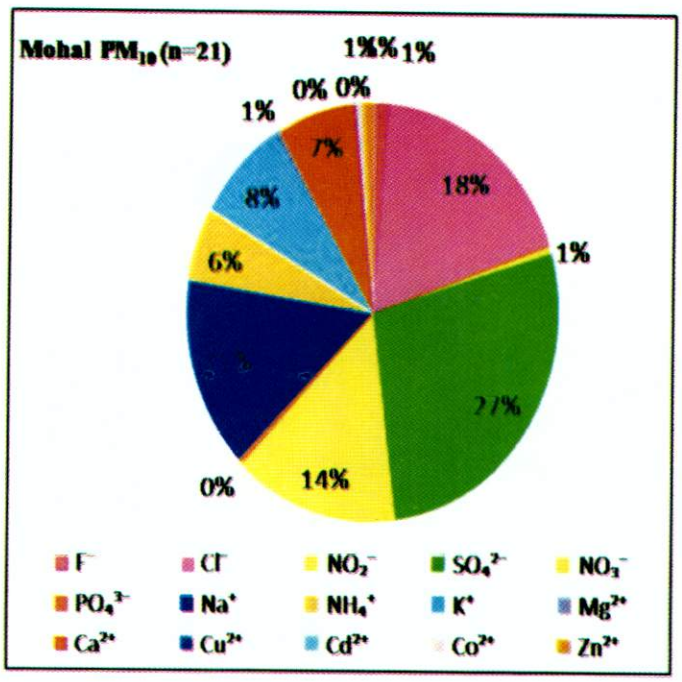
Summary of Completed Project / Activity

Ambient air pollution and its sources in the background sites of different hill spots in the northwestern Himalayas, Himachal Pradesh (*2009-2012, DST, New Delhi*)

- Ambient air pollution is one of the continuously increasing environmental problems in the Himalayan region which adversely affects the living organisms on the Earth's surface. Air pollution in different forms (particulate and gaseous) has been studied. Maximum daily concentration of TSP at Mohal was 381.0 µg m-3, while at high altitude location- Kothi, it was 388.0 µg m^{-3} (Table- 8). The lowest concentration at Mohal was 38.6 µg m-3 and 31.4 µg m-3 at Kothi. PM_{10} concentration at Mohal was found maximum in winter season, while at Kothi the maximum concentration was in summer season. PM_{10} at Mohal was observed as high as 138.3 µg m-3 and at high altitude Kothi, it was 96.9 µg m-3. The ionic balance of the PM10 aerosol samples showed a trend $NO_3^- > Cl^- > SO_4^{2-}$ for anions and $Na^+ > NH_4^+ > K^+$ for cations. In transition metals, Zn^{2+} stood at a high at both the locations (Fig.40).
- It is an interesting observation that the maximum concentration of $PM_{2.5}$ at both the study sites was found in the summer season. This concentration of $PM_{2.5}$ at Mohal was 99.3 µg m^{-3} while at Kothi it was 135.9 µg m^{-3}. Maximum concentration of SO_2 at Mohal was 14.5 µg m^{-3} while at Kothi, the maximum concentration of SO_2 was 10.7 µg m^{-3}. SO_2 at both sites as minimum as 0.2 µg m^{-3}. Maximum concentration of NO_2 at Kothi was 16.4 µg m^{-3} while at Mohal it was 17.7 µg m^{-3}. Both the locations have the with the lowest NO_2 concentration, during the summer months (April-May) i.e., 1.0 µg m^{-3}.
- Total rainfall at Mohal and Kothi was measured to be 9247 mm and 8590 mm from January 2009 to December 2012 respectively and snowfall was measured 6346 mm at Kothi. It is found that the daily average of pH values were 6.7 of the total rainwater at both the sites. The lowest pH value at Mohal was 4.2 and at Kothi it was 4.1. Thus, the rainwater at both the locations was slightly acidic.
- Owing to growth in tourism activities, vehicular congestions increase mainly in the summer season. Based on 12 hourly census (6 a.m.-6 p.m.) in a day on weekly basis, vehicles plying on NH-

21 at Mohal stood to be highest at 3110 day^{-1}. Maximum vehicles and visitors from January 2010 to July 2010 were recovded in the month of June touching as many as 3110 day^{-1} and 24390 day^{-1} respectively. At Kothi, the maximum number of vehicles and visitors stood to be 2867 day^{-1} and 28487 day^{-1} in May 2010 (Fig.41).

- The highest particulate pollution (TSP, PM_{10} and $PM_{2.5}$) episodes at both the sites were observed due to combination of local as well as outside sources. The local sources like vehicular influx during the in tourist season and biomass burning in the winter season are the important ones among them. While transport of pollutants through air masses into the present study locations is due to external sources. High concentrations of gaseous pollutants were mainly found in the winter season due to half fuel combustion and biomass burning (fuelwood, forest fires). Besides, the open burning of refuse, prevailing hot water sulphur springs at Vashit-Manali, Ramshila at Kullu and Ram temple and Gurudwara at Manikaran are considered to be the primary local sources in the Kullu valley.
- The Age-old practice of burning fuelwood for cooking and heating needs to be replaced with cooking gas and non-conventional energy sources. Development of green belt around the spots with locally available indigenous tree species in and around the hill spots would be an other ecological measure to bring the level of the particulate and gaseous pollutants in the Himalayan ecosystem under control.
- The maximum daily average temperature observed on August 29, 2010was 22 .2° C. The mean humidity level was highest as 99.6% at Mohal, while at Kothi it was 99.3% in the month of August. Winds at Mohal mostly blow from the north-west (292.5°-315°) or north-east (45°-67.5°) directions. As far as its direction at Kothi is concerned, the maximum winds blow here from north-east (00-22.50) direction.



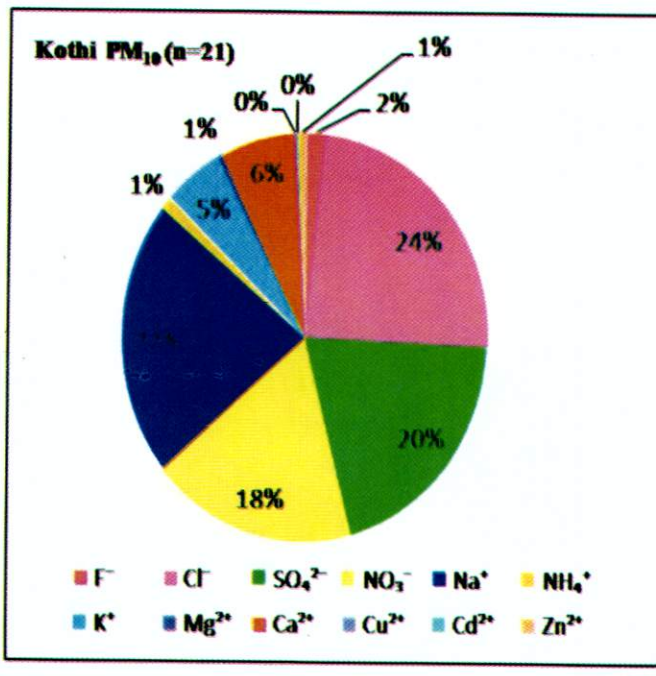


Fig.40. PM_{10} episodes and its chemical constituents

Table-8. Exposed samples for Particulate and gaseous matter from January 2009 to December 2012.

Month/ Year	TSP (24 h)				PM_{10} (24 h)			
	Mohal (1154 m)		Kothi (2478 m)		Mohal (1154 m)		Kothi (2478 m)	
	SA	SR	SA	SR	SA	SR	SA	SR
Jan 09 - Dec 09	181	3	128	55	180	3	97	86
Jan 10 - Dec 10	163	20	119	64	149	34	119	64
Jan 11 - Dec 11	151	32	93	90	149	34	71	112
Jan 12 - Dec 12	126	12	68	70	149	06	67	88
Total	**621**	**67**	**408**	**279**	**627**	**77**	**354**	**350**

Month/ Year	$PM_{2.5}$ (24 h)				SO_2 (24 h)				NO_2 (24 h)			
	Mohal (1154 m)		Kothi (2478 m)		Mohal (1154 m)		Kothi (2478 m)		Mohal (1154 m)		Kothi (2478 m)	
	SA	SR	SA	SR	SA	SR	SA	SR	SA	SR	SA	SR
Jan 09 - Dec 09	-	-	135	48	182	1	129	54	181	2	129	54
Jan 10 - Dec 10	114	69	91	92	168	15	114	69	171	12	118	65
Jan 11 - Dec 11	152	31	86	97	154	29	89	94	160	23	88	95
Jan 12 - Dec 12	115	23	67	71	153	3	76	82	153	3	76	80
Total	**381**	**123**	**379**	**308**	**657**	**48**	**408**	**299**	**665**	**40**	**411**	**294**

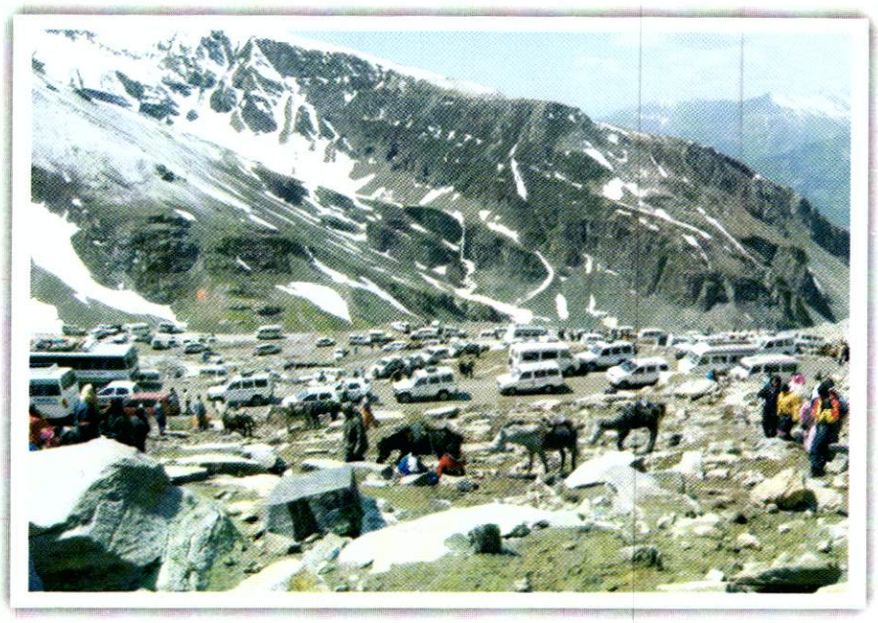
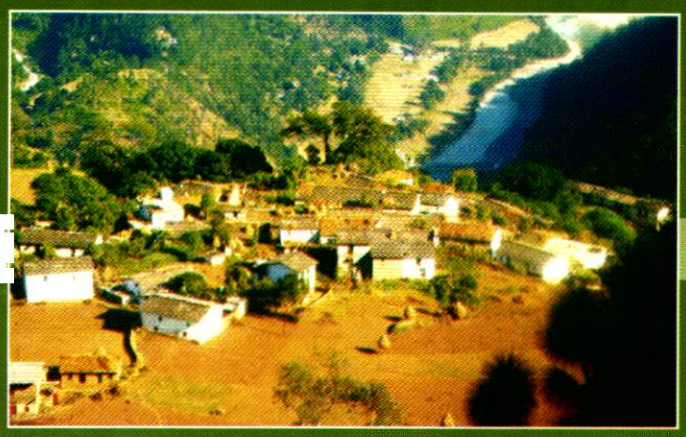


Fig.41. Tourist vehicle traffic near higher altitude site at Kothi



Theme

SOCIO-ECONOMIC DEVELOPMENT (SED)

Socio-economic development is the key for the growth of any society. The rural communities in IHR face diverse issues that need to be looked into for upgrading their socio-economic status. A large variety of programmes are being run by various state governments for poverty alleviation, reducing unemployment and to provide alternate means of livelihood, but their success level varies from region to region and community to community. An important criterion to improve quality of rural-life reveals the necessity of analyses and identify location specific needs along with an assessment of the required input for improvising traditional agriculture systems and natural resource uses with a balanced approach for human resource development. The biggest challenge is as to how in the event of a new development the community could accommodate it without compromising the day-to-day quality of life. Also, there is a need to assess impacts of development on the society. Communities need to be empowered to take decisions on long-term sustainability including economic prosperity and social well-being. The Institute, through its SED programme, tries to address some of the priority issues for socio-economic development in the IHR. In the reporting year it has taken up R&D related to ecological, economic and social viability of shifting agriculture, along with the promotion of community based natural resource management and the linking biodiversity conservation with sustainable development in northeast India, enhancement of livelihood security through sustainable farming systems and scaling up innovative resource management practices for improved livelihoods in the Central Himalaya along with the economic and cultural implications of migration, and assessing the impact of pesticide application in contamination of food chain in northwest Himalaya. To upgrade livelihood of Himalayan communities, the Institute has initiated a new programme on Eco-tourism as a tool for biodiversity conservation and sustainable livelihood all across the Indian Himalayan Region. A brief account of each activity is presented in subsequent paragraphs. The main objectives of the theme are: (i) Sustainable tourism; (ii) Entrepreneurship and self employment in the Himalaya; (iii) Indigenous knowledge: traditional lifestyle, architecture and healthcare practices; and (iv) Migration: socio-economic and cultural implications.

Eco-tourism as a Potential Tool for Biodiversity Conservation and Sustainable Livelihood in Indian Himalayan Region ***(2012-2017, In-house)***

Indian Himalayan Region (IHR) has been the destination of various types of tourism, such as nature based (alpine flowers, bird watching, trout fishing), adventure (trekking, rafting, gliding, mountaineering), cultural (festivals, food festivals), religious (temples, monasteries), leisure (sightseeing, ropeway), agro-tourism (passage through famous Apatani rice-cum-fish fields in Arunachal Pradesh, fish catching in rice-cum-fish fields), etc. The tourism, in turn, has potential

for economic development of the local communities and conservation of the rich biodiversity of the region. Keeping this in view a project is being implemented with a focus to develop an eco-tourism model, incorporating tourism with economy, culture and community conserved areas (CCAs)/community forests, and developing eco-tourism as a potential to promote rural livelihood as well as to conserve the biodiversity of the region. Status of selected eco-tourism sites in Himalayan States, analyses of economic relevance of eco-tourism and impact of tourism on people and environment will also be studied in detail along with policy issues, successful initiatives taken to promote this cause, and principles and values of sustainable eco-tourism.The project will be operated in four Himalayan States, i.e. Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh

Objectives

- To study the status of eco-tourism in terms of goals and impacts in select pockets of IHR.
- To institutionalize community conserved areas (CCAs) as potential gene bank for conservation of biodiversity and to generate sustainable livelihood option through functional participation of local communities in conservation and resource management.
- To enhance community knowledge on conservation using concepts like people's biodiversity register (PBR), village botanists and help the community capitalize on its indigenous knowledge to encourage conservation of natural resources.
- To inventorize biodiversity of the region including agro-diversity and CCA and highlight information gaps for improving policies.
- To develop an ecotourism model integrating tourism with economy, culture and community conserved areas (CCAs)/community forests/ village forests as a potential mechanism to promote sustainable livelihood and conservation of biodiversity.

Achievements

- Initially the data has been compiled from secondary sources. Tourism is the world's fastest growing industry in the recent years, and can play a dominant role in the economies of developing countries. France, Spain, United States, China and Italy are ranked top with regard to international tourist arrivals. Europe shares more than half of tourist arrivals (58.6%) of the world total.
- World travel and tourism industry is estimated to have generated US$ 6.9 trillion of economic activity in 2006. The industry is estimated to generate economic activity worth US$ 12.1 trillion, and generate employment for around 280 million people by 2016. The sector employs over 204 million people worldwide, which forms 10.6% of the global workforce. It is the world's leading economic contributor, producing an incredible 10.2 percent of the world's gross national product. It is the leading producer of tax revenues at US$ 655 billion and the world's largest industry in terms of gross output approaching US$ 304 trillion.
- In India, tourism has the potential to provide economic and social benefits. It has emerged as a major source of employment, with a share of 8.27 per cent of the total number of jobs in the country. With respect to IHR States, tourist inflow statistics of Himachal Pradesh which also includes religious tourists depicts that the tourist inflow volume to the state has nearly doubled from 6.55 million in 2004 to 16.15 million in 2012, suggesting a total growth of 146.54% (Fig.42). The foreign tourists comprise around 3.44% of the total arrivals.
- Northeast India is receiving just 1% of the total tourist arrivals in India (Table-9) and Assam, Meghalaya, Tripura and Sikkim are the major tourist destinations in the region. Interestingly the numbers of tourists are gradually increasing over the years in the region.

Table-9: Total number of tourist arrivals in northeast India

State	2004-2005		2005-2006		2006-2007		Share in Indian arrival% (06)	
	India	Foreign	India	Foreign	India	Foreign	India	Foreign
Assam	22888093	7285	2467652	10782	2768824	10374	0.60	0.09
Arunachal Pradesh	39767	321	50560	313	80137	607	0.02	0.09
Manipur	93476	249	94299	316	116984	295	0.03	0.00
Meghalaya	433495	12407	375901	5099	401529	4287	0.09	0.04
Mizoram	38598	326	44715	273	50987	436	0.01	0.00
Nagaland	10056	1084	17470	883	15850	426	0.00	0.00
Sikkim	230719	14646	251744	16523	292486	18026	0.06	0.15
Tripura	260907	3171	216330	2677	2306456	3245	0.05	0.03

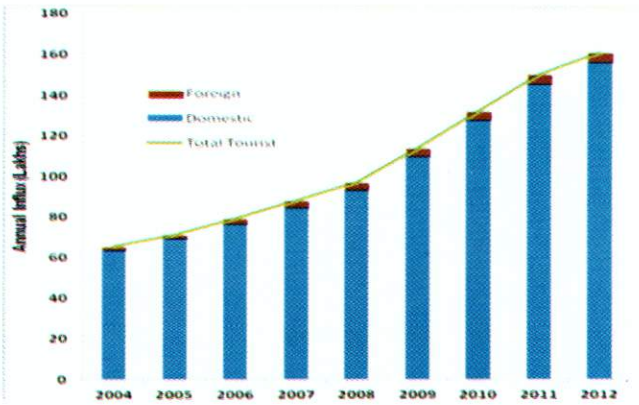


Fig.42. Profile of Annual Tourist Influx to Himachal

Study of Heavy Metals Transfer from Contaminated Soil to Food Chain and their Risk to Human Health in Himachal Pradesh *(2012–2015, DST, New Delhi)*

Human concerns on heavy metal contamination of vegetables are growing due to their ill health causing effects and non-biodegradable nature. Vegetables are rich source of minerals, vitamins, antioxidants, etc., for humans but increasing urbanization, industrialization as well as heavy use of pesticides, contaminated irrigation water, chemical fertilizers, solid waste composts with essential heavy metals like copper (Cu) and zinc (Zn) and non-essential heavy metals such as cadmium (Cd) and lead (Pb). The consumption of such contaminated vegetables can pose health threats to local population of Kullu, Himachal Pradesh which have more than 0.4 million population. There is scarcity of data on heavy metal contamination of vegetables and their risk to the local population, therefore the present study aims to study the transfer of heavy metals from contaminated soil to food chain and their risk to health of general public of Himachal Pradesh in general and Kullu in particular

Objectives

- To monitor the changing patterns of heavy metal contamination in vegetables grown locally and sold in urban markets of Kullu during different seasons.
- To monitor the heavy metal contamination levels in soil, water and vegetables collected from different production areas.
- To quantify the dietary intake of heavy metals through contaminated vegetables and their health risks to local consumers.
- To assess the influence of organic matter and sulfur on soil bioavailability of heavy metals and their accumulation in vegetable crops, grown on heavy metal contaminated soil.

Achievements

- Production and market sites for cauliflower (*Brassica oleracea* L. var. *capitata*), cabbage, (*Brassica oleracea* L. var. *botrytis*), radish (*Raphanus sativus* L.) and tomato (*Lycopersicon esculentum* L.) were selected for detailed investigation on status of heavy metal contamination of vegetables, water and soil.
- An initial analysis of vegetables sold in urban markets of Kullu during January-February 2013 revealed Cu, Zn, Cd and Pb concentration of 10.1-28.4, 33-45, 0.6-2.7 and 1.3-2.7, mg/kg dw, respectively (Table-10). Cd and Pb concentration in vegetables tested at market sites exceeded European Union (2002) and FAO/WHO (2007) safe limits. Whereas, Cu and Zn were found below their safe limits.
- Cadmium concentrations (mg/kg dw) in vegetables in market samples varied from 0.17 (Manali) to 2.37 (Patlikul), 0.13 (Nagger) to 1.29 (Nagwain), 0.17 (Bajaura) to 1.73 (Patlikul), and 0.37 (Kullu) to 5.54 (Bajaura) in tomato, cauliflower, cabbage and radish, respectively (Fig.43). The average Cd contamination level was found maximum in radish followed by tomato, cabbage and minimum in cauliflower.

Table-10: Minimum, maximum and average concentration of heavy metal in vegetables collected from market areas of Kullu, Himachal Pradesh during January-February 2013.

Vegetables		Heavy metals (mg/kg dw)			
		Cu	Zn	Cd	Pb
Tomato (n=8)	Minimum	7.55	7.55	0.15	0.79
	Maximum	28.35	64.50	2.58	2.04
	Average	15.99	32.95	1.44	1.26
Cabbage (n=8)	Minimum	1.85	6.00	0.16	0.23
	Maximum	22.30	70.50	1.88	4.45
	Average	10.13	34.90	0.81	1.83
Radish (n=8)	Minimum	3.84	28.04	0.36	0.01
	Maximum	46.90	87.68	5.69	7.60
	Average	20.16	51.45	2.71	2.69
Cauliflower (n=8)	Minimum	7.34	15.25	0.11	0.01
	Maximum	38.88	79.50	1.32	7.60
	Average	28.44	45.44	0.64	2.69
	Indian Safe Limit[a]	30	50	1.5	2.5
	WHO/FAO Safe Limit[b]	40	60	0.3	-
	EU Safe Limit[c]	-	-	0.2	0.3

n = Numbers of samples collected and analyzed in triplicates.
[a]Awashthi (2000); [b]WHO/FAO (2007); [c]EU (2006)

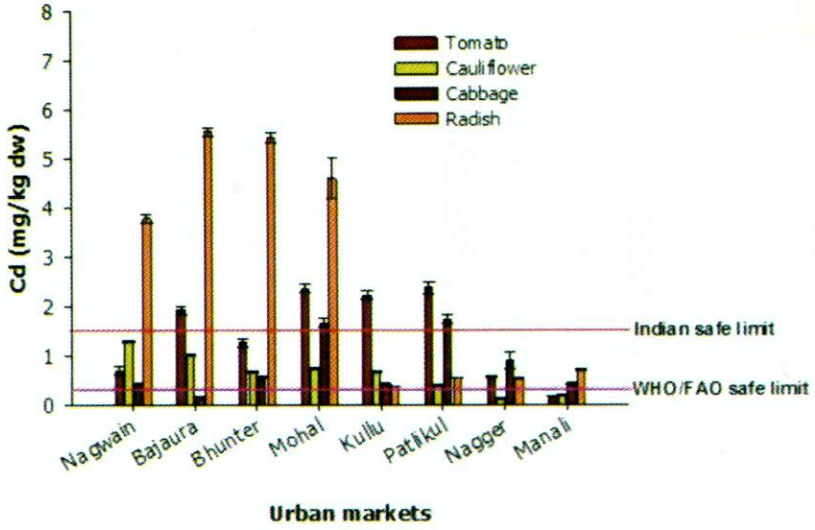


Fig.43. Spatial trends of Cd contamination in selected vegetables sold in urban markets of Kullu valley during January-February 2013.

Summary of Completed Project / Activity

Shifting Agriculture: Issues and Options with Focus on Adaptive Interventions to make it Ecologically, Economically and Socially Viable *(2007-2012, In-house)*

In northeast India, shifting cultivation, locally called as *jhum,* forms the primary agricultural practice mainly performed in upland areas.Nearly 4.5 lakh families practice shifting cultivation in the region (Table 11). In its natural form this agricultural practice was considered an efficient system of cultivation; however in recent times it has been considered untenable because of various reasons. It is also argued that in its distorted forms the practice not only reduces the agricultural outputs but also poses threats to the rich biodiversity. There are a large number of activities to amend the jhum system along with policy support. However, despite that the practice continues to be a predominant form of agriculture. Since the practice forms a way of life for many ethnic communities, there is a necessity to undertake work on shifting cultivation to make it a viable system. Considering this a project was undertaken with a focus to review the state and central policies in the forest and agriculture sectors dealing with shifting cultivation; reviewing the land tenure and customary laws of selected ethnic communities associated with this practice; document TEK on soil conservation, water and forest resource management and validation of indigenous knowledge; assessing impact of shifting agriculture on faunal diversity with special reference to avifauna and mammals; and most importantly identifying potential interventions and their application to make the system ecologically, economically and socially viable.

The study was conducted in seven districts of Arunachal Pradesh (viz. East Siang, West Siang, Upper Siang, Papumpare, West Kameng, Tawang and Lower Subansiri districts). The existing legislation/policies/acts, such as North East Forest Policy, 2001; Wildlife (protection) Amendment Act, 2002; Watershed Development in Shifting Cultivation Area, 1976-77;Balipara/Sadiya/Tirap Frontier Tract Jhum Regulation Act, 1947; Arunachal Pradesh Anchal Forest Reserve Act, 1975; Arunachal Pradesh Forest (Removal of Timber) Regulation Act, 1983; Assam Forest Regulation Act, 1891; and Forest (conservation) Act, 1980, etc., were reviewd and analysed for their positive and negative aspects in relation to shifting cultivation. At the same time the customary practices linked with shifting agriculture, such as festivals, rituals and rites,were documented.An analyses of two indigenous soil and water conservation (ISWC) practices, i.e., *Panpeng* of Adi community and *Phai*

of Nyshi community were carried out, which revealed that shifting agricultural fields with ISWC showed positive leanings for controlling soil erosion and maintaining its fertility in comparison to other fields without such practices. Identification and application of appropriate technologies and strategies to make shifting agriculture more productive is probably the singular challenge and provides options to address the issues.

To make shifting cultivation practice more sustainable, there is a need for concerted technology backstopping with relation to technology development/ modification, demonstration/ dissemination, adoption/adaption and capacity building/ enhancement, which are grossly inadequate in the region. The technologies should be simple and low cost based by using locally available resources. Development of an 'agro-horti-silvicultural model' by planting of multipurpose tree species in the jhum land along with improved practice of jhuming and its integration with horticulture and pisciculture along with conservation of forests found good community favour. The model is being implemented under 'Rehabilitation of Jhum area through integrated agro-horti-silviculture cultivation' by Govt. of Arunachal Pradesh under State Compensatory Afforestation Fund Management Planning Authority (CAMPA).

Ecotourism offers an appropriate option for better livelihood and has high potential in view of rich cultural heritage of the region. Interestingly communities are keen to adopt it in select areas. This is also being promoted in the form of Community Based Toursim (CBT) with a focus to increase community income and promote conservation of natural resources. CBT involves formation of management oriented village institutions. Considering that women are the backbone of hill agriculture, the gender perspective was also taken into consideration during the project implementation phase.

It is concluded that shifting agriculture when practiced with proper use of traditional ecological knowledge such as mixed cropping, traditional pest, insect &weed management, and soil conservation practices, zero tillage, *panpeng*and *phai*, etc. is a potential method to mitigate adverse impacts of climate change, provided the farmers are able to maintain, a longer fallow period along with the support of appropriate technological backstopping and have suitable options for agro-horti-silvicultural strengthening,and promotion of community based natural resource management.An enhanced capacity for achieving is and proper empowerment of community can certainly promote better livelihood from traditional systems.

Table-11. Area under shifting cultivation in different states of the northeastern India.

Studied villages	Average H.H. income /year (in '000 Rs.)							
	Income from Farming System				Govt. / private services / Pension	Labour	Business & tourism	Total
	Agri., Horti. and Tea cultivation	Cash crops** (vegetable & spices)	Fish**, dairy & poultry	NTFPs				
Jarapani	4.5	4.0	5.7	2.4	1.6	6.4	1.0	25.6
Juna	12.3	7.2	5.0	-	33.0	5.7	10.3	73.5
PingalKot	12.4	6.5	8.1	-	20.1	2.3	9.2	58.6
Gewar	17.9	12.3	9.7	-	19.0	3.7	9.5	72.1
MajherChaura	29.9	38.0	14.7	-	13.0	1.2	7.8	104.6
Bajwar	34.5	4.0	7.4	1.1	36.8	7.3	8.3	99.4
Lawbanj	42.2	8.9	7.6	2.6	32.0	4.3	8.6	106.2
Nakuri	7.5	6.7	8.8	4.3	32.7	3.3	10.3	73.6
Sauli	5.9	17.6	12.3	8.3	34.5	5.0	13.3	96.9
Badrinath	4.7	2.2	6.3	2.6	4.3	9.7	4.8	34.6
Dumloat	35.3	8.7	9.4	15.3	14.4	7.3	3.7	94.1
Pokhari	12.3	1.0	4.2	4.4.	7.3	13.7	2.3	45.2
Arah	36.8	9.3	7.8	4.2	7.9	1.7	12.7	80.4
Bantoli	46.6	1.0	1.4	-	39.6	5.4	3.3	97.3

Source: Primary survey; * Cash income/monitory equivalent (average of last 5 years), ** Supported through the project

Summary of Completed Project / Activity

Enhancement of Livelihood Security through Sustainable Farming Systems and Related Farm Enterprises in North-West Himalaya ***(2007-2012, World Bank- ICAR)***

The challenge of long term sustaining growth has been highlighted by several recent studies that find total productivity factor in agriculture declining between the 1980s and 1990s. The green revolution in wheat and rice, white revolution in milk, yellow revolution in oilseed' and the "blue revolution" in fisheries have augmented the food basket of the country. But the challenges of technological expansion, extension of services and adoption/ adaptation etc. are yet to be addressed. To address these challenges and to generate additional income and employment for the poor, the role of agricultural research and development (R&D) is critical. Given the limited scope for area expansion, increases in productivity, profitability and competitiveness will have to be the main parameters of agricultural growth in future and this should be led or triggered by advances and innovations in, and applications of science in agriculture. In other words, Indian agriculture will have to shift from resource or input-based growth to knowledge or science-based growth. Integrated farming system approach for improved livelihood through community based natural resources management has been identified for execution of the present project.Strengthening of inter relationship between different components of the hill farming system and dependency of the villagers on the natural resources has been taken into consideration. *The main emphasis of the present study is to improve the sustainability of the farming systems and natural resource management in less favorable environments. Particular attention has been given to rain-fed agriculture, common lands and waste lands of the Champawat and Tehri districts of Uttarakhand, adopting community based natural resource management and village cluster based approach.*

Harvesting of grasses has started during the second year of prototype development and a total of 18.76 tons of green grasses have been harvested by the village communities of 5 clusters of Chmpawat and Tehri districts during the year. **Cultivation of MAPs and flowers has emerged as short term benefit ensuring option which has proved more beneficial than traditional agriculture. Provision of sufficient planting material from 5 mother nurseries and promoted cultivation of Six MAPs (7.2 ha) and 2 varieties of cut-flowers (8.32 ha) for ensuring short term benefits to the farming community through participatory approach was done.** Signing of MoUs was facilitated with pharmaceutical companies after providing legal status to the 132 MAPs growers. Processing of raw material of MAPs is in progress after establishing an oil extraction unit and providing required training to the local farmers. A total of 21.68 quintals raw materials of selected MAPs and 157060 spikes of cut-flowers were harvested by farmers in all clusters after fourth year of cultivation. This has provided a sum of Rs. 9,72,820.0 net monetary benefits after marketing of their produce to the traders in the local market. Emphasis has been given to the harvesting and storage of water, soil/ water conservation practices and mass scale cultivation of improved grasses on degraded /waste lands as well as terrace bunds and risers of agricultural land. Four water harvesting structures for storing rain water have been constructed and stored water is being used for life saving irrigation during summers and winters. The horticultural models in village clusters of Tehri district have started production and village level collection centers have been developed for collection and packaging under village management committees.

Table-13. Average seasonal production and net income from floriculture in selected clusters of Champawat (Rs/ Nali*)

Cultivated flowers	First season (March-June, 2012)				Second season (July- October, 2012)			
	Production (Spikes)	Market Cost/ spike	Cultivation costs	Net income	Production (Spikes)	Market Cost/ spike	Cultivation costs	Net income
Gladiolus	930	4.0	1010.0	2700.0	880	6.0	1380.0	3900.0
Lilium	410	18.0	2080.0	5300.0	400	25.0	3160.0	6840.0

**1 Hectare = 50 Nali*

Summary of Completed Project / Activity

Pesticide Residue Contamination of Food Chain: Appropriate Monitoring and Control Measures from Field Studies in Himachal Pradesh *(2009-2012, In-house)*

The contamination caused by pesticide residues resulting from their indiscriminate use in agriculture and horticulture is one of the growing environmental concerns as it contaminates water, soil and the food chain, thus posing a serious risk to human health. Management of pesticide residues is essential. As limited data are available on pesticide residues contamination of environmental matrix in hilly areas, the present study was undertaken with a focus to assess pesticide residue levels in soils, water and crops grown locally and sold in local markets; dietary exposure of local consumers to pesticide residue through contaminated crops and their health risks by comparing generated database with their maximum residue limits (MRLs); effect of household practices on reduction of pesticide residue levels in edible part/s of crops, and the effect of organic matters on accumulation of pesticide residues in edible parts of crops. The salient achievements of the study were as follows.

Surface water, soil, apples, cauliflowers and tomatoes collected from different markets and production sites in Kullu were found contaminated with residues of endosulfan, chlorpyrifos, cypermethrin and malathion, however the concentration was below the permissible pesticide residue levels in these crops. The concentrations of residues of these pesticides in the above crops were found higher at production sites as compared to at market sites. Daily intake of these pesticide residues via consumption of apples, cauliflowers and tomatoes were recorded higher in male than female population. Consumption of pesticide residues via apples, tomatoes and cauliflowers were further found within the accepted daily intake (ADI).

Washings of crops with tap water and peeling of apples reduced concentrations of pesticide residues in crops and apples, respectively as compared to unwashed/unpeeled samples. Organic matter(farm yard manure, vermi-compost, municipal compost, etc., amended soil reduced cypermethrin and chlorpyrifos induced oxidative damages in cauliflower plants grown on soil contaminated with pesticide residues. The local farmers and stakeholders were also made aware about the strategies needed to reduce the health risks of pesticide residues by conducting a training programme. The present study concludes that current practice of using chemical pesticides at contaminated surface water, soil and crops with their residues, yet, their contamination levels were found within the recommended safe limits. It is suggested that impacts of these pesticide residues on soil and aquatic micro-organisms needs to be studied in detail for their proper management in soil for sustaining agriculture in Kullu, Himachal Pradesh.

Summary of Completed Project / Activity

Biodiversity Conservation through Community Based Natural Resource Management in Arunachal Pradesh *(2008-2012, GOI-UNDP CCF-II)*

Northeast region is India's biological frontier being the biologically richest area in the country. Arunachal Pradesh comprise maximum land area among all north-eastern states and is inhabited by 26 major and 110 minor indigenous communities. It has also been designated as a globally important Endemic Bird Area as out of the 1200 bird species in India, nearly 600 have been recorded from Arunachal. Culturally, it is also quite rich being home to several diverse inhabitants. However, the rich bioresource of the state, particularly its fauna, is being seriously threatened in the recent time under various forces. Therefore, an effort has been made through this project to conserve the rich biodiversity of the state, through community participation and adopting an integrated approach embracing the acknowledged fact that biodiversity conservation approaches do not work in isolation of the traditional communities inhabiting along side the forest fringes. The project focuses on local human resource development and a mechanism to institutionalize the process of environmental sustainability through formation of community based institutions and their involvement in the entire process of interventions for biodiversity conservation and livelihood development. The project envisages to develop viable, replicable and effective community based natural resource management initiatives in the proposed Tawang-West Kameng Biosphere Reserve (TWKBR) and Apatani Plateau in Lower Subansiri District of Arunachal Pradesh by providing incentives to the local communities to effectively conserve and enhance biodiversity.

The project initiatives comprised strengthening of Community Based Tourism (CBT) as a potential alternate to livelihood and biodiversity conservation. CBT was promoted in TWKBR, while a model for culture based tourism was developed inApatani plateau. In TWKBR, capacity of villagers was enhanced through organization of training workshops for various stakeholders for income generation and site management.Trainings were organized for villagers comprising home stay operators, home based restaurant operators, pack animals, porters, guides, cooks and cook helpers, cultural programs, local handicrafts and camp managers. Earning scope for Community Conserved Area Management Committee (CAMC) was identified that comprised CCA entry fee, camera fee, trekking camping site charge, camping accommodation charge, village camp site accommodation charge and CCA conservation fee. In Apatani Plateau, a culture based ecotourism model was developed in association with Achukuru Welfare Society (AWS) that comprised kitchen garden, nursery, community based sales counter, museum, duckery unit and pisciculture, etc., developed over a pond. Two traditional cottages with standard living facilities were also constructed over a pond in the model site. In order to supplement the traditional cottages, toilet cum bathroom facility was developed to attract tourists. The bund of the pond was utilized for developing a kitchen garden that exhibits the rich floral diversity used traditionally for medicinal (ethnobotanical) and edible purposes.

Community based sales counter has been developed, which acts as a platform to exhibit and sell the locally made products such as bamboo based handicraft items, wood carvings, beads, ornamental items, etc., to tourists visiting the CBT model. Other than the above mentioned interventions, selected policy briefs were also prepared to influence and promote community based tourism, which comprised Guidelines for promotion and Management of Community Conserved Areas in Arunachal Pradesh, and Arunachal Pradesh Ecotourism Policy; these were submitted to State Government of Arunachal Pradesh. The *visible* outcomes of CBT activities at Apatani plateau revealed that the community started cultivation of medicinal plants along with seasonal vegetables. Similarly at TWKBR the villagers started conserving rare and threatened flora and fauna at Thembang Bapu CCA through joint initiatives. The Community Conservation Area Management Committee (CCAMC) has started apprehending tourists if involved in illegal collection of beetles and wild mushroom; destruction route animal traps, if any; putting ban on commercial collection of firewood, medicinal plants, hunting and fishing. In order to reduce the intensity of hunting, efforts were made to understand, identify and prioritize human-wildlife conflicts and list the animal species (Table-14) having conflict with humans in the study areas.

Table-14: List of the animal species having conflict with humans.

Species	Conflict			
	Livestock depredation	Crop raiding	Hunting	Conflict intensity
Snow Leopard (*Unciauncia)*	√		√	+++
Arunachal Macaque *(Macacamunzala)*	–	√	√	+++
Asiatic Wild Dog or Dhole (*Cuonalpinus*)	√	–	√	+++
Indian Porcupine (*Hystrixindica)*	–	√	√	+++
Wild Pig (*Susscrofa*)	–	√	√	+++
Resus Macaque (*Macacamullata)*	–	√	–	++
Yellow Throated Marteen*(Martesflavigula*)	√	–	–	++
Dog *(Canisfamiliaris)*	√	–	–	++
Asiatic Black Bear (*Ursusthibetanus)*	√	√	√	++
Capped Langur *(Trachypithecuspileatus*)	–	√	√	+
Marble Cat (*Felismarmota)*	√	–	√	+
Bandicoot Rat (*Bandicotaindica)*	–	√	–	+
Common Leopard (*Pantherapardus*)	√	–	√	+

Summary of Completed Project / Activity

Cultural Landscape: The Basis for Linking Biodiversity Conservation with Sustainable Development of Arunachal Pradesh, India *(2008-2012, UNESCO-McArthur Foundation, New Delhi)*

Cultural landscapes are complex socioeconomic expressions of ecosystems that have co-evolved under the influence of biophysical factors as well as of human societies at different levels of their cultural, social, and technological development. Human cultures have always been influenced and shaped by the nature of the ecosystem. At the same time, mankind has also influenced and shaped its environment to enhance the availability of certain valued services. Unless ecosystem management is firmly rooted in the local cultural ethos, it can affect the livelihood concerns of people, particularly marginalized societies living in the fringe of the forests, causing social disruptions and ecological degradation. Therefore, the way of life of the traditional communities living near bioresources must be comprehensively understood and be integrated in biodiversity conservation strategies for effective conservation and sustainable development. Keeping this in view, this study is aimed at addressing biodiversity conservation with concern for sustainable development of traditional communities living in the mega cultural landscape along an altitudinal transect of the Tawang and West Kameng districts in Arunachal Pradesh.The area is inhabited by Monpa and Sherdukpen communities along with Mijis (Sajolang), Buguns and Akas. Two minor tribal communities Lishpa and Chugpa also inhabit the region.

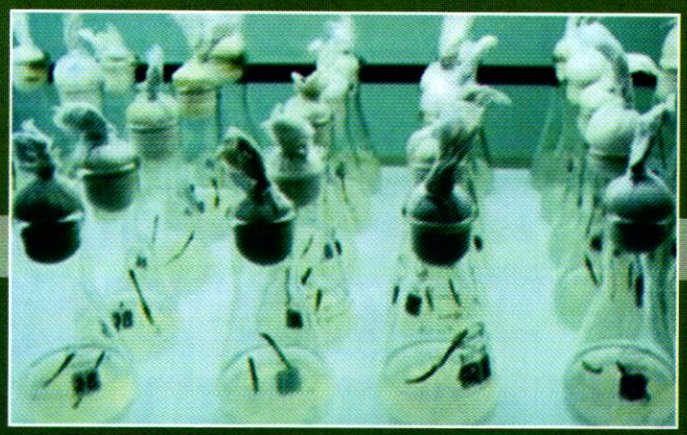
Detailed landscape analysis was done along with figuring out the linkages between natural and human-managed ecosystems and the manner in which they are linked to the village ecosystem functioning. An assessment was made to evaluate traditional ways of management of biomass, soil fertility and water resource conservation and the kind of eco-cultural drivers that ensure effective management of these resources. Further, detailed analysis of the culture-based non-codified institutional arrangements, such as the organisation of cultural calendar linked to the biophysical dimensions of the ecosystems that they are concerned with, issues related to competition vs coexistence of different ethnic groups within and outside the identified boundaries of the cultural landscape and their implications for sustainable use of natural resources within and between societies, and the role of institutional arrangements for effective management of natural resources with emphasis upon the traditional institutional arrangements, were also attempted.

It was found that Monpas traditionally classified the forests into five land use types based on ownership viz. *Mangijombana* (traditional council owned), *Borang* (community owned), *Ja-dung Borang* (village forest), *Ja-sesing* (oak forest – individually owned), and *Lenchong-sing* (pine forest-individually owned). Each category has importance from the perspectives of resource use and plays a significant role on socio-economy of the community, and has intricate linkages with the traditional agro-ecosystem. The land ownership of all the tribes showed a well-demarcated area under the jurisdiction of individual tribes administrated by a traditional village council headed by a chief or headman or by village secretary and president in some cases. Majority of the land belongs to village community with few exceptions of clan and individual land areas prominently seen in Aka communities practicing settled agriculture.

The communities have high dependency on natural resources for meeting their food, fodder, fiber, construction, handicrafts, beverages, colouring agents (dyes) and health care needs. The traditional grazing systems among the Monpas of Zimithang Circle, Tawang revealed that the Monastery has been playing a major role in controlling the tax in the area. The communities have traditionally developed strategies of conserving biological resources and such practices are governed by rituals and customs. Religious institutions like Monasteries (Gompas) are playing a vital role in conserving selected species, such as *Cupressus cashmeriana, Cupressus torulosa, Thuja orientalis, Pinus roxburghii, Pinus wallichiana, Cryptomeria japonica, Juniperus* sp., *etc.* There was a restriction on use of certain plant species and patches of forests in the name of local deities. From the point of view of the cultural and spiritual value, the whole Panchenpeng valley along with the Gorchemchorten and Shockseng Gompa is considered as sacred by the local Monpa people, where hunting and fishing are totally banned.

Twenty four plant species are ranked higher in cultural and traditional belief system of Sherdukpens and therefore these species were conserved. The various animal body parts that are being traditionally used by Monpas in various aspects e.g. food, therapeutic purposes, traditional medicine and for storing various food grains and products were documented. A total of ten species were recorded out of which species like Musk deer (*Moschus moschiferus)*, Common Leopard (*Panthera parades),* Tiger (*Panthera tigris)*, Asiatic Black Bear (*Urasus thibetanus)*, Arunachal Macaque *(Macaca munzala)*, Capped langur (*Trachypi thecuspileatus)* and Himalayan Goral *(Naemorhedus goral)* were endangered species. An investigation of the social and cultural values associated with high altitude lakes, viz. Bangajan, Nagula, PangchenLumpoMuchat and Thembang Bapu revealed their vital role in conserving wetland biodiversity and landscapes. Various intangible cultural practices like painting, folklore and folktales, which are directly and indirectly associated with biodiversity conservation were also documented.

An analysis of various food habits of Sherdukpen tribe revealed eight ethnic food items, viz. *Hu jyo, Bokpi, Thukpa, Momo, Loco Momo, Khapse, Chukchro* and *Churpi*. Besides, the indigenous drink (*phok)*, and alcoholic beverages (*Nodok Phok, Bukku Phok, Gacham Phok, Ningri*and *Ara*) were also documented. Trying to understand the influence of Thai architecture on the monasteries, it was observed that the monastery of Chillipam area of West Kameng district is influenced by Thailand architecture in its structural design. This religious structure shows the change in culture in the traditionall design in monastery construction.



Theme

BIOTECHNOLOGICAL APPLICATIONS (BTA)

Three major groups of bioresources, viz. plants, animals and microorganisms are being addressed under this Theme. Plants are the primary producers, hence a thorough understanding of the factors that govern their productivity and functioning is of paramount importance especially in the light of harsh environmental conditions prevailing in the Himalaya, and current concern about the global climatic change. An understanding of the mechanism of plant adaptation is necessary as it helps in increasing productivity of the plants. Plant propagation packages, addressing the need of local people, are being developed using conventional and biotechnological tools; moreover, studies on phytochemical and molecular profiling of medicinal and aromatic plants are underway.

Documentation of animal and microbial diversity is equally important. A study on diversity and locally useful species of fish is underway in Arunachal Pradesh. Exploration on microbial diversity with special reference to rhizosphere micro-organisms has been carried out which has led to the formulation of carrier based bioinoculants for mountains. The micro-organisms that thrive under extreme environments, from polar deserts to geothermal springs, are referred to as extremophiles. Psychrophiles and thermophiles, in particular, have got special attention and are being explored for their diversity, biotechnological applications and the strategies adapted for survival under extreme climatic conditions of IHR. The theme envisages: i) Identification and documentation of bioresources of applied value of IHR, ii) Generation of technological knowhow of the process development, and iii) Human resource development.

Promoting Conservation and Sustainable Utilization of Himalayan Biodiversity Elements using Biotechnological and Physiological Approaches ***(2012-2017, In-house)***

The ecological and economical importance of biodiversity for maintaining the environmental balance and socio-economic development of the inhabitants has been realized throughout the globe. At least 40% of the world economy and 80% of the needs of poor people are derived from biological resources. Among the world mountain ecosystems, the Himalayan ecosystems have special significance as they support representative, natural, unique and economically important biodiversity. But, high anthropogenic pressures coupled with changing environmental conditions has resulted in rapid depletion of the ecologically and economically important elements of biodiversity. Realizing the importance of biodiversity for the sustenance of inhabitants and overall environmental conservation, the attempts at local, regional, national and global levels have increased considerably and concerns of both ecologists and economists are being considered together to evolve workable strategies at different levels for the sustainable development. Therefore, biodiversity conservation and harnessing its potential for overall development of the region have emerged as national

and global priorities. A very few studies have been focused on population assessment, developing propagation (conventional & biotechnological) protocols, cultivation packages, including agrotechniques of ecologically and economically important plants and *ex situ* and *in situ* conservation. Moreover, studies on physiological and biochemical basis of plant adaptation to stress under varied environmental conditions would be necessary not only to understand the basic mechanism but also to supplement the above studies. Investigations on phytochemical and genetic diversity of various populations have been considered for screening elite populations/clones. The combined outputs of the above mentioned studies would be helpful in promoting awareness among the inhabitants. Therefore, the present study has been proposed to address the above issues across the Himalayan region, contribute for the conservation and sustainable use of biodiversity elements and linking database with national, regional and international levels.

Objectives

- Understand the patterns of physiological, biochemical and genetic responses of sensitive and high value biodiversity elements in different altitudinal as well as longitudinal regimes in the Himalayan region.
- Evaluate the responses in different propagation systems of sensitive and high value biodiversity elements, use of biological material for hardening and genetic fidelity analysis of propagated plants in order to optimize the suitable methods for large scale production of quality plant material production.
- Establishment of demonstration models, development of dissemination packages on cultivation and establish *ex situ* gene banks of elite planting materials.
- Inculcate awareness among the diverse stakeholders about the potential benefits (including value added products) and benefit sharing mechanisms.

Achievements

Headquarters, Uttarakhand

- A two days stakeholder consultation cum brain storming meeting was organized at G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal under the project with a major aim to optimize the benefits from selected high value plants to the people in the region.
- Initially six different species namely *Aconitum heterophyllum, Cinnamomum tamala, Origanum vulgare, Picrorhiza kurrooa, Rosmarinus officinalis and Valeriana jatamansi* were selected for detailed study. Collection of plant material from different populations representing varied habitat conditions and diverse altitudinal zones has been initiated. Collected plant materials from diverse locations were planted in Surya-Kunj, Nature Interpretation and Learning Center and proper accessioning of each individual was done. Preliminary screening of *Valeriana jatamansi* for DNA damage prevention analysis was done.
- *In vitro* propagation protocol is being developed for *Valeriana jatamansi* (a source of Valerian); aseptic cultures have been established and multiple shoots have been obtained on MS medum; these shoots are being rooted and subsequently the rooted plants will be assessed for genetic fidelity and growth performance in the field conditions.

Himachal Unit, Himachal Pradesh

- For the up scaling of seed germination protocols, *Carpinus viminea, Pittosporum eriocarpum* and *Corylus jacquemontii* (Multipurpose Tree Species; MPTs), and *Aconitum heterophyllum, Skimmia laureola* and *Withania somnifera* (High Value Medicinal Plants; HVMPs) and conventional propagation protocols, *Buxus wallichiana, Ulmus wallichiana* and *Cinnamomum tamala* (MPTs) and *Paris polyphylla, Lilium polyphyllum, Trillium govanianum* and *Ferula jaeschkeana* (HVMPs) were selected. Review of literature on various aspects of these species was done.
- Six sites namely: Solagnala, Madhi, Rohtang Pass, Prini, Naggar and Garsa in Kullu district of Himachal Pradesh were surveyed and selected for the detailed investigation on assessment of biochemical diversity of Nagchatri (*Trillium govanianum*) and Himalayan Lily (*Lilium polyphyllum*) and for development of their propagation protocols.
- A One day Training Programme on "Biodiversity

Conservation and Management in Relation to Climate Change" was organized at Govt. Senior Secondary School, Baldwara, Mandi, Himachal Pradesh on March 23, 2013. Capacity building of the 132 students and teachers representing 08 Schools and local inhabitants was done through a comprehensive lecture on Biodiversity Conservation and Management in relation to climate change; propagation techniques, practical exercise of the participatory rural appraisal, and qualitative (rapid sampling & identification of species) and quantitative assessment (quardrat method) of biodiversity (Fig.44 A&B).

- Over 300 seedlings of *Withania somnifera* and *Grevillea robusta* were distributed to Schools of Kullu valley.

Fig.44. (A-B). A- Training Programme at GSSS, Baldwara, Mandi; and B- Demonstration of quantitative assessment of floristic diversity.

Sikkim Unit, Sikkim

- Plants of *Quercus lamellosa* have been multiplied both by conventional and tissue culture methods for large scale production. About 500 seedlings are growing in net house through conventional method for reintroducing in natural habitat (Fig.45).
- Micropropagation method was developed for *R. nevieum* (State tree of Sikkim) from the cotyledonary nodal segments of 7-week-old seedlings. Maximum multiplication of shoots was observed in Anderson medium containing 25 µM 2iP with phytagel (0.3%). At present the total number of *in vitro* multiple shoots is over 1000. Elongated shoots from proliferated shoots required 1.0 µM IBA for rooting. More than 200 tissue culture raised plants have been transferred to pots containing peat moss and garden soil for hardening (Fig.46).
- Micropropagation studies of *R. griffithianum* are continuing. Shoot proliferation of *R. griffithianum* has been obtained and multiple shoots have been placed for rooting.
- Different nursery infrastructures have been maintained and improved, and the seedlings and saplings were monitored for their survival.
- Functional arboretum continuously maintained and improved and over two dozen of woody taxa viz., *Michelia doltsopa, Michelia velutina, Michelia cathcartii, Alnus nepalensis, Saurauia nepalensis, Pieris ovalifolia, Ficus* sp., *Castanopsis tribuloides, Daphniphyllum himalayense Symplocos glomerata, Quercus lamellose,* etc. were recorded for their phenology.
- A One day Training Workshop for the students and teachers from five schools of Sikkim was organized; over 30 outsiders participanted.

Fig.45.* Conventional methods for propagation of *Quercus lamellose.

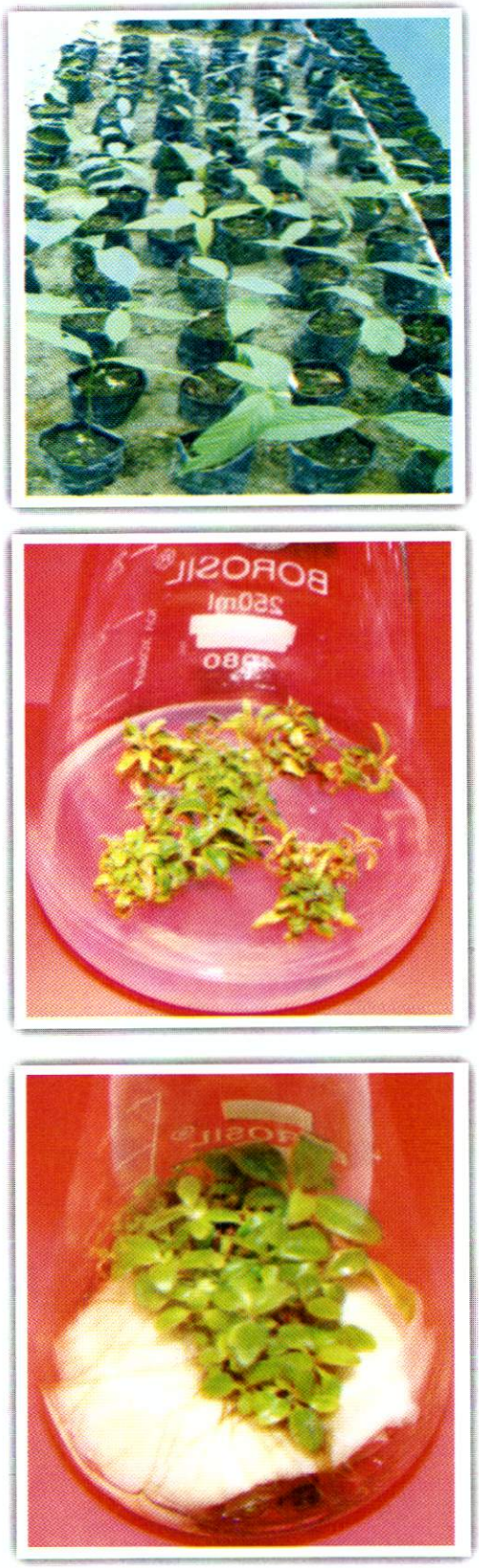


Fig.46. In vitro **propagation of *R. griffithianum*: (a) established shoots derived from nodal segment grown on AM medium supplemented with 2 iP, and (b) root induction from *in vitro* regenerated shoot on liquid AM medium with IBA.**

- **Garhwal Unit, Srinagar**

  Studies on the imposition of drought stress in potted *Panicum miliaceum* plants at anthesis and 10-day after anthesis stage clearly show sharp reduction in biomass production, grain number and grain weight as compared to control plants (Table-15). Drought stress at anthesis stage led to no grain formation in stressed plants. Further, biomass production also reduced by 66 % compared to control plants. Approximately 10% reduction in biomass production was observed in plants exposed to drought stress 10- days after anthesis, but the number of grains produced and the grain weight declined by 73% and 81%, respectively as compared to control plants. These data clearly indicate the importance of anthesis and post-anthesis stage in yield and biomass production in *P. miliaceum*.

Table-15. Impact of drought stress at anthesis and 10-day after anthesis on biomass production, grain number and grain weight in *Panicum miliaceum*. Values are in percentage of control plants.

Treatment	Biomass (%)	Grain number (%)	Grain weight (%)
Control	100.00	100.00	100.00
Anthesis	33.65	0.00	0.00
10-day after anthesis	89.90	26.67	19.44

Extremophiles from Himalaya: Ecological Resilience and Biotechnological Applications *(2012-2017, In-house)*

The Microbiology Laboratory of the Institute has taken initiatives on various microbiological research aspects of IHR, covering a wide altitudinal range in the last two decades. The focus of these studies has been on the isolation, characterization and the associated applications. A high altitude microbial culture collection, including extremophiles, has been developed in the laboratory over the years. One important issue, complementary to these studies, that requires attention is 'ecological resilience' possessed by these micro-organisms. Besides, microbial activities performed under extreme climates are likely to have applications of 'environmental' as well as 'biotechnological' importance. The present proposal is,

thus, formulated to address these issues considering the characterization of extremophiles with particular reference to their biotechnological applications and ecological resilience. Selected cultures, that have been established as suitable bioinoculants, will be used for conducting nethouse / greenhouse / field assays with particular reference to (1) improved plant health, and (2) reducing the heavy metal load at contaminated sites (in collaboration with Kullu and Sikkim unit).

Objectives

- Phenotypic and genotypic characterization of extremophiles, inhabiting the extreme climatic regions in IHR (HQs), heavy metal contaminated sites (Kullu unit) and rhizosphere micro-organisms (Sikkim).
- Determination of microbial activities, with special reference to production of secondary metabolites, such as enzymes, pigments, antimicrobials, and the role of suboptimal conditions on microbial growth and related activities, in view of their survival under extreme temperature conditions (HQs).
- Applications of promising microbial cultures in environmentally important aspects, such as, improved plant growth through inoculation, biological hardening of *in vitro* raised and conventionally developed plants (HQs & Sikkim unit), and phytoremediation with particular reference to heavy metal contaminated sites (Kullu unit) under mountain ecosystem.
- Preservation and Accessioning of microbial cultures and gene sequences in Microbiology (GBPIHED) Laboratory / National / International Culture Collections and Gene Banks (through HQs for the entire project).

Achievements

- Thirty five thermotolerant bacterial isolates have been subjected to morphological, physiological and biochemical characterizations. The bacteria have also been screened for enzymatic activities.
- Plants regenerated through multiple shoot induction from shoot tips of *Rhododendron niveum* and nodal explants of *R. griffithianum* have been selected for bacterial inoculation experiments. Suspension cultures of *Bacillus subtilis* and *Pseudomonas putida*, originally isolated from temperate locations in high altitudes have been selected for inoculation.
- Heavy metal contaminated sites have been selected in Kullu region and methodology for isolation of heavy metal resistant microbes is being standardized.
- Leaf and rhizome extracts from a medicinal herb, *Berginia ligulata*, are being analyzed for biochemical constituents, particulary antimicrobials.

Characterization of Pyschrotolerant Fungi with Particular Reference to Lignin Degradation under Mountain Ecosystem *(2010-2015, ICMR, New Delhi)*

Lignocelluloses are mainly present in the wood cell wall where lignin acts as a barrier against microbes. Lignin is a natural biopolymer which is abundant in nature. Biodegradation of lignin is a crucial step in the global carbon cycle. There are three categories of fungi which can degrade lignin: White rot, brown rot and soft rot. Brown rot fungi are basically basidiomycetes which can modify lignin by demethylation and they have preference for coniferous substrates. Biodegradation is a slow process under low temperature environments. The present project is based on isolation and characterization of cold tolerant ligninolytic fungi with reference to their biodegradable abilities under low temperature environments of IHR.

Objectives

- Characterization and screening of fungal isolates for lignolytic activity.
- Characterization of enzymes involved in lignin degradation.
- Study of molecular diversity of laccase gene in the positive isolates.

Achievements

- Laccase production by a newly isolated temperature and pH tolerant fungal strain (GBPI-CDF-03) from glacial site in IHR has been investigated. The fungus developed a white cottony mass on potato dextrose agar and revealed thread like mycelium under microscope. ITS region analysis showed its maximum similarity with *Trametes hirsuta*. The fungus tolerated temperature from 4- 48 °C ± 2 (25 °C opt.) and pH 3-13 (5-7 opt.). Molecular weight of laccase was determined approx 45 kDa by Native PAGE; the amplified laccase gene fragment contained 200 bp. The

fungal laccase oxidized ABTS, guaiacol, syringaldazine and DMP in plate assays, at optimum growth temperature. The efficiency for production of laccase was higher at suboptimal temperatures. The optimum pH for laccase production, at optimum growth temperature, was determined between 5.5 to 7.5. In optimization experiments, fructose and ammonium sulfate were found to be the best carbon and nitrogen sources, respectively, for enhancing laccase production. Addition of $CuSO_4$ (up to1.0 mM) induced laccase production; maximum being with 0.4 mM. Addition of organic solvents also induced the production of laccase; acetone being the best. The study has implications in bioprospecting of ecologically resilient microbial strains for biotechnological applications.

Preventing Extinction and Improving Conservation Status of Threatened Plants through Application of Biotechnological Tools (Operating Separately in Headquarters, Himachal Unit & Sikkim Unit)
(2012-2017, Department of Biotechnology, New Delhi)

Biodiversity is most valuable for the human beings directly, indirectly, aesthetically and ethically. The Indian Himalayan Region (IHR), a part of the Himalayan Global Biodiversity Hotspot, supports a representative, natural, unique and socio-economically important biodiversity. The rural population of the region is largely dependent on biodiversity for their sustenance as it provides various services to the mankind for sustenance. But, due to over exploitation and habitat degradation by various reasons, the biodiversity is depleting at an unprecedented rate. About 142 species of vascular plants have been listed in the Red Data Book of Indian Plants and 120 species of medicinal plants in different threat categories using IUCN criteria. Most of them are native to the Himalaya and very well known for their socio- economic and conservation values. Continued over-exploitation and habitat degradation of these species may result in their extinction within a few years. Therefore, in view of the ecological and economical importance of such species, there is a need for the population inventory, Ecological Niche Modeling (ENM), meta-population characterization, molecular and biochemical profiling of the populations (species with relatively wider distribution as well as those facing extinction), reproductive biology studies, standardization of tissue culture and other macro-propagation techniques, and reintroduction of the species for genetic enrichment and ecosystem/species restoration. The study aims to test the hypotheses that the biotechnological tools can help in improving the conservation status of the threatened species.

Objectives

Headquarters

- Quantitative assessment of geographic distribution and status of populations of target medicinal plants, i.e. *Angelica glauca, Dactylorhiza hatageria, Paris polyphylla, Podophyllum hexandrum* using Ecological Niche Modeling.
- Identification of conservation bottlenecks and requirements of the abovementioned species, and development of a species-species conservation plan.
- To analyze the morphological and biochemical diversity among selected populations for identification of elite individual/populations in *Angelica glauca* and *Podophyllum hexandrum.*
- To refine and upscale the existing propagation protocols (using conventional and biotechnological tools) for reintroduction of species.
- To develop suitable methods for reintroduction of the selected species in their natural habitat and reintroduction of adequate number of plants of *Angelica glauca, Dactylorhiza hatageria, Paris polyphylla* and *Podophyllum hexandrum.*
- Raising awareness and imparting conservation training with the involvement of communities/ Forest Department.

Himachal Unit

- To assess, map and monitor the populations of selected threatened plants in Himachal Pradesh, North Western Himalaya.
- To develop Ecological Niche Models for predicting the potential areas of distribution of the selected species.
- To develop seed germination and vegetative propagation protocols.
- To establish and maintain threatened species in *ex situ* and *in situ* conditions.

Sikkim Unit

- To assess, map and monitor the populations of threatened plants in Sikkim Himalaya.
- To develop Ecological Niche Models for predicting the potential areas of distribution of the selected species.
- To develop seed germination and vegetative propagation protocols.
- To establish and maintain threatened species in *ex situ* and *in situ* conditions.
- To develop efficient micro-propagation protocols for mass propagation of a selected number of threatened plants.
- Performance evaluation of seedlings, plants raised through tissue culture and vegetative means in arboretum as well as under field conditions.
- To establish a field gene bank incorporating all possible species populations.

Achievements

Headquarters

- Seeds and tuber/rhizome of target species were collected in the month of May & June, and these are being used for various experiments. Seed moisture content and viability tests were performed.
- Experiments to influence seed germination in *Angelica glauca* were examined under laboratory conditions following different plant growth regulator treatments; more than 50% germination was observed following treatment with 25µM GA_3 + 25µM BAP, and 250µM GA_3 + 250 µM BAP (compared to 0% in control) after 4 weeks.
- Aseptic cultures were established using embryos for mass multiplication of *Podophyllum hexandrum*. The seeds were thoroughly washed with disinfecting agents and cultured on MS medium for germination; following germination the embryos were cultured in medium containing different combinations of plant growth regulators.
- Tubers/rhizomes of *Podophyllum hexandrum* and *Angelica glauca* collected from higher altitudes were sown in pots and growth, morphological characteristics were recorded periodically.

Himachal Unit

- Twenty nine populations of *Arnebia euchroma* occurring between 3,710– 4,394m, asl were studied in the Lahaul & Spiti and Kinnaur districts of Himachal Pradesh (Fig.47). The total shrub density ranged from 40-1190 Ind ha^{-1}; total herb density 4.60-70.55 Ind m^{-2} and relative density (%) of *Arnebia euchroma* ranged from 0.68-41.04 % in the sampled populations. The richness of shrubs ranged from 1-6 and herbs 4-27.
- Forty two distributional record data and bioclimatic variables were utilized for the prediction of potential areas of *Arnebia euchroma* with the help of ecological niche modeling packages. The model test for *Arnebia euchroma* yielded satisfactory results (AUC_{train} = 0.998 ± 0.0015 and AUC_{test}= 0.997 ± 0.001). Amongst the predictor bioclimatic variables, Precipitation Seasonality (BIO 15, Coefficient of Variation); Precipitation of Driest Period (BIO 14) and elevation were the most influential and contributed 39.7%, 22.4% and 16.6%, respectively to the Maxent model.
- Seeds of four populations of *Angelica glauca* were collected from the surrounding area of Barshaini, Shilla and Malana in October 2012. Seed germination trails have been conducted in the laboratory in controlled condition by using the various seed dormancy breaking chemicals. Monitoring of germination of seeds is in progress.

Fig.47. Map showing populations of *Arnebia euchroma* in Himachal Pradesh.

Sikkim Unit

- Studies on improvement in seed germination of *Phoenix rupicola* and *Rhododendron leptocarpum* using simple soil treatments were undertaken (Fig.48). These critically endandgered species *Phoenix rupicola* and *Rhododendron leptocarpum* were subjected to germination studies on 7 types of soil, viz., – forest soil, sterile soil, rhizosphere soil, garden soil, and rhizosphere soil: garden soil (1:3, 1:1, 3:1, v/v).
- In order to develop *in vitro* propagation protocols, seeds of *Phoenix rupicola* and *R. leptocarpum* were used for tissue culture studies. For *Phoenix rupicola* following surface disinfestation steps, complete embryos were extracted from seeds and placed on culture medium. The basal medium containing BAP (0.5-25µM) and GA_3 (3 µM) or IBA (5µM) were tested. WPM medium with 0.5-25µM BAP, combinations of IBA and GA_3 and hormone free WPM medium with antioxidants were also examined for the germination of somatic embryos (Fig.49). No conclusive correlation could be established between medium salt, plant growth regulators and percent response.
- In *R. leptocarpum* seeds were germinated under aseptic conditions where about 30-35% germination was achieved on hormone-free MS medium (Fig.50). These seedlings were further used for shoot multiplication. While comparing the effect of cytokinin type (2iP, Zeatin and TDZ) on shoot formation, the best response was achieved in AM medium supplemented with 2iP (Fig.51).

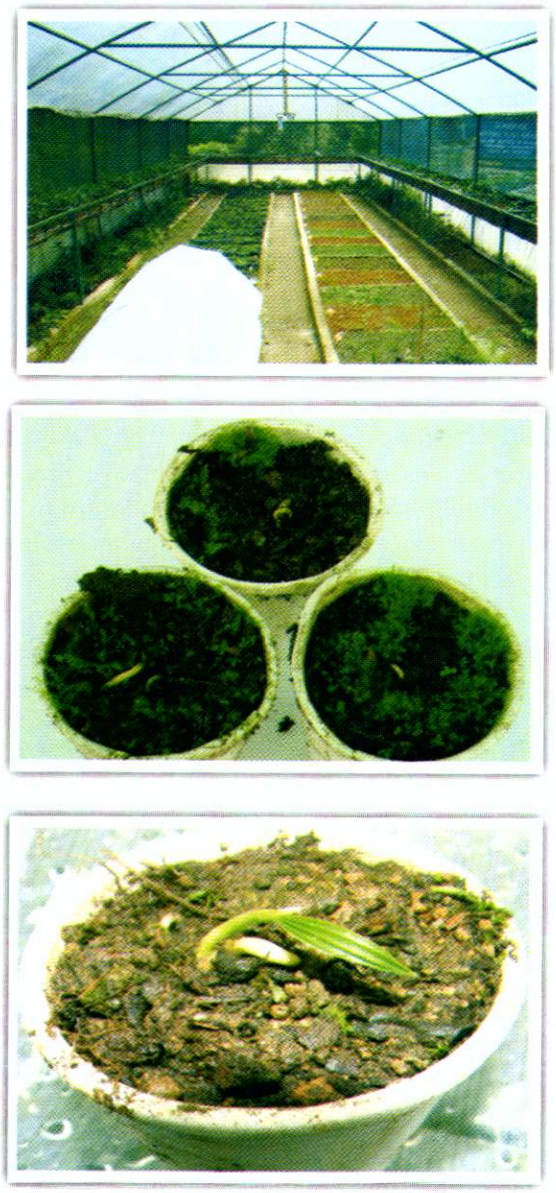
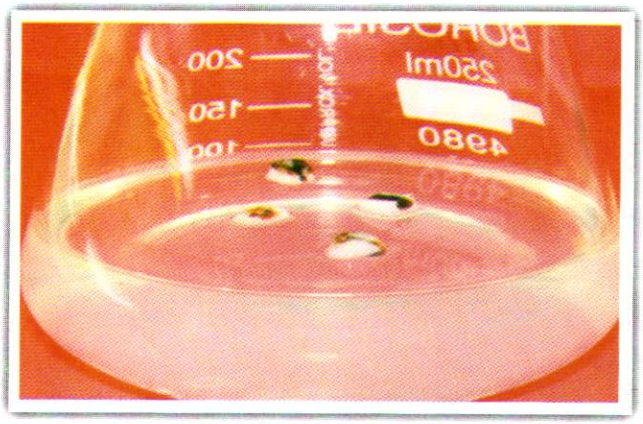


Fig.48. Conventional methods for propagation of *Phoenix rupicola.*



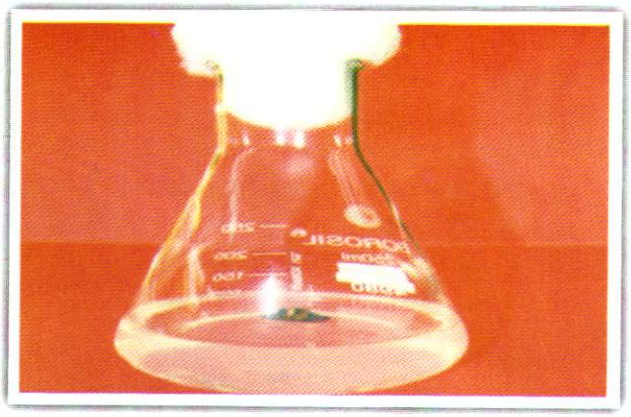


Fig.49. Freshly inoculated *immature embryos* for *induction of callus on the surface of cotyledon segments of Phoenix rupicola.*

Fig.50. *In vitro* propagation of *Rhododendron leptocarpum* on MS – Hormone- free medium.

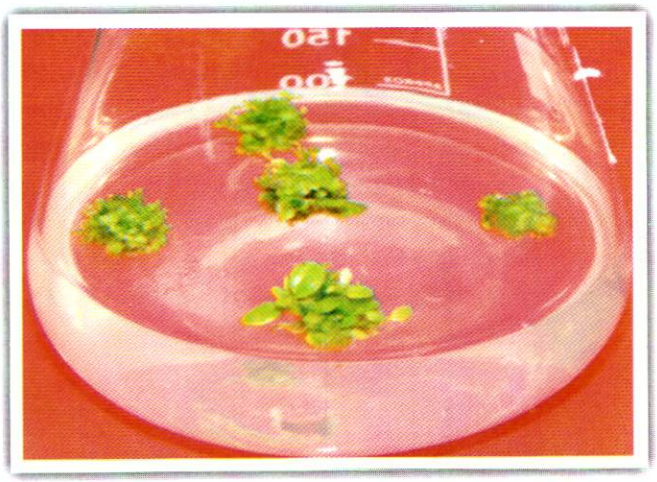


Fig.51. Established shoots derived from nodal segment grown on AM medium supplemented with 25 µM 2iP and 0.6 µM IAA.

Twisted Chir Pine in Uttarakhand: Molecular Markers for Early Detection of 'Twisted' Trait at the Nursery Stage *(2012-2014, UCOST, Dehradun)*

The hills of Uttarakhand in Indian central Himalaya provide one of the best habitats of chir pine (*Pinus roxburghii*; *Gymnosperm; 2n=24*) forests which play an important role in the economy. Out of a total 24,414.80 km^2 area under forests, Chir occupies 3,943.83 km^2 in the state which is 16.15% of the total forest area. Based on the literature of Civil & Soyam, Department of Forest, Almora, 81.43% chir forest has been reported in Almora district. Good quality chir trees are growing at altitude between 750-2000m asl. There are two types of twists in chir trees: (i) twist in anticlock direction which is initiated at the early stage of trees at the angle of 7^0C which renders the wood un-useful for commercial purposes, and (ii) Clockwise twist initiated at a certain age and height of trees. Chir used to be harvested on a large scale for timber, indigenous medicines and for other industrial raw materials; however its economic value gets adversely affected due to twisted twists. In view of the importance of this trait, a study has been initiated to record morphological parameters, ecological factors, and segregate this trait at the nursery stage using molecular markers

Objectives

- Identification of twisted pine locations at different phytogeographical areas in Uttarakhand.
- Comparison of twisted pines with straight pines at phytogeographic, phenologic and genetic level.
- Identification of markers for 'twisted' trait in chir pine (*Pinus roxburghii*).

Achievements

- Pine having complex structural secondary metabolites created problems in isolation of pure DNA; hence the procedure for pure DNA isolation was modified and subsequently standardized for PCR. Pure isolated DNA was very well amplified in PCR using RAPD kits. A total of 40 RAPD primers (operon, kit) were used to generate separating profiles between these two traits (Fig. 52).
- Twenty trees of each trait from above mentioned sites of dense pine forests were randomly selected for the study. Leaf samples of five selected sites (Panwanaula, Majkhali, Matela, Someshwar and Dhaula Devi) were taken.

- Patches of twisted and straight chir pine were visited, trees checked and identified.
- Morphological characterization of twisted and straight chir pine trees was done.
- DNA isolation protocol for old (containing deposition of complex compounds) vs new trees and PCR analysis were established.
- Based on the molecular profiles more than 55% diversity was observed.

Fig.52. Molecular differentiation between straight and twisted pine.

Saprolegniasis in Mid-altitude Fish Ponds of Central Himalaya: Iteology, Pathology and Management Strategies *(2011-2014, CSIR, New Delhi)*

Fisheries constitute a significant sector of the Indian economy not only from the view point of food supplies and foreign exchange earnings but also for potential employment generation. Out of the total inland fish production of over 3.6 million metric tons, more than 60% is contributed by fish culture in ponds and reservoirs. The average productivity from ponds is around 2500 kg/ha/yr, though in Andhra Pradesh and Haryana, it is more than 5000 kg/ha/yr, and even higher yields to the tune of 6000-8000 kg/ha/yr are being realized by farmers in several parts of the country. Endowed with water resources, Uttarakhand has a great potential for fish culture in ponds. However, unavailability of good quality of fish seed and feed coupled with outbreak of diseases often cause economic loss, which has hampered development of fishery in the state

Saprolegniasis is the most problematic fungal infection of fish in lakes and ponds. The disease is caused by any of the several species of the family Saprolegniaceae that are a ubiquitous component of aquatic environment. Previous exposure to stress, physical injuries, pre-existing illness and inadequate nutrition appear to predispose fish to the disease. Under congenial conditions, these fungi often cause epizootic infection resulting in grave loss. The mid altitude exotic carp farming has shown promise and only a fraction of the suitable areas has been brought under fish culture. Thus, there is a potential for many fold increase in fish production. However, fungal diseases along with several other factors have been limiting factors for the development of fishery. The objective of this study is to identify causal agents, environmental factors influencing appearance and development of disease and to develop strategies for reducing loss from diseases in fish ponds

Objectives

- Survey of fish ponds in mid hills of Kumaun region for fish diseases and selection of sites for detailed investigations based on disease prevalence and loss due to disease outbreak.
- To explore fungal infection in fingerlings and adult fish and to isolate, culture, characterize and identify associated fungal species.

- To determine seasonal changes in physico-chemical and microbiological parameters of water and variables that influence fungal growth and intensity of infections.
- To determine pathogenic potential of isolates under laboratory conditions and mode of infection through investigations on clinical signs and histopathology.
- To explore therapeutic and prophylactic measures for mycoses in fish.
- To create awareness and provide comprehensive understanding to the farmers in fish diseases and their integrated management.

Achievements

- Fingerlings (20–25 gm) of exotic carp species viz., Silver carp (*Hypophthalmichthys molitrix*), Grass carp (*Ctenopharyngodon idellus*) and Common carp (*Cyprinus carpio*) at a density of 3/m^2 were stocked into the ponds at selected sites.
- Physico-chemical and microbiological variables in the experimental ponds were well within the range of permissible limits. Water temperature ranged between 9.1 and 30.2°C; pH range of water in the ponds was 6.7-8.0, lower values being during summer. Dissolved oxygen ranged from 4.9-8.8 mg/l, BOD was from 4.6-8.3 mg/l. Conductivity and total dissolved solids were in the range of 90.2-214.7 mg/l and 49.8-102.5 mg/l, coliforms (140-2400 MPN/100 ml) and bacterial count (HPC 22-54 x 10^5), respectively.
- In all, 16 species of extra aquatic fungi and 19 species of zoosporic fungi including virulent pathogens of fish, of species like *Achlya*, *Aphanomyces* and *Saprolegnia* (Fig.53) were isolated from pond water.
- Moderate water temperature and D.O. in spring and autumn favoured Saprolegniasis in fish. Such conditions are also congenial for asexual reproduction in watermolds.
- High temperature of summer-rainy season suppressed the growth, asexual reproduction and pathogenic ability of fungal species.
- Eight species of watermolds, viz., *Achlya flagillata*, *A. prolifera*. *Achlya* sp. *Aphanomyces laevis*, *Saprolegnia diclina*, *S. ferax*, *S. glomerata* and *S. parasitica* were isolated from symptomatic fish.
- During pathogenicity test mortality in different species infected with *Saprolegnia parasitica* was higher than those infected with other fungal species.

Fig.53. *Saprolegnia* spp. isolated from the study site.

Summary of Completed Project / Activity

Development of Propagation Protocols, Multiplication and Field Evaluation of Selected Economically Important Plants in Indian Himalayan Region

(2007-2012, In-house)

The ever increasing human population has placed tremendous pressure on plants, the primary producers. There has always been a growing demand for plants and plant based products. Reduction in the forest cover from the Indian Himalayan region, due to over exploitation, has also resulted in decreasing the availability of non-timber forest products including several medicinal plants of high value. Since the Indian Himalayan region is home to a large number of economically and ecologically important plants, including non-timber forest products, to cope with such challenges, large scale plantations need to be taken up. Therefore, large scale multiplication of quality planting material would be required. Besides conventional methods of propagation, *in vitro* propagation techniques have the recognized potential for rapid multiplication of elite clones not only to provide the much needed planting material for cultivation to derive economic benefits but also for restoration of degraded land and conservation. Keeping these goals in mind, investigations have been undertaken on various target species based on local demand, and results of different studies taken up in different regions across the IHR (HQs, Garhwal, Himachal & Sikkim units), with the following objectives: (i) Comprehensive base line information, germplasm collection and maintenance in nursery, (ii) development of propagation protocols by conventional (by cuttings and seeds) and *in vitro* methods, (iii) large scale propagation of *R. maddeni* and *R. dalhousiae* plants for conservation using existing protocols, (iv) large scale multiplication and field performance of transferred plants, (v) analysis of chemical constituents, and (vi) training of students, farmers and villagers.

Target species: *Zanthoxylum armatum* DC [syn Z. *alatum* Roxb. (Rutaceae)], *Amomum subulatum* Roxb. (Zingiberaceae) - HQs; *Quercus* spp. (Fagaceae), *Rhododendron* spp. (Ericaceae) - Sikkim unit; *Olea ferruginea* Royle (syn. *O. cuspidata* Wall. ex G. Don. (Oleaceae)] - Himachal unit, Kullu. All are economically important species. Achievements of the project are summarized below:

Head Quarters

- Seeds of *Z. armatum* possess hard coat and thus were scarified to break coat imposed dormancy, and treated with different concentrations of sulphuric acid (2-20 min). Among various treatments, 50% sulphuric acid (15 min, washing & sowing in soil) resulted in about 85% germination (compared to 0% in control) after 140 days. Plants are being raised using this method and transferred to pots where survival rate of 100% is observed (Fig.54 a& b).
- Nodal explants taken from branches of *Z. armatum* trees were used to develop *in vitro* cultures. The sprouted shoots were multiplied in MS medium supplemented with auxins and cytokinins; following shoot proliferation and further multiplication, different treatments were provided to induce root formation in these shoots (Fig. 54c). Rooted plants have been transferred to pots.
- Multiple shoots of *A. subulatum* were cultured on the MS medium supplemented with different concentrations of cytokinins. Effective and maximum shoot proliferation was obtained on MS medium supplemented with 0.5 µM BAP and 1.0 µM kinetin; the shoots were multiplied, rooted, hardened and planted in soil; over 1000 plants are ready for field transfer (Fig.54 d-f); assessment of genetic fidelity of these *in vitro* raised plants are being done.

Himachal Unit

- Stem cuttings (15-20cm) of *Olea ferruginea* from Suind, Kolibehar, Sapangi, Thalaut and Kais population treated with different concentrations of IAA, NAA, IBA, GA_3 and thiourea were planted in nursery. Initial sprouting was observed in 90% cases and data on rooting is awaited.

- Cultures of *Olea ferruginea* were re-established using nodal explants from mature tree of

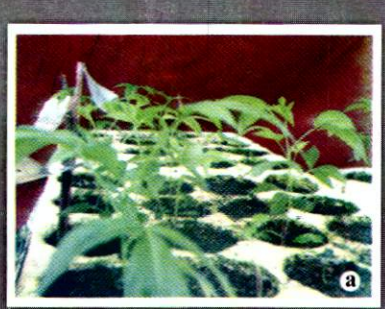
Kolibehar population. Murashige and Skoog's (MS) medium containing half strength salts and combination of BAP and NAA were found more suitable when compared with either NAA or BAP alone, in inducing bud breaks and shoot proliferation.

- Antioxidant potential of stem barks, leaves and fruits of *Olea spp.* were evaluated using three *in-vitro* models, i.e., DPPH, ABTS and FRAP assays. Indian olive (*Olea ferruginea*) was studied. The results revealed that antioxidant activity in methanolic extracts of *O. ferrugenia* ranged between 0.15-0.24, 28.02-31.4 and 0.0019-0.0138 Ascorbic Acid Equivalent/g fw among different populations, locally cultivated/grown in Kullu. The results further showed that the ripe fruits possess more antioxidant activities as compared to raw fruits of *O. ferrugenia.* The species is a potential and rich source of natural antioxidants, and can be exploited for pharmaceutical purposes.

Sikkim Unit

- Mass propagation protocol of selected economically important plants of Indian Himalaya, namely *R.maddeni, R. dalhousie, R. griffithianum and Q. lamellose* were chosen. Since natural regeneration in these species is poor, *ex situ* method for propagation was explored. Among them micropropagation technology stood out as the best option as it outweighed vegetative and other conventional methods.
- The first successful micropropagation protocol for an important Sikkim Himalayan rhododendron, *R. dalhousiae* Hook. f. or Lahare Chimal was developed. Large number of plant have been successfully produced and transferred to the field. Application of this protocol has potential for large scale commercial propagation and conservation of this species in a limited time.
- Conservation and mass scale propagation of endangered *R. maddenii* using existing protocols-for Arboretum & Watershed was continued.
- Experimentation with *Rhododendron* using an "air-wet" method has proved successful and seems to be a promising alternative which has been used effectively for rooting of rhododendron.
- Growth parameters of tissue culture raised *R. maddeni, R. dalhousie* and conventionally propagated other valuable rhododendron species, *R. griffithianum, R. baileyii, R. grande, R. dalhousiae R. cilatum* that were planted at Rare and Threatened Plant Conservation Park, Himalayan Zoological Park, Bulbulay, Gangtok (Fig.55) were assessed for plant height and basal and stem diameters; these provided a healthy indication about the growth of the tissue culture raised plants.

- The two oak species (i.e. *Quercus lamellosae and Q. pachyphylla*) were found to be difficult broad- leaved tree species to propagate *in vitro*. The calli when grown on Woody Plant medium supplemented with 25 µM BAP and 2.94 µM GA_3 showed somatic embryogenesis. The various stages of somatic embryogenesis, viz; globular, heart and torpedo shape were clearly visible to the naked eye. However, several attempts to induce the germination of these somatic embryos failed. One of the reasons for the failure of *in vitro* culturing of the oak tissues is the rapid blackening of the explants. This is at least partly caused by oxidation of polyphenols which are abundant in various oak species and occur in most parts of the trees. Also, strong clonal effects are typical at different steps of the *in vitro* propagation.



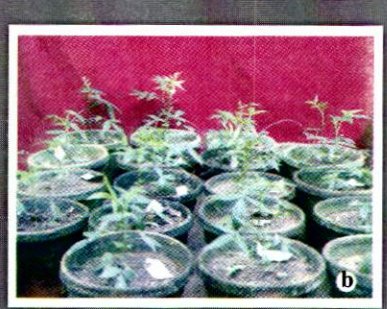


Fig.54. Propagation of *Z. armatum* and *A. subulatum*. (a) seedlings obtained following acid treatment to *Z. armatum* seeds, (b) saplings of the same in pots under green house conditions, (c) multiple shoot formation in *Z. armatum* following culture on MS medium supplemented with growth regulators, and various stages during in vitro propagation of *A. subulatum* (d-f).

Fig.55. Plantation of *in vitro* propagated *R.maddeni* at Rare and Threatened Plant Conservation Park, Himalayan Zoological Park, Bulbulay, Gangtok.

Summary of Completed Project / Activity

Assessment of Microbial Diversity in Himalayan Soil and Determination of Potential Applications *(2007-2012, In-house)*

Research projects related to microbial diversity and potential applications have been initiated in the Institute since 1993. The focus of these projects has been on isolation, identification, and characterization of microbial communities. While the temperate and alpine locations have been explored for enumerating the diversity of free-living bacterial, actinomycetes and fungal communities, the symbiotic associations between selected trees and the arbuscular mycorrhizal fungi have been investigated. Investigations have also been carried out on microbial diversity of the hot spring sites, located in the Garhwal Himalaya. Microbial inoculants suitable for colder regions of mountains have been developed.

The present proposal has been formulated on the basis of the leads obtained from the earlier work done in the area of microbial diversity of IHR with an emphasis on: (1) rhizosphere microbial communities, and (2) extremophiles. In addition, studies on water microbes in river *Jataganga* and microbial diversity in agriculture plots under shifting cultivation in northeast India have also been initiated. The following were the objectives: (i) Assessment of diversity of micro-organisms

growing in extreme conditions (thermophiles and psychrophiles) of Indian Himalayan Region., (ii) Determination of potential applications of selected micro-organisms with an emphasis on production of secondary metabolites and enzymes, (iii) Initiation of a collaborative study between HQ and NE unit with an objective "influence of fire process during shifting cultivation on soil microflora and nutrients", and (iv) Preservation of pure cultures in the Institute's laboratory and accessioning of selected cultures in National and International Culture Collections and Gene Banks. The achievements are being highlighted under the following heads:

Characterization of hyperthermophiles isolated from a hot spring

Thirteen morphologically distinct strains of hyperthermpohilic bacteria, isolated from Soldhar hot spring located in Garhwal region of IHR have been characterized and identified using phenotypic and genotypic characters. Based on the 16S rRNA analysis, 11 strains showed maximum similarity with *Geobacillus stereothermophilus*, one with *G. kaustophilus* and one was identified as *Geobacillus* sp.

Characterization of antagonistic actinomycetes isolated from glacial sites

Five strongly antagonistic species of *Streptomyces*, isolated from glacial sites have been characterized. While two of the species were identified as *S. griseobrunneus*, the rest three were *S. sampsonii, S. aurantiacus* and *S. griseoluteus.* All the five species hydrolysed glycol-chitin as a substrate in denaturing conditions showing variable amount of different isoforms.

Rhizosphere microbiology of *Ginkgo biloba*

The rhizosphere populations, including arbuscular mycorrhizae and endophytes, associated with *G. biloba* of different age groups growing under Uttarakhand have been assessed. An endophytic bacterium, identified as *Pseudomonas* sp (MTCC9476), has been isolated from cortical cells of *G. biloba roots.* The bacterium in suspension culture is applicable for raising healthy plants of *G. biloba* under field conditions.

Antimicrobials from Ginkgo biloba leaves

Antimicrobial potential and minimum inhibitory concentration (MIC) of leaf extracts of *Ginkgo biloba* have been determined. Species of Gram +ve, Gram –ve bacteria, actinomycetes, and fungi were used as test organisms. The antimicrobial activity varied both in respect of the test organisms and the solvents, bacteria being most sensitive to the antimicrobials, followed by actinomycetes and fungi.

Temperature along with time length with reference to detection of ginkgolides and bilobalides by thin layer chromatography (TLC) has been optimized during post chromatographic derivation. The method is based on the impregnation of commercially available silica gel F_{254} with sodium acetate

Microbial activity in river *Jataganga*

Microbial diversity with particular reference to water quality of river *Jataganga*, district Almora, Uttarakhand as influenced by the anthropogenic activities, has been analysed. Water samples, collected from different sites, experiencing different anthropogenic pressures have been considered for determination of total viable counts and biological indicators.

Influence of fire operations on microbial diversity under shifting cultivation in North East Himalaya

Fire, either as a natural or anthropogenic activity, is likely to influence the microbial dynamics which in turn affects soil fertility of soil. Shifting cultivation offers a unique opportunity to study the effect of fire on soil microbial communities, with particular reference to their role in the age old traditional agricultural practice. Soil samples collected from the fired and fallow plots under shifting cultivation in northeast India were analysed for their physico-chemical and microbial characteristics. The fire operations resulted in stimulation of microbial communities. The bacteria were the most affected group followed by actinomycetes and fungi, respectively. The representative microbial species recovered from the 'fired plots' mainly belonged to the genus *Bacillus, Pseudomonas, Streptomyces, Aspergillus, Penicillium and Trichoderma*. Most of these species were found to be positive for phosphate solubilization and antagonism. In view of the importance of these species in plant growth promotion and biocontrol, recovery of these species after fire operations is indicative of the microbiological merit of shifting cultivation.

Microbial culture collection

A microbial culture collection has been established in the Microbiology Laboratory of the Institute; the cultures have also been accessioned by National / International Depositories. Nucleotide sequences have been accessioned by NCBI.

Summary of Completed Project / Activity

Molecular Characterization of Selected Medicinal Plants of Himalayan Region *(2009-2012, In-house)*

Himalayan region is a rich reservoir of valuable resources of medicinal and aromatic plants along with the other economically important plants. One hundred and seventy five out of 280 medicinal plants which are mostly used by pharmaceutical industries are from Indian Himalayan region. Most of the plant derived medicines are derived from plants either in simple plant part forms or in crude extract and mixture forms. Some of the well known plants of Himalayan region *Taxus baccata, Aconitum heterophyllum, A. balfaorri, Podophyllum hexandrum, Picrorhiza kurrooa, Valleriana wallichi, Pinus roxburghii, P. gerardiana, Zanthoxyllum armatum, Swertia angustifolia, Angelica glauca, Heracleum candicans, G. biloba* etc. have biologically active compounds and secondary metabolites have also been identified and purified from these plants. In order to identify genetically high yielders in terms of their active component (podophyllotoxin- anticancerous drug, ginkogolites- used in memory loss, and artemisinin- antimalarial drug) in medicinal plants, the relevant medicinal plants have been selected for the study. The main objectives of the study are: (i) collection and maintenance of germplasm, (ii) development of morphological, chemical and molecular profile, and (iii) establishment of relationship among morphological, chemical and molecular profiles.

The achievements are as under:

- Inter and intra specific molecular diversity through RAPD, ISSR and AFLP was estimated in *Podophyllum* species. Using 20 AFLP markers, 88.01%; polymorphism was observed amongst the species and the paired relationship of intercontinental species in the *Podophyllum* group [*P. hexandrum*, and *P. sikkimensis* (Indian May apple) vs. *P. pelatum* (American May apple)] appears to be paraphyletic.
- Sixty RAPD markers were used to develop species specific markers. Out of 60 only 4 markers were clearly differentiable in the species. These markers were eluted and cloned in *Eco* RI site.
- Two and three leave plants were observed in *P. hexandrum*. These plants were used to develop specific molecular profile with Operon primers.

- *Podophyllum hexandrum* germplasms which were collected from Kullu showed high amount of podophyllotoxin (1.5%) whereas in *P. sikkimensis* low (0.336%) podophyllotoxin was observed.
- Based on morphological and molecular dendrogram *P.hexandrum* (Kullu) and *P.sikkimensis* were in one group. This reflects that their origin may be the same.
- Some podophylotoxin pathway specific genes were identified and their expression is in progress.
- In *Ginkgo biloba* L. (2n=24; family Ginkgoiaceae) leaf samples of seven trees from different places [old Rajbhawan (Nainital)-85yrs, Kalika (Ranikhet)-150yrs, Glanthorn (Nainital)-33yrs, Chaubatia- (Ranikhet)-130yrs, High Court (Nainital)-33yrs, Institute (GBPIHED: Kosi-Katarmal)-16yrs, Kumaun University (Nainital)-35yrs] in Kumaun region of Uttarakhand were analyzed to develop chemical and molecular profiles. The content of ginkgolides (on dry wt basis) were found to vary in all the 7 trees; ginkgolide A (GBA) ranged from 0.058%-0.346%, while ginkgolide B (GBB) ranged from 0.12-0.19%. Samples collected from Kalika (150 yr) showed highest GBA (0.346%) and Old Rajbhawan (85 yrs) showed highest GBB (0.19%) content as compared to trees from other areas (Fig. 56)
- Male and female trees were identified in Kumaun region, one male (Snow view) and six female old trees of *G. biloba* were identified by using sex specific primers (Fig. 57). Cloning was done and sequencing is in progress.
- In *Artemisia annua* poly cross mating was carried out for gene pool exploitation. A wide variation in artemisinin content (0.01-0.7%) was observed in HPTLC. Studies on biosynthesis of artemisinin under different biotic and abiotic stresses were also carried out.

Fig.56. Female tree with ovules and HPTLC of *G. biloba* extract.

Fig.57. Segregating profile of male and female in *G. biloba*.

Summary of Completed Project / Activity

Phosphate Solubilizing Fungi in Himalayan Soil: Diversity and Applications ***(2010-2012, DST, New Delhi)***

Micro-organisms play a fundamental role in the biogeochemical cycling of phosphorus in natural ecosystems. Since phosphate solubilization is a prime process for plant growth, the importance of phosphate solubilizing micro-organisms is well recognized. Temperature, pH and biomass are vital factors for various activities of micro-organisms. The major microbiological process by which insoluble phosphorus compounds are mobilized is by the production of organic acids. Literature on microbial diversity of colder regions is scanty. The objectives of the project were: (i) Phenotypic and genotypic characterization of fungal cultures isolated from temperate Himalayan soil, (ii) Screening and selection of efficient phosphate solubilizing fungi, with special reference to litter decomposition and plant growth promotion, (iii) Demonstration of the preparation and usage of carrier based formulations of efficient fungi to the target people of Indian Himalayan Region (IHR) (participatory technology development), and (iv) Dissemination of the technique to the local people through booklets and people's participation.

Diversity of phosphate solubilizing fungi, originally isolated from soil samples collected from the low temperature locations in IHR have been investigated with particular reference to phosphate solubilization efficiency. Ten species of *Aspergillus*, 8 of *Penicillium* and 3 of *Paecilomyces*, isolated from the high altitude (1800–3610 m above mean sea level) were screened and selected for detailed investigations at different temperatures. These species exhibited tolerance to a wide range of pH (1.5 to 12.0), and temperatures (4°-50°C). Species of *Aspergillus* were found to be the best solubilizers followed by *Penicillium* and *Paecilomyces*, respectively. The phosphate solubilization related parameters (reduction in pH, production of biomass, and phosphatase activity) were found to be temperature dependent. Solubilization at low temperature, without decline in the initial pH of the media, indicated towards involvement of mechanism(s) other than the organic acid production. This may be attributed to the production of cold active metabolites, which play active role in the phosphate solubilization. The suboptimal conditions recorded for the growth and biomass production were found to be optimal for the production of metabolites mediating the phosphate solubilization process. These fungal species showed slow but constant solubilization of phosphates for prolonged periods as compared to the earlier reports mostly from tropical regions. The best tricalcium phosphate solubilizing fungi were screened for aluminium and iron phosphate solubilization as well. These fungal cultures were also tested for the plant growth promoting efficiency in green house conditions.

Occurrence of cold tolerant fungal communities is likely to mediate important ecological role in low temperature environments prevailed with low nutrient status and low decomposition rates. The efficient species also provide an opportunity to be developed as potential 'bioinoculants' for various applications in the mountain ecosystem. From field application point of view, carrier based formulations of promising fungal cultures were prepared and examined to maintain viability and the desired traits up to two years under refrigerated conditions.

Summary of Completed Project / Activity

Role of Mycorrhizae on Gas Exchange Characteristics, Particularly Photosynthesis and on Water Relations in Three Central Himalayan Oak Species: Implications with Reference to Climate Change ***(2010-2013, DST, New Delhi)***

Oaks (*Quercus* spp.) are the climax species of the central Hiamalyan region. They are well known to protect the fragile ecosystem and help in soil and water conservation and soil fertility. The leaves are used widely in the hills for fodder. Regeneration of oaks is very low and oak forests are deteriorating at an alarming rate due to tremendous anthropogenic pressure.

Oaks are known to form mycorrhizal associations which help in absorption of nutrients, especially phosphate, help in disease resistance and drought tolerance. Therefore, three oak species (*Q. glauca*, *Q. leucotrichophora* and *Q. semecarpifolia) of* this region based on their occurrence in different altitudes, were selected for this study. The main objectives of the study were: (i) to observe the effect of mycorrhizal inoculation on overall growth, (ii) to investigate the effect of climate change with reference to elevated temperature and CO_2 on inoculated and mycorrhizal oaks over uninoculated controls, (iii) do mycorrhizae protect oaks from drought stress? and (iv) to develop a simple nursery level protocol for raising seedlings for forestry.

The achievements of the project are given as under:

- Physiological studies were carried out on the photosynthetic performance and water relation of 3 oak species using seedlings and trees.
- Gas exchange studies showed that *Q. leucotrichophora* showed the highest net photosynthesis rate and transpiration, and the water potential of 1.5 MPa; these values were highest as compared to other species. Preliminary study reveals that this species must have adapted a strategy for survival, occupying a wider altitudinal range from 1000 to 2500 m asl, i.e. 1500 m, in terms of area.
- Climate change altitude gradient (m asl) base line studies have been done on the 3 above mentioned oak species. High CO_2 concentration (550 ppm) and increase in temperature (1 ^{0}C above ambient) were provided to the plants kept at 3 altitudes 2000 m at Shyahidevi, 1600 m at Salla Rautela and at 1200 m at Katarmal.
- A significant difference in results was observed in *Q .glauca* and *Q. semecarpifolia* at 2000 m; *Q. leucotrichophora* was not affected at all at the three sites for both treatments.
- Due to elevated CO_2, *Q. glauca* showed a decline in net photosynthesis and in water use efficiency over control (at $p < 0.01$ and 0.1) whereas *Q. semecarpifolia* showed a decline only in WUE over control (at $p < 0.01$). In *Q. glauca* high temperature resulted in decline in net photosynthesis and in water use efficiency over control (at $p < 0.01$). On the other hand *Q. semecarpifolia* showed an increase in net photosynthesis, stomatal conductance, internal CO_2 concentration and transpiration, however, water use efficiency showed a decline over control at $p < 0.01$.
- The above study suggests that since *Q.glauca* and *Q. semecarpifolia* were planted at 2000 m, i.e. above normal growing range of 900-1800 m for *Q.glauca,* and below normal growing range of 2300-3200 m for *Q. semecarpifolia,* the environmental conditions may not have been suitable and the plants therefore have undergone stress at the new altitudes.

Theme

KNOWLEDGE PRODUCTS AND CAPACITY BUILDING (KCB)

There are hundreds of different cultures in the Indian Himalayan region, each with its unique practices and way of looking at life. While there is a diversity of cultures and local knowledge systems, certain characteristics are common to many knowledge systems. The knowledge accumulated, documented, produced or developed over a period of time in any field related to human well being and natural resource management, environmental conservation required to be transmitted or exchanged through capacity building efforts and needs to provide unique paradigms designed to empower all the stakeholders and enhance their institutional and human capacities for integrating environmental considerations and related issues into development planning and decision making. Transfer of knowledge and capacity building requires high levels of planning, management and evaluation skills to ensure clarity of purpose, focused partnerships and assessment of effective progress. The theme emphasizes the need to protect rights not only to traditional knowledge itself, but to all the inter-linked components of traditional knowledge systems including bio-genetic resources, eco-technologies, landscapes, cultural and spiritual values, and customary laws and institutions. It therefore sets out a framework to develop mechanisms to protect traditional and modern knowledge which are holistic and based on human rights, including rights to land and natural resources, and the rights to self determination. The level of understanding, skills, enthusiasm and values of the user groups are considered key factors in stimulating the learner's interest and appreciation of implementation of the knowledge produced. In addition, one must consider a number of other factors including policy and regulation to environment, nature of resource base, local capacities, external support, and prevailing natural resource management practices that considerably influence the effectiveness of the integrated knowledge base and its implementation. Knowledge base of the different traditional societies and knowledge developed through science and technology interventions, if successfully adopted/ implemented through capacity building would certainly generate ecologically sound, economically viable, socially acceptable and institutionally enforceable outputs. With greater realization of the value of this knowledge base, for looking at issues linked to social process and natural resource management there is increasing realization that in many ecological/ social situations, knowledge should be an integral part of a holistic and cost-effective approach for sustainable development.

The objectives of the theme are: (a) to undertake in-depth studies on documentation and validation of knowledge (traditional/indigenous/rural or developed through scientific & technological interventions) system of traditional/modern societies including their cultural, biological, material, spatial, landscape as well as intellectual components and their on-going interaction, as the basis for protecting and safeguarding of the modern knowledge base; (b) to utilize natural resources for income generation using local knowledge and capacities through science and technology

interventions; (c) to translate existing knowledge related to Bio and natural resources etc. into products; (d) to enhance capacities and skill of human beings in harnessing the potential of knowledge systems for environmental conservation and management and socio-economic development; (e) to provide the opportunity to stakeholders to interact with each other and with institutions working on knowledge building/upgrading/updating system together to address research, action and policy needs of this complex subject and help to develop appropriate strategies, guidelines, and policy briefs for development

Capacity Building for Entrepreneurship Development and Self Employment in Indian Himalayan region *(2012-2017, In-house)*

The traditional societies of the Indian Himalayan Region (IHR) face a range of socio-economic and environmental problems. They live in geographical isolation under ecologically sensitive and economically constrained conditions. Remoteness, marginality, harsh climatic conditions, tough terrain, poor infrastructure, lack of employment opportunities, drudgery and meager livelihood opportunity are often responsible for the poor economic condition of the people inhabiting the rural set up. In addition, dominance of rainfed agriculture on the steep slopes (which constitutes 85% of the total agricultural land) that is too marginal, fragmented and scattered in nature, small land holdings result in low crop yields and therefore, does not provide income generating opportunities for the ever-increasing population of the region. People living in this natural resource rich region happen to be poor. Because of limited opportunities of economic development within the region, the frustrated youth are migrating in large numbers to the other parts of the country in search of employment. Thus to minimize the existing rate of migration on the one hand and to utilize diverse sustainable bioresources on the other, cost-effective, simple practices and technological interventions are required in most of the sectors of rural economy so as to provide viable alternatives for improving livelihood and food security of the growing population in a sustained manner. Of late, development planners and extension workers have realized the importance of suitable technologies and practices, and have therefore, stressed upon the need for a large scale demonstration of technologies and on-site trainings, capacity/skill development of the users/target groups in rural and marginal areas of the region. To improve the livelihood of people through sustainable management of natural resources, GBPIHED has been making continuous efforts and has established Rural Technology Complex (RTC) at the Head Quarters with sub centers at different agro-ecological zones of the region which housed various location specific and cost effective technologies under four groups, i.e., (1) Yield Increasing (2) Income generating (3) Life supporting (4) Value additions and other activities. The RTC also imparted live demonstrations on these technologies through organizing capacity building and skill development training programmes for a larger number of stakeholders belonging to different sections of the society. A large number of rural people have adopted some of the valuable technologies and are getting benefits in terms of food and economy. There is a need to upgrade, revalidate and strengthen the cost effective technologies through various experiments to provide a better protocol for utilizing these technologies. Therefore, the major goal of the participatory and action research will be to focus on revalidation of established rural technologies through conducting experimental trials, yield enhancement of various crops under different doses of compost and microclimate conditions

Objectives

- To provide various hill specific, low cost technological interventions based on locally available resources alone with capacity building (through trainings/live demonstration/field exercises) of stakeholders and training of trainers (TOTs) on a regular basis.
- Guidance and support for field implementation of technology packages to the stakeholders, and subsequent monitoring, evaluation, follow up and adoption, so as to establish financial viability through interventions/support.
- To develop multiple livelihood options including training on specialized skills on relatively long term basis, and to achieve livelihood security so as to achieve overall improvement in the quality of life of rural folk.

Achievements

- More than 40 technologies were established, tested/modified and maintained at the RTC with a view to replicate and/ or disseminate.

- During the reported period (July, 2012- March, 2013) a total of 21 training and awareness programmes of various durations were conducted for different stakeholders i.e., officials from Govt. organizations, Industrial Training Institute (ITI), Almora, NGOs, SHGs, farmers, students, etc. A total of 556 persons (female, 220 and male, 336) from 7 districts were directly benefited through these training programmes (Fig. 58).
- During the project period (July, 2012- March, 2013) an amount of Rs 4.46 lakh (Rupees four lakh forty six) was generated by RTC at HQs through sponsored training.
- Technical guidance and support for Protected cultivation, integrated fish farming,, water harvesting, biobriquetting, biocomposting, vermin composting, waste land development, horticulture, agroforestry, medicinal plant cultivation and conservation etc. were provided to more than 50 persons for field implementation at different selected sites.
- Efforts were made to demonstrate appropriate /suitable technologies/technological interventions and build the capacity of the farming communities to adapt climate resilient practices to mitigate the impact of climate change/variability in rural landscape of the Central Himalaya

Fig.58. Workshop on Capacity Building and Entrepreneurship Development through Rural Technology

Enhancement of Livelihood Security through Sustainable Farming Systems and Related Farm Enterprises in North-West Himalaya (2007-2013, NAIP/ICAR)

The concept of livelihood diversification is emerging as a survival strategy of rural households in central Himalaya. The rural people are looking for diverse opportunities to increase and stabilize their incomes, which are determined by their portfolio of assets - social, human, financial, natural and physical capital. The contribution made by livelihood diversification to rural livelihoods is a significant one, which has often been ignored by policy makers who have chosen to focus their activities on agriculture. The livelihood diversification activities are of increasing importance for rural poor people empowerment through additional income earning and improvements in family welfare. However, agriculture is the mainstay of the people living in the hills, but food self-sufficiency eludes the hills and this has led to growing disparity in the living standards. Attaining livelihood security, sustainable food production and environ mental protection has always been a challenging task in the Himalayan regions. Moreover, the natural resources lie in a poor state because of high dependency on them for diverse subsistence needs of the rural communities. Cultivation of medicinal and aromatic plants (MAPs) plays unique role in India's economy by enhancing the income of the rural people. There are plenty of medicinal plants in the central Himalaya which find their place in day-to-day uses and many of these are widely used as herbal remedies and have have huge potential to improve the socio-economy of the society subject to sustainable harvesting, localized production and value addition. Their marketing can also be done locally. Economic condition of many rural farmers, particularly those involved in medicinal plant production has improved and it has become a means of improving livelihood for many unprivileged classes too. The main emphasis in the present component is given to improve the natural resource base through diversification and strengthening the farming system with technological measurement while ensuring people's participation.

Objectives

- To develop selected prototypes (models) for increasing community livelihood on village commons (i.e. Van- panchayat and other community lands) and improve natural resource status in the identified village micro-watersheds.
- To document indigenous knowledge, develop local capacity and strengthen village institutes for sustained people's participation and development of natural resource management.

- To develop village information system for decision support.
- To identify indicators of sustainability for the perceived success and failure of farming systems in target districts in terms of equity (including gender), production and environmental stability, and standardize a methodology of such indicators.

Achievements

- Two medicinal plant species i.e. *Asparagus officinalis* and *Ocimum sanctum* were selected for large scale cultivation in the selected village cluster.
- A total of 1 hectare village common land was procured and brought under nursery development of selected medicinal plants i.e. *Asparagus officinalis* (Satavar), and *Ocimum sanctum* (Tulsi).
- About 10,000 seedlings of *Asparagus officinalis* (Satavar) were raised in the nursery for distribution to the interested farmers.
- A water harvesting tank of size14 x 10 x 5 ft having capacity of 16500 lts was constructed at the nursery development site for proper irrigation of the seedlings of medicinal plants.
- About 60 farmers of Manjgaon village cluster have been provided technical know-how regarding nursery raising of medicinal plants (*Asparagus officinalis* (Satavar, *Ocimum sanctum* (Tulsi). Besides, seeds of these two medicinal plant species were provided to the farmers to raise seedlings and about 60 farmers have benefited from this venture.

Fig.59. Sustainable farming system.

Community Driven Climate Resilient Hill Farming in Village Ecosystem of *North-West Himalaya*, Uttarakhand *(2012-2015, NICRA/ICAR)*

Mountain ecosystem represents one of the most fragile and climatically vulnerable regions in India. Mountain society and their sustenance through hill farming has been largely isolated and ignored from modern development and has generally not been benefited by the green revolution. Hill agriculture is dominantly associated and supported by natural resources particularly forests. This is further aggravated by inaccessibility and limited infra structural facilities due to remoteness and terrain conditions. The close association of hill farming with natural ecosystems and mountain communities historically supported the limited population and sustained hill farming in the event of climatic aberrations. However, the traditional farming has not been able to keep pace with the enhanced needs to even meet the domestic requirements of the growing population.

Mountain ecosystem is to be placed as a priority in the global agenda with regard to environment and sustainable development characterized by complexity and specifications. Climate change can directly impact quality of ecosystem services and thus mitigation and adaptation are significant in maintaining ecosystem balance. Low and poor understanding of mountain ecosystem prevail among different agencies with reference to climate change impacts. Soils of world's agroecosystem are depleted of their soil organic carbon pool by 25-75% which results in low productivity. Among several solutions being debated world-wide for mitigating climate change one important option is sequestration of carbon in agroecosystems. In addition, adoption of best practices like conservation tillage, cover enhancing SOC pool, improving soil quality, increasing productivity and enhancing soil resilience to adapt to extreme climatic event and mitigate climate change impacts are the need of the day.

Objectives

- Mountain specific climate issues, traditional farming, livelihood and socio-economic response of hill villages.
- Integration of climate resilient modern technology in synergy with traditional farming, natural resource management and village social milieu.
- Climate management dynamics and carbon sequestration in mountain village ecosystems.

Achievements

- In-depth study on farmer's perception and response to climate variability/change impact in a village cluster in lower Nayar valley of Garhwal Himalaya has been carried out.
- Climate variability/change and its impact on various food production systems like agriculture, animal husbandry and other systems of village ecosystem i.e. forests, wild bioresources and water resources were studied and analysed in detail following standard methodologies.
- People's and farmer's perception on climate change impact, local evidences of climate variability/ change as well as factors responsible for change and major future climate change risks as perceived by villagers have been evaluated and documented.
- Community based adaptations particularly in agriculture and livestock sectors with regard to climate impact were documented and analysed. The cost-benefit analysis of adaptation is being worked out.
- Four cost-effective polyhouses of locally available resources (bamboo made) of different sizes (12 ft (width) x 40 ft (length) x 9 ft (height) and 10 ft (width) x 12 ft (length) x 9 ft (height) were built and demonstrated in the agricultural land of progressive farmers of Kaindul village for cultivation of seasonal and off-seasonal vegetables under protected conditions as an adaptative strategy so as to cope with climate change impacts. Awareness is also being raised for promoting simple, appropriate and climate friendly technologies. Field model demonstration of biocomposting and vermicomposting were also demonstrated for large scale adoption.

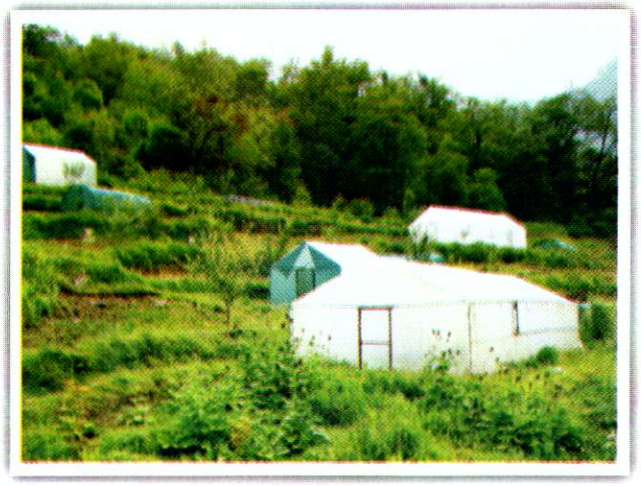


Fig.60. Community Driven Climate Resilient Hill Farming.

Threat Assessment and Conservation of Himalayan Silver Birch (*Betula utilis*): A Keystone Species in Timberline Zone of Central Himalaya, Uttarakhand ***(2012-2015, DST-SERB)***

The Central Himalaya is a reservoir of temperate biodiversity and is mostly occupied by timberline and alpine vegetation. The unique geographical setup, topography and undulant landscape, the varying climatic conditions along altitudinal gradients, attribute it a diversified ecological habitat ranging from tropical forests and grasslands to alpine meadows which have vast and diverse natural resources. Unfortunately,. due to legal and illegal exploitation from the wild, anthropogenic pressure and lack of knowledge about sustainable harvesting of useful bioresources, many of have been listed under the categories of rare, threatened, endangered or at the verge of extinction. The timberline, the most prominent and significant ecological boundary where the sub-alpine forest terminates, has been identified as a zone sensitive to environmental and climate change, could be monitored effectively for future impact of climate change. The native species of timberline in NDBR are *Betula utilis, Rhodendron companulatum* and *Abies Pindrow.* Among these species *Betula utilis* is a keystone species and plays a critical role in maintaining the structure of an ecological community and helping to determine the types and numbers of various other species in the community. *Betula utilis,* native to the Himalaya, generally grows in sub-montane to sub-alpine regions between 3400m asl to 4500m asl and tends to form forests, growing as shrubs or trees reaching up to 20 m in height. It is generally found as a pure patch or in association with *Cedrus deodara, Taxus baccata, Pinus wallichiana, Asculus indica, Abies pindrow, Acer acuminatum, Sorbus aucuparia, Prunus cornuta and Salix spp.*

Objectives

- To assess the impact of climate change & other anthropogenic activities in lower and upper range of *Betula utilis* forests.
- To understand the response of these factors in terms of population dynamics, seedling recruitment & phenology.
- To determine land-use changes in the distribution of *Betula utilis* and associated species at two points of time using remote sensing data.

Achievements

- Study area has been selected at core zone of Valley of Flowers National Park (VoFNP) and Nanda Devi National Park (NDNP) under Nanda Devi Biosphere Reserve (NDBR) for detailed timber line tree vegetation analysis and phenological study of *Betula utilis* and associated species.
- The total tree density of pure forest was found 1388 as compared to mixed forest (1116) in Valley of Flowers (VOF) and total density of mixed Betula forest was found higher (1632) as compared to the pure Betula forest (1536) in Tolma and Lata Kharak region.
- The basal area of mixed Betula forest (47.50 m^2 ha^{-1}) was found higher as compared to pure forest (25.35 m^2 ha^{-1}) in the VOF and the basal area of the mixed Betula forest was found higher (110.08 m^2 ha^{-1}) as compared to pure forest (55.54 m^2 ha^{-1}) in Tolma region.
- *Betula utilis* (IVI-286.56) constituted a pure patch of forest in the timberline area with important value index for *Betula utilis* (IVI- 85.68), *Cedrus deodar* (IVI-63.43) and *Abies pindrow* (IVI-49.68) dominant species in the mixed forest in VOF. *Abies pindrow* (IVI-63.25) was found associated with *Betula utilis* (IVI-217.31) and formed mixed patch at timberline. *Betula utilis* (IVI-114.35), *Pinus wallichiana* (IVI-70.83), *Abies pindrow* (IVI-58.42) were the dominant species in the mixed forest in Tolma region.
- The diversity index for tree layer ranged from 12.03 to 186.55 in VOF for pure and mixed forest respectively, whereas it was found between 54.81 to 157.60 respectively for pure and mixed forest in the Tolma region. Among the different sites (pure & mixed) in the Valley of Flowers the diversity index of saplings was between 71.38 to 174.14, whereas it was found between 82.08 to 166.04 for the seedling layer. In the Tolma region diversity index value of sapling and seedling layers was found between 83.34 to 187.31 and 0.8565 to 177.25 for pure and mixed forests respectively. Diversity index value for the shrub and herb species was estimated between 199.73 to 219.48 and 297.65 to 346.67 for mixed forest and pure forest respectively.
- High Satellite data products on impact of climate change on timber line particularly on *Betula utilis* have been procured from National Remote Sensing Centre (NRCA), Hyderabad and are under analysis/review for detail observations

Summary of Completed Project/Activity

Capacity Building for Entrepreneurship Development and Self Employment in the Himalayan Region *(2007-2012, In-house)*

Of late, development planners have realized the importance of suitable or appropriate technologies and practices, and therefore, have stressed upon the need for a large scale demonstration, on-site training, capacity building and skill development of user groups in rural and marginal areas of the region. G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) is one among the very few organizations in the Indian Himalayan region involved in testing, developing, upgrading, validating and demonstrating promising appropriate technologies through action and participatory research. To overcome some of the problems identified for ecosystem development and economic upliftment of the mountain people and for the overall improvement of their status a number of on-farm and off-farm technology packages were demonstrated at the rural Technology Complex and sub centers. These technologies are not only simple, cheap, practical, eco-friendly etc., but also provide opportunities for entrepreneurship development & self employment and at the same time reduce the working hours of mountain inhabitants and their out migration.

The RTC has been designed in a way that aims to bring changes, over a period of time, leading to improvement in the economic status of the inhabitants, generation of employment possibilities, reduction of environmental degradation and sustainable use of the available resources. As a result of these efforts a number of farmers and other stakeholders, i.e. NGOs and some educational institutions in the region have adopted some of the potential rural technologies at various levels in different agro-climatic zones. A total of 187 capacity building programmes were organized at HQs and its regional units through which over 11,000 stakeholders that include farmers, representatives of NGOs/Govt. agencies, ex-soldiers, students, etc. benefited. About 675 villages in 13 districts of Uttarakhand were covered under these capacity and skill development programmes.

The technologies preferred and adopted by the farmers include protected cultivation, water harvesting tank technology, zero energy cool chamber, bio-and vermin-composting, bioprospecting of wild bioresources, biobrequetting, mushroom cultivation, slopping watershed environmental engineering technology (SWEET), etc.

The programmes of RTC have gained tremendous popularity among the stakeholders, as is evident from the continued demand for conducting trainings, capacity building and setting up of various demonstrations. Various organizations/persons are sponsored (bearing all expenses) for trainings capacity building, demonstrations, etc. Now that the RTC operating from HQs has become self sustaining. an amount of about 21 lakhs were generated through sponsored programme during the project period. It is hoped that the improved capacities of local farmers will help widespread adoption of rural technologies in central Himalaya and other parts of the Indian Himalayan region, facing common problems/issues and having similar topographies, environmental set-up and socio-economic conditions.

Summary of Completed Project/Activity

Sustainable Tourism: Assessing the Eco-Tourism Potential of Garhwal Himalaya
(2007-2012, In-house)

Tourism has been the strongest and fastest growing industry worldwide and it can become an important constituent of the country's economy. Development of tourism in India is a recent phenomenon compared to some other countries. In the past three decades, Indian tourism has developed considerably and made rapid strides in bringing good chuncks of profits to the country. Now tourism has established itself as a prime component in the Indian economy. Uttarakhand, rich religious tourism tradition and adventure tourism potential is enjoying worldwide reputation as an international tourism hotspot. Tourism industry is felt to have ecological impacts on the hill/mountain environment as the rising numbers of tourists present both threats and opportunities. This industry is confronted with arguments about its compatibility with environmental management and local community development. Therefore, there is an urgent and immediate need to create and increase awareness, do advocacy and impart necessary training for capacity building of various stakeholders to enable them to handle tourism in an environmentally responsible manner and develop tourism in areas making environment an integrated part of it. The summary of achievements of the project is as follows:

- Popularized lesser-known tourism spots (e.g. Panch Kedar, Tungnath, Rudranath, Madmaheshwar and Kalpeshwar – Ansuya, Triyuginarayan, Kalimath, Pawalin Kantha, etc.) and highlighted their tourism value for promoting tourism in these areas, in order to reduce pressure on well-known tourist places and provide opportunities to local people to participate in managing tourism and to derive benefits from it.
- The impact of tourism on various sectors/areas/aspects i.e. agriculture, livestock, forestry, infrastructure, land use pattern, human population, socio-cultural traditions, etc. was studied and options for maximizing benefits/opportunities and mitigation of the problems encountered was carried out.
- Documented traditional food systems of local community which contain treasures of knowledge from long evolved cultures and patterns of living in local ecosystems. However, these food systems which are intricately related to the complexities of social and economic circumstances are becoming increasingly more affected by the forces of globalization. The main objective in this context is to promote tourism and health through traditional food products having nutraceutical potential. A dialogue was held with Sirsi, Budasu, Rampur and Triyuginarayan village institutions for demarcating community conserved area from existing Van Panchayats area (about 5-10 ha. forest land) for wild bioresource management.
- The net economic returns earned by various stakeholders during tourist seasons involved in various income earning activities (hotel/lodge/shop owners and employee, person supplying fuel wood, milkman, sweepers, shop owners, shop employee, porters and horse owners) were quantified and worked out.
- Developed capacity building of local tour guides/students on avifauna diversity and its linkages with ecotourism promotion, biodiversity conservation and income generation.
- Assessment of carrying capacity of lodges/hotels in different places between 35 km distance in Kedarnath pilgrimage site were carried out.
- Organized series of training programme on "Promoting eco-tourism for local stakeholders involved in various tourism related activities" at tourism interpretation centre, Triyuginarayan. More than 350 participants actively participated in the training workshops between 2007-2012. Besides, 120 students of Govt. Intermediate Colleges of adjoining areas were also imparted knowledge on tourism/eco-tourism and its environmental, economic and socio-cultural implications.
- Developed and expanded tourism/eco-tourism knowledge network with various R & D institutions (HNB Garhwal University, Tourism Department, GMVN, District Adventure Tourism Office, Health Department, Forest Department, etc.), line departments, village institutions and NGOs i.e. Kedarghati Eco-tourism Development Action and Research and Swarajay Bahudeshya Sanstha etc.

Summary of Completed Project/Activity

Demonstration, Value Addition and Up-gradation of Traditional Wild Edible Products for Sustainable Livelihood in Kedarnath Valley of Uttarakhand *(2008-2012, DST-SSD)*

Forest based resources have played a key role in the sustenance of human civilization since time immemorial and are till now deeply associated in serving a large number of human populations throughout the world. Wild edible fruits are one of the precious groups of non-timber forest products that have played a prominent role in uplifting the socio-economy of human beings, particularly in tribal, rural and marginal areas for thousands of years. With the growing concern and commitment for the development of hill areas and livelihood enhancement increased interest is being taken in the untapped and underutilized bioresources to contribute to the food security of households. These resources are recognized and valued not only for their short term economic benefits, but also for the sustenance that they offer to the large number of rural households in The Himalayan region. A variety of wild edibles with huge economic potential also provide an important source of family income for those with access to capital or land and the initiative to further market or commercialize a particular wild edible product. Fortunately, the study area, Kedar valley occupies one of the important religious and tourist centers of the country, visited by millions of pilgrims and tourists every year and provides a good platform for marketing of value added products from wild edibles. The summary of major achievements follows:

- A total of eight wild edible plant species i.e., *Viburnum mullaha*, *Pyracantha crenulata*, *Berberis asiatica*, *Rubus ellipticus*, *Principia utilis*, *Viburnum cotinifolium*, *Elagnus latifolia* and *Pyrus pashia* were studied for their various vegetation parameters and bioprospecting potential.
- The results of indigenous knowledge documentation revealed that the selected species have huge medicinal and nutritional value without any side effects. It is also noticed that the traditional practices related to medicinal uses are on the decline day by day.
- Ten training programmes were organized between 2008-2012 through which 1234 participants were provided training and given live demonstrations about value addition of wild edibles and agro-products while making a variety of local value added edible products.
- A small bioprospecting unit has been established for demonstration and processing of locally available bioresources. So far more than 165 families in the 13 villages of upper Kedar valley in district Rudrapryag have made strategic interventions in bioresource based products and enterprise development for enhancing local livelihood opportunities and creating economic incentives for conservation.
- Conservation measures were initiated taking into consideration the high popularity of wild edible products through domestication/cultivation by mean of vegetative and seed germination methods. Two potential wild edibles i.e. *Viburnum mullaha* and *Paeonia emodi* having tremendous potential for bioprospecting have been selected for nursery raising and brought under cultivation on a small scale.

Summary of Completed Project/Activity

Strengthening Fodder Resources and Developing a Model for Reducing Drudgery of Rural Women in Kedarnath Valley, Uttarakhand (2009-2012, DST-SYSP)

- In the Garhwal region part of the Himalaya, about 77.4% of the total human population is rural because of geographical inaccessibility. This inaccessibility of the area and deprived socio-economic status of locals is responsible for the total dependence of the local inhabitants on nearby forest areas for their fodder demands. Collection of fodder is the first step that turns the wheel of the agricultural economy of the village community. Agriculture along with animal husbandry is the principal occupation and source of livelihood for over 70% of the population of the Uttarakhand state of India. Uttarakhand is well endowed with a variety of livestock. Large population and now productivity are the hallmark of livestock in the state, across all species. Cattle are the preponderant and most popular species; however, buffaloes are the premier milch animal and the main stay of the state dairy industry, while, goat and sheep are the popular species among marginal, sub-marginal and landless farmers of the state. In the state, animal husbandry plays a vital role in the rural economy largely based on different land base interventions.
- A large variety of tree species, forest floor, phytomass and agricultural by-products are used as animal fodder in the Himalaya. A total of about 48 prominent and locally preferred fodder species (including trees, shrubs and herbs) were listed for fodder by locals are also the ones having high crude protein percentage and organic matter digestibility.
- Fodder calendar developed on the basis of seasonal availability of major fodder resources could help the livestock owners to harness these fodders according to different seasons in the year. Green fodder is available in all seasons. Availing these greens for livestock feeding would have positive bearing on the health and lactation yield of animals.
- Feed supplies to livestock in mountain areas could be augmented through rangeland management. The traditional knowledge of the farmers in the mountains is of crucial value towards rangeland conservation and utilization.
- A well-developed fodder bank on > 20 ha of wasteland in a mountain village of 100 households coupled with well-developed agroforests by fast-growing grasses can reduce pressure on nearby forests around the year.
- Investment of human energy in raising of fodder used as fresh feed can now be used in saving the health of forests by adopting various cost-effective and novel scientific practices. These are new feeds and feeding activities being introduced like cultivation of pastures and fodder crops on the farms or in backyards or cropland bunds or village common lands, which may include leguminous browse shrubs or trees; fodder conservation; as well as silage preparation.

R&D HIGHLIGHT OF THE REGIONAL UNITS

GARHWAL UNIT

- Introduced, tested, developed, upgraded, validated and demonstrated appropriate hill specific rural technologies through action research and participatory approaches for natural resource management and livelihood enhancement at Rural Technology Centre in Triyuginarayan at an altitude of 2200m asl.
- Strong linkages and networks developed with various institutions, NGOs and line departments and the names and addresses and contact numbers of resource persons listed for directory preparation for future use.
- The capacity building and outreach programme in the area of value addition of wild bioresources has made a significant impact in the study area and has stimulated local youth and village institutions to adopt the value addition practices based on wild bioresources for income generation and livelihood enhancement.
- Assessment of resource availability of potential wild edibles, phenophares, conservation status, nutritional value, value addition and cost benefit analysis of product developed for income generation were undertaken. Exhibitions of wild edible products, regional and village level business workshops were organized bi-annually and annually. Awareness generation through print as well as electronic media was also popularized. About 290 households of 45 villages in upper Kedar valley and Niti valley have adopted the local value addition of variety of wild edible plants as small household activity for income generation. The various local value added products i.e. squash, juice and sauce are prepared by the people for their household consumption and also for marketing.
- Assessment of nutritional, nutraceutical potential, commercial utilization, value addition and large scale domestication of wild and herbal species (i.e., *Allium strecheyii, A. rubellium, A. humile, Angelica glauca, Carum carvi, Pleurospermum angelicoides* and *Cinnamomum tamala*) were carried out. Besides, efforts were also made to enhance the yield of these wild herbal species through the application of simple scientific & technological interventions.
- About 23 ha of village common degraded land were developed under 7 prototypes (2 MPTs and 5 Horticulture models) in three village clusters of Tehri Garhwal district. In addition, a fodder bank model has been developed on a 5 ha degraded wasteland in Maikhanda village in Rudraprayag district.
- Enhanced capacities and skill of local stakeholders in community based tourism (CBT) i.e. homestay accommodation, agro-production system, bioprospecting of wild bioresources and product development for livelihood improvement.
- Popularized lesser-known tourism spots in upper Kedar valley with the support of village institutions and highlighted their uniqueness for promoting tourism in these areas, to reduce pressure on well-known tourist places and provide

opportunities to local people to participate in managing tourism and deriving benefits from it.

- In-depth study on local people's perception and attitude towards helicopter services and its impact on local economy and environment has been carried out.
- The impact of tourism on various sectors/ areas/aspects i.e. agriculture, livestock, forestry, infrastructure, land use pattern, human population, socio-cultural traditions, etc. and option for maximizing benefits/opportunities and mitigation of the problems encountered was carried out.
- Developed strategies, action and management plans, policy briefs for sustainable tourism for Uttarakhand.
- In 2012, a total of 3750 fodder plants of eleven species such as *Chimnobambusa falcata, Thamnocalamus spathiflorus, Arundinaria* spp, *Quercus leucotricophora, Ficus nemoralis, Ficus auriculata, Debregeasia salicifolia, Ficus subincisa, Celtis australis, Morus alba, Bauhinia varigata* were planted in a fodder bank model. Besides, empowered women folk in a cluster of villages in Talla and Malla Maikhand area.
- Assessment of survival, growth and carbon stocks of multipurpose tree species after 20 years of plantations developed on village community degraded land following agroforestry and restoration ecology approaches were carried out.
- Prioritization and categorization of ailment specific MAPs and their contribution in traditional health care system of tribal and non-tribal communities inhabiting 22 villages of higher Himalayan region covering 7 valleys in the districts of Rudraprayag, Chamoli and Pauri were evaluated.
- Climate change impact in mountain agro-ecosystem and enhancing climate resilient ecosystem and adaptation/ mitigation strategies in Nayar valley and other areas of Garhwal region.
- Promoted homestay accommodation and eco-tourism product development through locally available resources. Empowered local people/youth in the field of simple and eco-friendly technologies for improving the yield particularly vegetables (off-season) and traditional crops. This linkage of local production and consumption systems helped people to involve themselves in tourism and make good profit from this venture.
- Assessed solid waste and horse/mule dung generation in Kedar pilgrimage sites and developed guidelines and action plan for recycling, biocomposting and management.
- Assessment of contribution of pack animals in reducing of CO_2 emission and impact of helicopter services on local economy.
- Development of participatory and action research approaches for promoting science and climate science education involving high school science students and teachers of central Himalaya (Uttarakhand).
- Development of propogation packages of *Paeonia emodi, Viburnum mullaha, Inula racemosa,* etc. for their effective utilization, cultivation and conservation.
- Assessment of regeneration potential and anthropogenic pressure on *Betula utilis* at timberline zone for its effective conservation and management.
- In-depth ecological and socio-economic studies were undertaken in Kedarnath wildlife sanctuary to understand resource extraction and conservation attitudes of the fringe area settlements.
- Enhancing sustainable livelihood options as an adaptive strategy to reduce vulnerability and increase resilience to climate change impact in the Central Himalaya.
- Assessment of socio-ecological and religious perspective of agrobiodiversity in changing scenario and issues and priority for sustainable agriculture in the Central Himalaya.
- Inventorization and population assessment of belowground biodiversity (BGBD) particularly earthworm in a traditional village landscape of the Central Himalaya.
- A total of 1 hectare village common land was procured and brought under nursery development of selected medicinal plants i.e. *Asparagus officinalis* (Satavar) and *Ocimum sanctum* (Tulsi).
- About 60 farmers of Manjgaon village cluster were provided technical know-how regarding nursery raising of medicinal plants (*Asparagus officinalis* (Satavar, *Ocimum sanctum* (Tulsi. Besides, seeds of these two medicinal plant species were provided to the farmers to raise the seedlings and about 60 farmers have been benefited from this venture

HIMACHAL UNIT

- Information on biodiversity assessment (qualitative and quantitative), valuation (Conservation: nativity, endemism & threat categorization; Socio-economic: utilization pattern) and conservation prioritization in the Nargu Wildlife Sanctuary, Himachal Pradesh was compiled, analyzed and synthesized. The study provided comprehensive datasets on compositional, structural and functional aspects of biodiversity. Assessment and monitoring of the forest communities along altitudinal and disturbance gradients and climatic regimes. The study showed variations and changing patterns of vegetation across all the gradients.
- Information on assessment, mapping, valuation (Conservation: nativity, endemism & threat categorization; Socio-economic: utilization pattern), prioritization and conservation of medicinal plant diversity in the Chandra valley, Upper Beas Valley, Parbati Watershed, Mohal Khad Watershed and Banjar Valley in Himachal Pradesh was compiled, analyzed and synthesized. Cultivation of *Aconitum heterophyllum* was promoted in Jana village, Kullu valley and Khansar village in Lahaul valley, and *Withania somnifera* in lower Kullu valley, Mandi Pandoh Area and Smaila and adjacent villages. Agrotechniques of the 26 high value medicinal plants were developed and disseminated to the progressive farmers. Various training programmes and exposure visits were organized for awareness and education on medicinal plants.
- Conventional (seed germination and vegetative) propagation protocols for over 20 multipurpose tree species and medicinal plants were developed. The seedlings were distributed to the farmers for cultivation, plantation, restoration of degraded lands and development of School Campuses.
- From Sainj Hydro-Electric project area, 148 species of vascular plants belonging to 72 families and 128 genera; 16 forest communities and 134 economically important; and Upper Beas Valley, 149 species (16 trees, 18 shrubs and 115 herbs including ferns) and 4 communities (*Pinus wallichiana*, *Cedrus deodara*, *Pinus roxburghii,* and *Alnus nitida*) were recorded. Various ecosystem services were assessed and documented.
- From Hadimba Mata, Kalinag, Jamadagni Rishi, Rupasna, Bhirghu Rishi and Sangchul Rishi Sacred Groves in Kullu district a total of 133 species of vascular plants belonging to 62 families and 115 genera were recorded. One tree community i.e., *Cedrus deodara* was identified from Hadimba Mata, Kalinag and Jamadagni Rishi Sacred Groves.
- In CDBR, from 46 sites 196 species representing 51 families and 141 genera; 84 economically important plants (used as medicine (98 spp.), wild edible/food (46 spp.), fodder (27 spp.), fuel (11 spp.), timber (02 spp.), religious (08 spp.), Agricultural tools (07 spp.), insect repellant (02 spp.) and other species for various other purposes) and 28 plant communities (16 shrubs and 12 herbs) were recorded. Species diversity (H′) for shrubs ranged from 0.00-3.60 and herbs, 0.98-2.65. Concentration of dominance (Cd) of shrubs ranged from 0.25-01 and herbs 0.09-0.58.
- Total 29 populations of *Arnebia euchroma* between 3,710– 4,394m, amsl were studied in the Lahaul & Spiti and Kinnaur districts of Himachal Pradesh. The total shrub density ranged from 40-1190 Ind ha^{-1}; total herb density, 4.60-70.55 Ind m^{-2} and relative density (%) of *Arnebia euchroma* ranged from 0.68-41.04 % in the sampled populations. The richness of shrubs ranged from 1-6 and herbs 4-27.
- Pollination Deficit Protocol experiments were conducted in 20 apple orchards (10 near to natural habitat with or without the treatment of bee hives and 10 far from natural habitat with or without the treatment of bee hives of *Apis mellifera*) to know the effect of bees on apple crop production. Highest population density of indigenous honey bee (*Apis cerana*) was recorded from the open pollinated orchards of near to natural habitat orchards which ranged between 5 - 7 and 4.6 – 6.9 bees/250 apple flowers of production and pollinizer varieties.
- Generated a data base on morphometric analysis for strengthening strategic environmental assessment of hydropower projects in the Sutlej basin in Himachal Pradesh and in the Alaknanda basin in Uttarakhand in the Indian Himalayan Region.
- The solid waste management study in six towns (i.e., Bilaspur, Hamirpur, Mandi, Kangra, Chamba, Keylong) of Himachal Pradesh showed that biodegradable waste, on average, made up 76% of the total waste generated. This could serve as an

important raw material for bio-composting as if kept away from medical waste.

- Created natural resource and social database for land use and land cover maps using RS&GIS for Cold Desert Biosphere Reserve (CDBR) showing about 36.02% in core zone, 49.46% in buffer zone and 14.52% in transition zone in the Spiti region of Himachal Pradesh.
- The recent tourist inflow statistics of Himachal Pradesh were compiled and analyzed for indirect assessment of the level of services. Besides the amenity value for the people of the state, the high influx of tourists to the state, which was 16.15 million during year 2012, provides an indirect estimate of consumers of the recreational services that are associated with tourism. The tourist statistics also suggest a consistent growth in inflow which in addition to impacts of improved mobility, increasing per capita income, and promotional policies, also owes partly to climate change.
- Monitoring of pesticide residues i.e., endosulfan, chlorpyrifos, cypermethrin and malathion in soil, water and food chain and assessment of their health risk to humans was done. The results revealed that surface water, soil and all the tested crops were contaminated with tested pesticide residues, however, their concentrations were found below maximum residue limits (MRLs) in apples, cauliflowers and tomatoes collected from both the field and market sites. It also showed that the concentrations of pesticide residues were recorded higher at production sites as compared to at market sites. Daily intake of tested pesticide residues through consumption of apples, cauliflowers and tomatoes was recorded higher for the male than the female population, but their consumption via apples, tomatoes and cauliflowers was, however found within the accepted daily intake.
- Arboretum, Herbal Gardens and Medicinal Plant Nurseries were strengthened through introduction of new accessions at Mohal, Doharanala and Kasol in Himachal Pradesh. Conservation models were developed in the Govt. Schools of Himachal Pradesh.
- Agrotechniques developed/compiled for 26 commercially viable medicinal plants were disseminated to different stakeholders. Agrotechniques of *Aconitum heterophyllum, Picrorhiza kurrooa, Angelica glauca, Withania somnifera, Valeriana jatamansi, etc. were* demonstrated in the farmers' fields. Over 300 seedlings of *Withania somnifera* and *Grevillea robusta* were distributed to the Schools of Kullu valley.
- A One day Training Programme on "Biodiversity Conservation and Management in Relation to Climate Change" was organized at Govt. Senior Secondary School, Baldwara, Mandi, Himachal Pradesh on March 23, 2013. Capacity building of the 132 students and teachers representing 08 Schools and local inhabitants was done through a comprehensive lecture on Biodiversity Conservation and Management in relation to climate change; propagation techniques, practical exercise of the Participatory Rural Appraisal; and Qualitative (Rapid sampling & identification of species) and quantitative assessment (Quadrat method) of biodiversity were under taken Pre and post training programme feedbacks were taken. The training programme showed significant improvement in the knowledge of the participants about biodiversity conservation and management and climate change.
- Organized the celebration of "International Day for Biological Diversity" in collaboration with Govt. Senior Secondary School, Panarasa, Mandi on May 22, 2012 at Govt. Senior Secondary School, Panarasa, district Mandi, Himachal Pradesh. Comprehensive lecture on "Biodiversity Conservation and Management in Himachal Pradesh" was delivered for enhancing the skill of 271 Students and Teachers.
- Organized World Environment Day Celebration on June 05, 2012 for the Students, Teachers, Mahila Mandals and Yuwak Mandals of Kullu Valley at GBPIHED, Himachal Unit, Mohal-Kullu, Himachal Pradesh. 112 students and teachers from Kullu valley were given exposure of the Institute activities related to the environment and development. They were also made aware about environmental conservation and management through power point lectures presentation.
- Organized Volunteer Group Programmes (3 Nos) for the 15 Teacher Volunteers, Govt. of Delhi and NCT, New Delhi representatives (10-14 June); 12 Teacher Volunteers, Govt. of Delhi and NCT, New Delhi representatives (22-26 September, 2012; and 06 AMCOR and NBA Volunteers and Earthwatch India Team (02) (10-14 June 2012) under the

working group, developed the policy document, *Sikkim Biodiversity Action Plan*, August 2012. Published by Sikkim Biodiversity Conservation and Forest Management Project, FEWMD, Government of Sikkim, Printer at Concept, India. P. 44. The document was released by the Hon. Chief Minister of Sikkim on 15th August 2012.

- Growth parameters of tissue culture raised *R. maddeni*, *R. dalhousie* and conventionally propagated amongst with other valuable rhododendron species, *R. griffithianum, R. baileyii, R. grande R. dalhousiae, R. cilatum.* that were planted at Rare and Threatened Plant Conservation Park, Himalayan Zoological Park, Bulbulay, Gangtok were recorded. Plants of the same batch are doing quite well at the Institute's arboretum as well. It is further significantly noted that the *R. maddenii* is the first Rhododendron species in the country, which has been mass multiplied using tissue culture technology by the scientists of the G.B. Pant Institute in Sikkim.

NORTH EAST UNIT

- During the reporting period, efforts were made under GOI-UNDP CCF-II project entitled "*Biodiversity conservation through community based natural resource management in Arunachal Pradesh*" to strengthen alternate livelihood options, particularly Community Based Tourism (CBT) as a potential mechanism for livelihood and biodiversity conservation. CBT was promoted in Tawang and West Kameng Biosphere Reserve (proposed BR - TWKBR) and a model for culture based tourism was developed in Apatani plateau.
- In TWKBR, capacity of villagers was enhanced through organization of training workshops for cooks, guides camp site development financial management, home stay and home based restaurant, development etc., orientation programmes for youths for the management of tourists.
- In Apatani Plateau, a culture based ecotourism model was developed in association with Achukuru Welfare Society (AWS), a society dedicated for economically deprived and socially despised people. The model comprised kitchen garden, nursery, community based sales counter, museum, duckery unit and pisciculture, etc., developed over a pond.
- During the reporting year, there has been significant policy related work in the form of development of (I). Guidelines for promotion and Management of Community Conserved Areas in Arunachal Pradesh and (II). Arunachal Pradesh Ecotourism Policy, which were prepared under the GOI-UNDP CCF-II project and submitted to State Government of Arunachal Pradesh. CBT promoted as conservation incentive for the villagers, helped villagers gradually realize that conservation can also help to improve their livelihood condition.
- In an effort to understand the downstream impacts of hydroelectric projects in Himalayan region, a case study of Ranganadi hydroelectric project (405 MW) in the state of Arunachal Pradesh was carried out. During the reporting period, based on field observations and preliminary data collection, it was found that water availability and quality in the downstream reaches (particularly in Assam) seems to be the most important issue, which needs further detailed study.
- The secondary data on future climate change (using climate and hydrological models) shows that (i) Rainfall will decrease 5-15% by 2050 and increase 25-35% by 2080 as compared to baseline (i.e. 1961-1990), (ii) Temperature will increase during both time scales: 2.2-2.8^{0}C by 2050 and 3.4->5^{0}C towards 2080, (iii) 2-3% increase in annual precipitation by 2050 and 20% decrease by 2080, and (iv) water yield may increase by 3.5 % till 2050 and can possibly reduce by 8.7% till 2080 with reference to the baseline (i.e. 1961-1990).
- Secondary information collected so far revealed that in India, tourism has the potential to provide economic and social benefits. It has emerged as a major source of employment, with a share of 8.27 per cent of the total number of jobs in the country. With respect to IHR States, tourist inflow statistics of Himachal Pradesh, which also includes religious tourists depicts that the tourist inflow volume to the state has nearly doubled from 6.55 million in 2004 to 16.15 million in 2012, suggesting a total growth of 146.54% from inflow levels of year 2004, which is equal to an average growth 16.28% per annum.
- Data also revealed that northeast India is receiving less than 1% of the total tourist arrivals in India. The positive thing about the arrivals in the states

GBPIHED-EWI Himalayan Ecosystems Research Project on *"Assessment and quantification of forest ecosystem services with special emphasis on pollination in the Indian Himalayan agro-ecosystems"*. The volunteers were appraised about the Institute and GBPIHED-EWI project activities. They were trained on the methodologies to be used for information generation in the field on various ecosystem services, made aware about the pollination and pollinators and facilitated in the field for information generation.

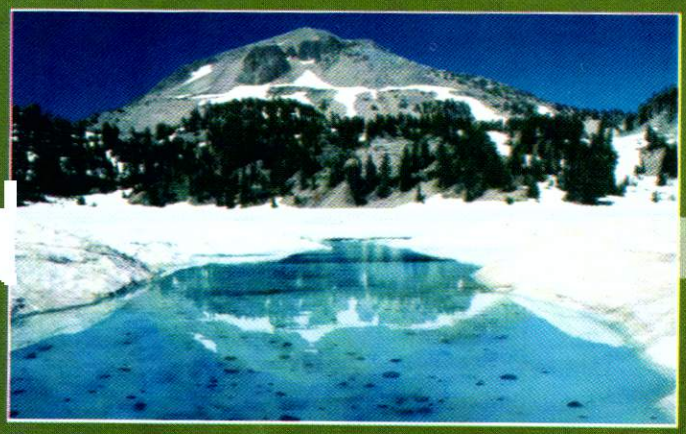
- Organized 09 Exposure Visits for the farmers (23) of Mandi district on January 05, 2012; and farmers (19) of Mandi district on February 28, 2012; farmers and NGOs (28) of Mandi district on March 13, 2012; students and teachers (11) of Lal Chand Kaura Paedmont School, Bhuntar on April 16, 2012; students and teachers (32) of DAV Senior Secondary School, Mohal, Kullu on April 24, 2012; students and Professors (74) of Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan on April 18, 2012; students and teachers (36) of Manali Public School, Manali on May 10, 2012; students and teachers (143) of Inspire , Inspire Internship Camp- 21-25 August, 2012 (Funded by DST, Govt. of India, New Delhi); and students and Professors (56) of the Govt. Post Graduate College, Kullu on November 12, 2012 to the GBPIHED, Himachal Unit, Mohal-Kullu. The participants were briefed about the R&D activities of Himachal Unit through LCD presentations. Exposure to laboratories, library, environmental observatory and demonstration sites namely arboretum, medicinal plants and MPTs nurseries, herbal garden, green house, shade house, vermi-composting, weed composting, solid waste management, pollution monitoring stations, etc. was given.

SIKKIM UNIT

- An extensive study programme (first phase), "Response assessment and processing of knowledge base to serve long term management and use of biodiversity in the Himalaya –focus on Khangchendzonga Biosphere Reserve, Sikkim" accomplished in Khangchendzonga Biosphere Reserve (Sikkim).
- An extensive study programme (first phase) on upscaling mechanism for biodiversity conservation completed (Sikkim). *Ex-situ* cultivation of *Swertia chirayita* (critically endangered) standardized.
- A monographic work as extensive review made and published on *Swertia chira*yita by B.K. Pradhan, and H.K. Badola, 2012, [Pp. 33-355 n Panda, S. and Ghosh, C. (*eds*), *Diversity and Conservation of Plants and Traditional Knowledge*. Bishen SIngh Mahendra Pal Singh, Dehra Dun, India).
- Occurrence of *Phoenix rupicola* and its habitat characteristics at the three sites at Sevoke, Pashok and Namthang in the Sikkim Himalaya has been completed and about 65 individuals have been recorded so far.
- Habitat study of critically endangered *Rhododendron leptocarpum* has been undertaken at Tshoka within the Khangchendzonga Biosphere Reserve. Visual counts have resulted in more than 460 individuals presently growing at the site.
- Seed materials of both *Phoenix rupicola* and *R. leptocarpum* have been collected and both are undergoing further experiments in propagation measures in the field sites as well as in the lab and greenhouses under different growing conditions and media.
- First phase of socio-economic/resource survey based questionnaire and formats were designed and tested in the close peripherals of south-west KBR. Further structured questionnaire and field formats are under the process of development. Two remote villages were surveyed for the households' socio-economics, biodiversity conservation and bioresource values and their use practices, etc. Amongst ten most prioritized (preferred) fuel wood species, *Alnus nepalensis* and *Schima wallichii* appeared to be at the top for either village; however, *Castonopsis tribuloides* and *Quercus lamellosa* were other highly preferred species. Data are under various levels of computation and analysis.
- One day training workshop for over 30 students (Class X & XII; biology) and teachers of five schools in Sikkim was organized. In addition to lectures, exposure to lab/nurseries, they were involved in field based vegetation survey exercise in arboretum. Following issue prioritization exercise, participants extensively interacted on various conservation threats and possible mitigation approaches.
- As lead member (H.K. Badola) of the international

like Assam, Meghalaya, Tripura and Sikkim is that they have a considerable share of the total tourist arrival. It was found that the number of tourists arrivals are gradually increasing over years in Arunachal Pradesh, known as 'the land of rising sun' and 'the land of dawn-lit mountains'.

- The road sectors covered under wildlife and biodiversity management along the Trans-Arunachal Highway are Nechipu to Bana (West Kameng district), Seppa to Passa (East Kameng district), Potin to Bopi (Lower Subansiri district), Godak to Tai (Upper Subansiri district) and Tai to Bame (West Siang district) in Arunachal Pradesh. The survey revealed some perceived threats such as widening may deprive the birds, animals, reptiles, orchids, mosses, lizards and insects of their habitat. Opening and improvement of roads may also facilitate poaching of wild animals and collection of parts or whole of endangered vulnerable plants, thereby endangering them further. Fast moving traffic and increase in movement of vehicles shall obstruct natural passages and corridors of long ranging animals, either by affecting their foraging or causing genetic isolation of small herds.
- Various policies and acts dealing with road development were analyzed. Some of them are Balipara/Sadiya/Tirap Frontier Tract Jhum Regulation Act, 1947; Wildlife (Protection) Act, 1972 and 1991; The Arunachal Pradesh (Land Settlement and Records) Act, 2000; Resettlement and Rehabilitation Policy of state of Arunachal Pradesh, 2008; Arunachal Pradesh (Biological Diversity) Rules, 2011; The Road Transport Corporation Act, 1950; The National Highways Act, 1956; Guidelines under Forest (Conservation) Act, 1980 for up-gradation of 'Kutcha road constructed prior to 1980 in forest areas to Pucca roads', 2005; National Policy on Resettlement and Rehabilitation (NPRR), 2003 and many others.
- The proposed Trans-Arunachal Highway segments are endowed with rich floristic diversity of tropical evergreen, tropical deciduous, subtropical evergreen, subtropical deciduous, and temperate evergreen forests, which are rich in species composition and diversity distributed along the altitudinal gradient of 400-2500 m asl. In all, 859 species of higher plants, higher and lower cryptogams were recorded from the forest of three road segments only.
- The forest vegetation is mostly mixed type, composed of grass flora at ground floor while the middle storey are dominated by herbs, shrubs, climbers and lianas. The tree species, which dominate the top storeys include *Dubanga grandiflora, Terminalia species, Stereospermum chilonoides, Pterospermum acefolium, Litsea species, Musa balbisiana, Enseta glauca, Altingia excelsa, Phoebe goalparensis, Arthocarpus chama, Tetramelis nudiflora, Michelia champaca, Dillenia indica, Actinodaphne obavata, Ficus species, Bambo species* and *Schima wallichii*. The subtropical forest along the road side is rich with *Altingia excelsa, Schima wallichii, Suirauia species, Ficus species, Bombyx ceiba, Terminalia myriocarpa, Castanopsis species, Albizia stipulata, Calamus species* and *Engelhardia spicata*. The secondary forest is mainly dominated by the members of Euphorbiaceae such as *Macranga denticulata, Macranga peltata,* and other family members such as *Saurauia species, Ficus species, Meliosma simplicifolia* and *Talauma hodgsoni*.
- As the proposed Trans-Arunachal Highway Segments are passing through rich biodiversity and cultural corridor zones, majority of the plant species reported are mostly used as ethnbotanical resources for sustenance of livelihood by the five major tribes namely *Nyishi, Tagin, Apatani, Galo and Adis*. Of the total 859 species reported along the road side, almost 724 (84.28%) species are reported as ethnobotanically significant plants, which include food, medicine, cultural and timber plants. Among the ethnobotanical plants, tree habit represents 231 (31%) species, which is followed by herb species with 224 (30%), shrubs with 151(21%) species and climbers with 109 (15%) species.



APPLICATION OF R&D OUTPUTS IN DEMONSTRATION & DISSEMINATION

Integrated Eco-development Research Programme (IERP) in the Indian Himalayan Region ***(1992 – Long Term Scheme, MoEF, Govt. of India)***

Ministry of Environment and Forests (MoEF), Government of India entrusted the responsibility of Integrated Action Oriented Research, Development and Extension (named as Integrated Eco-development Research Programme - IERP) in the Indian Himalayan region (IHR) to the Institute in 1992. The Institute funded R&D projects under two broad thrust areas [namely, Technology Development and Research (TDR) for Integrated Eco-development, and Technology Demonstration and Extension (TDE)] up to 2006-2007. Since then, location-specific/action-oriented IERP projects are being funded under 6 identified themes [namely, Watershed Processes and Management (WPM), Biodiversity Conservation and Management (BCM), Environmental Assessment and Management (EAM), Socio Economic Development (SED), Biotechnological Applications (BTA), and Knowledge Products and Capacity Building (KCB)] of the Institute.

Objectives

- To provide extra mural funds to different Universities/Institutions/NGOs/Voluntary agencies for the support of location-specific R&D activities in the Indian Himalayan region (IHR).
- To develop scientific capabilities in the IHR and strengthen infrastructure for environmental research.
- To develop and execute coordinated programmes as per R&D needs of the IHR or on the recommendations of the completed projects with the help of identified network partners.

Achievements

- Funds for 32 ongoing/completed projects were released to different organizations after careful examination of the reports, Utilization Certificates (UCs) and Statements of Expenditure (SEs), etc.
- Annual Progress Reports, (APRs) of 32 on-going projects were processed and referred to the subject experts for evaluation. Subsequently, the comments of the subject experts on the APRs were sent to the concerned PIs for follow-up action.
- Final Technical Reports (FTRs) of 11 completed projects were sent to various govt./user agencies for follow-up action on the recommendations of the project and also to the subject experts for their comments/suggestions.
- Coordinated programme entitled "*Sacred values, eco-restoration and conservation initiatives in the Indian Himalayan region*" was continued and strengthened in the two States (Uttarakhand and Meghalaya) of the IHR.
- Forty one IERP projects were on-going in 5 States (Himachal Pradesh, J&K, Meghalaya, Nagaland and Uttarakhand) of the Indian Himalayan region.

Strengthening and Management of ENVIS Centre on Himalayan Ecology at the Institute-Head Quarters ***(1992 – Long Term Scheme, MoEF, Govt. of India)***

management of Library and Information Centre, a network version of the software PALMS developed by the Scientist of this Institute is being used. As a result, the Library is providing a number of services such as Article Alert, Current Awareness, Selective Dissemination of Information, Reprography, Reference, Indexing, Bibliography, Web Services (Online Journals) etc., for the development of the human resources. The Library of the Institute is accessible through the Institute's web site (http://gbpihed.gov.in).

During the reporting year, 474 new book titles were added to the Library. R & D achievements of the Institute were disseminated through its regular in-house publications, namely Hima-Paryavaran – a biannual newsletter and Institute Annual Report to various academic and scientific institutions, Government departments, NGOs, policymakers, planners and individuals working on various aspects of mountain environment and development.

Central Laboratory Facility

The Institute has strengthened the facilities of physico-chemical, biological, heavy metal analysis of drinking, raw, waste water and quantification of volatile compounds of soil and plant samples. The heavy metals in water and soil samples are detected through Atomic Absorption Spectrophotometer (Make- Varian AA280Z, equipped with graphite tube atomizer). For the quantification of aromatic and volatile compounds the institute has a Gas Chromatography unit (make- Chemito, Ceres 800^{+}). Institute is also having the facility of detection of C, H, N & S through CHNS-O analyzer (make- Elementar, Vario EL-*III*) and UV-Vis spectrophotometer (make- UV 5704, Electronics corporation of India Ltd.) for soil, water & plant analysis. The Institute has extended these services for other organizations (NGO's and other Government Organizations) on payment basis. In the financial year 2012-13, The Institute collected 0.94 lakh rupees as central laboratory service charge from 20 organizations (6 - Govt. organizations & 14 - NGO's). Figure-61 shows month wise collection of testing charges and services offered to different other organizations.

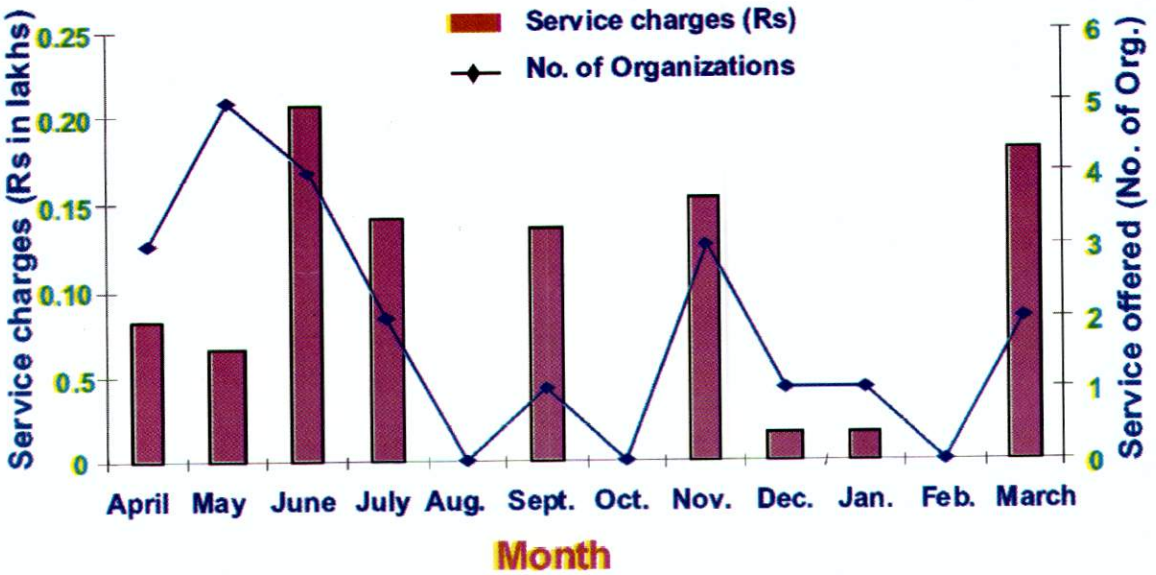


Fig.61. Graphic view representing total fee collected from Central Laboratory Services in 2012-13.

Environmental Information System (ENVIS) Centre on Himalayan Ecology was set up in the Institute in the financial year 1992-93 as a part of ENVIS network in India by the Ministry of Environment and Forests (MoEF), Govt. of India, the nodal agency in the country for collecting and collating all available information from all the ENVIS Centres to provide national scenarios to the international set up, INFOTERRA Programme, of the UNEP.

Objectives

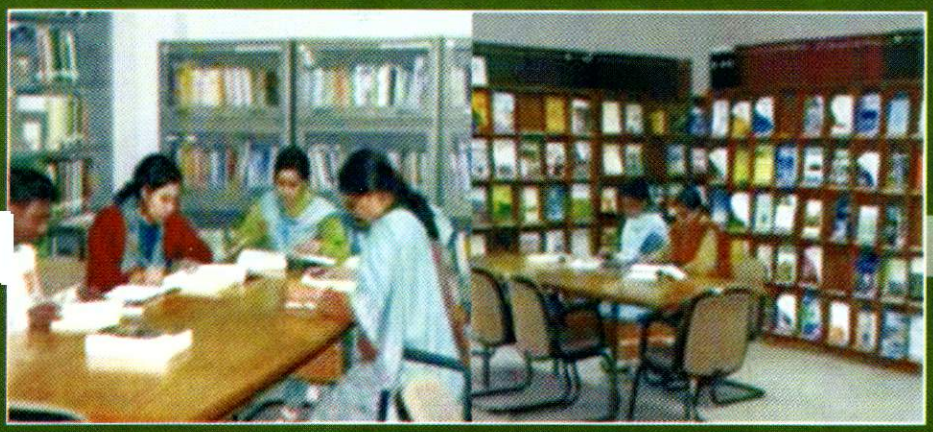
- To collect, collate, compile and build qualitative and quantitative databases of information related to various aspects of Himalayan Ecology.
- To disseminate all available information, free of cost, to various stakeholders/users including all the District Information Centres (operating in the Himalayan states of the country), ENVIS Centres/Nodes and other user agencies/groups through print and electronic media.
- To develop, up-grade and maintain ENVIS website at the headquarters of the Institute.

Achievements

- Information on various aspects of Himalayan Ecology from various District Information Centres, Universities/University Campuses, Research Centers, Government Institutions, NGOs and experts/individuals working in the Indian Himalayan region (IHR) were collected and compiled during the year 2012-13.
- Research abstracts/articles/technical reports and news-clippings on Himalayan environment related issues were collected from various sources. The abstracts and news-clippings (bi-lingual) were published in the 'Selected Abstracts' and 'News and Views' section of the ENVIS Bulletin (Vol. 20, pp. 1-103, 2012).
- About 62 research abstracts, related to the various aspects of Himalayan Ecology, were added on the Abstract Database of the ENVIS Centre. At present, this database contains 2057 abstracts.
- State-wise and district-wise resource profile (related to demography as per Census 1991, 2001, 2011, educational infrastructure, health, etc.) of all the Indian Himalayan states has been compiled and updated for uploading in the website of the ENVIS Centre.
- State-wise information on agriculture data (e.g., area under crops, area for fruits, horticulture crops, consumptions of pesticides, irrigated area, Krishi Vigyan Kendras (KVKs), etc.) of Indian Himalaya states has been compiled for uploading in the website of the ENVIS Centre.
- State/district-wise information on forestry data (e.g., forest cover/forest area/tree cover, etc.) of different forest assessments (e.g., 2001-2011, etc.) of Indian Himalayan states has been compiled and updated for uploading in the website of the ENVIS Centre.
- State/district-wise information on distribution of wastelands in Indian Himalayan states has been compiled for uploading in the website of the ENVIS Centre.
- About 55 queries, of individuals/institutions related to Himalayan environment and development, were responded to during the year 2012.
- All available information on various aspects of Himalayan Ecology, which were collected and compiled during the year, were disseminated to 341 stakeholders through electronic and print media.
- Electronic versions of all the ENVIS publications in CD formats were prepared and distributed to various stakeholders.
- ENVIS Bulletin (Volume 20) and ENVIS Newsletter (Volume 9) on Himalayan Ecology were prepared, published and made available online through the website of the ENVIS Centre.
- All the publications of the ENVIS Centre, such as - ENVIS Bulletins, ENVIS Monographs and ENVIS Newsletters, which were published so far, were uploaded (in PDF format) in the website of the ENVIS Centre.
- Website of the ENVIS Centre on Himalayan Ecology <http://gbpihedenvis.nic.in> was re-designed, maintained and upgraded at the headquarters of the Institute (GBPIHED); efforts for the conversion of ENVIS website from its STATIC mode to DYNAMIC mode were also carried out.

Strengthening and Maintenance of the Central Library at HQ

The Central Library of the Institute at its headquarters, had 15,506 books at the end of the financial year 2012-2013, The library is subscribing a total of 90 periodicals (51 Foreign and 39 Indian). For



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2. AWARDS AND HONOURS

Award of Honour given by Department of Microbiology, College of Basic Sciences, CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh during the Inspire, Inspire Internship Camp- 21-25 August, 2012 (Funded by DST, Govt. of India, New Delhi) at Dev Sadan, Kullu, Himachal Pradesh (S.S. Samant).

Honoured with 'Best Citizens of India Award' by International Publishing House, New Delhi (Negi, G.C.S.).

Leading Scientists of the World by International Biogeographical Centre, Cambridge, England (R.K. Maikhuri).

P. Ghosh, Best Poster award, in Agricultural and Forestry Science section at the 100th Indian Science Congress, Kolkata, 3-7th January 2013.

Rashtriya Gaurav Award by India International Friendship Society, New Delhi (Negi, G.C.S.).

Young Scientist award in Biotechnology in 7th Uttarakhad Science Congress, Dehradun (Arun Kumar Jugran)

Participation of Institute Faculty/Project Staff in Different Events:

Events	HQs	Units			*Total*
		NE	Sikkim	Garhwal	HP	
National						
• Conferences / Workshops	55	09	20	48	24	**156**
• Training Courses	18	03	10	19	14	**64**
• Meetings	63	08	27	29	19	**146**
• Participation as a Resource Person	26	11	19	40	62	**158**
• Any Other	11	06	36	35	23	**111**
International	12	00	04	08	07	**31**

DAVER KARNATAK & ASSOCIATES
CHARTERED ACCOUNTANTS

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New Delhi- 110002, 011-43508411, +919810086211
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INDEPENDENT AUDITOR'S REPORT

To
The Members of
G.B. Pant Institute of Himalayan Environment & Development
New Delhi

We have audited the attached Balance Sheet of G.B. PANT INSTITUTE OF HIMALAYAN ENVIRONMENT AND DEVELOPMENT which comprise the Balance Sheet as at March 31, 2013, and the Income and Expenditure Account, Receipt & Payment account for the year then ended and a summary of significant accounting policies.

Management's Responsibility for the Financial Statements
Management is responsible for the preparation of these financial statements in accordance with The Law of India. This responsibility includes the design, implementation and maintenance of internal control relevant to the preparation of the financial statements that are free from material misstatement, whether due to fraud or error.

Auditor's Responsibility
Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with the Standards on Auditing issued by the Institute of Chartered Accountants of India. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement.
An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgement, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error .In making those risk assessments, the auditor considers internal control relevant to the Societies preparation and fair presentation of the financial statements in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of the accounting estimates made by management, as well as evaluating the overall presentation of the financial statements.
We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Opinion

In our opinion and to the best of our information and according to the explanations given to us, the financial statements of G.B. PANT INSTITUTE OF HIMALAYAN ENVIRONMENT AND DEVELOPMENT for the year ended March 31, 2013 are prepared, in all material respects, in accordance with The Law of India.

The said account gives the information required and gives a true and fair view.

(a) In the case of Balance Sheet, of the State of Affairs of the Institute as at **31st March 2013.**

(b) In the case of Income and Expenditure Account the INCOME for the Year ended on that date.

(c) In the case Receipt and Payment Account the Receipt and Payment on Cash and/or Bank account during the Year ended on that date.

Emphasis of Matter

We Draw attention to
Internal Audit Report 2012 dated 07/03/2013, requires proper reply of The Management of the Society, Management Reply is not presented before us, and as per our knowledge is also not send to internal auditors for settlement of these Para.

Financial Statement. Point no. 4 of Significant accounting policy point no 4. Depreciation on fixed assets has been provided on straight line method as per the rate prescribed in schedule XIV to the company's act 1956 irrespective of days of use in first year depreciation is charged for whole year.

Fixed Asset Register, required to be made in correct format to show the correct details of fixed asset.

Our opinion is not qualified in respect of this matter.

Report on Other Legal and Regulatory Requirements

a. We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purpose of our audit;

b. In our opinion proper books of account as required by law have been kept by the society so far as appears from our examination of those books maintained at Head Office at Kosi- Katarmal, Almora.

c. The Balance Sheet, Income and Expenditure Account, dealt with by this Report are in agreement with the books of account maintained by the Society;

Date : 06/11/2013

Place : Almora

For Daver Karnatak And Associates
(Chartered accountants)

CA. Sanjay Karnatak
FCA.DISA,DIRM (ICAI)
M No. 501670

G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
BALANCE SHEET AS ON 31ST MARCH 2013

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
LIABILITIES			
CORPUS / CAPITAL FUND	1	80649841.81	69536388.81
RESERVE AND SURPLUS	2	403036300.96	405890482.46
EARMARKED / ENDOWMENT FUNDS	3	0	0
SECURED LOANS & BORROWINGS	4	0	0.00
UNSECURED LOANS & BORROWINGS	5	0	0.00
DEFERRED CREDIT LIABILITIES	6	0	0.00
CURRENT LIABILITIES AND PROVISIONS	7	63691178.64	61115506.59
TOTAL		**547377321.41**	**536542377.86**
ASSETS			
FIXED ASSETS	8	403036300.96	405890482.46
INVEST. FROM EARMARKED/ENDOWMENT FUND	9	76146710.81	66206455.71
INVEST. OTHERS	10	0	0.00
CURRENT ASSETS , LOANS, ADVANCES ETC.	11	68194309.64	64445439.69
MISCELLANEOUS EXPENDITURE			
TOTAL		**547377321.41**	**536542377.86**
		0.00	
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES & NOTES ON ACCOUNTS	25		

AUDITOR'S REPORT
As per our separate report of even date annexed.
For: Daver Karnatak and Associates
CHARTERED ACCOUNTANTS

(Sanjay Karnatak)
PARTNER
M.NO.501670

DATED : 06.11.2013
PLACE :ALMORA

(DR. P.P. DHYANI)
DIRECTOR

(Dr. S.C.R. Vishvakarma)
D.D.O

(SURYA KANT)
ACCOUNTS OFFICER

G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
INCOME & EXPENDITURE A/C FOR THE YEAR ENDED 31ST MARCH 2013.

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
INCOME			
Income from Sales/Services	12	46385.00	59755.00
Grants/Subsidies(net off exp)	13	132461372.80	128803394
Fees/Subscriptions	14	0.00	0.00
Income tfr from Fixed Assets fund	-	22022987.18	21079559.71
(to the extent of depreciation & WDV of asset sold)			0.00
Income from Royalty, Income from Inv. Publication etc.	16	0.00	0.00
Interest Earned	17	1786052.00	1605085.10
Other Income	18	2670694.00	1665093.00
Increase (decrease) in stock of Finished goods and work in progress)	19	0.00	0.00
TOTAL (A)		**158987490.98**	**153212886.81**
EXPENDITURE			
Establishment Expenses: a) Institute	20	59322516.00	52368082.00
b) Projects		11259043.00	7061433.00
c) F.C (Projects)		2285739.00	1141144.00
Administrative Expenses :a) Institute	21	32729460.00	40391726.00
b) Projects (As per Annexure)		20199228.00	17321694.00
c) F.C (Projects)(As per Annexure)		2240316.80	3511760.00
Expenditure on Grants, Subsidies etc.	22	4425070.00	7007555.00
Interest			0.00
Depreciation (Net Total at the year-end-as per Sch. 8)		22022987.18	21079559.71
TOTAL (B)		**154484359.98**	**149882953.71**
Balance being excess of Income over Expenditure (A - B)			0.00
Transfer to special Reserve			**0.00**
Transfer to/ from General Reserve			**0.00**
BAL.BEING SURPLUS TRF.TO CORPUS/CAPITAL FUND		**4503131.00**	**3329933.10**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	25		

AUDITOR'S REPORT
As per our separate report of even date annexed.
For: Daver Karnatak and Associates
CHARTERED ACCOUNTANTS

(Sanjay Karnatak)
PARTNER
M.NO.501670

DATED : 06.11.2013
PLACE :ALMORA

(DR. P.P. DHYANI)
DIRECTOR

(DR. S.C.R Vishvakarma)
D.D.O

06/11/13
(SURYA KANT)
ACCOUNTS OFFICER

G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
RECEIPTS & PAYMENTS A/C FOR THE YEAR ENDED 31ST MARCH 2013

RECEIPTS	CURRENT YEAR	PREVIOUS YEAR	PAYMENTS	CURRENT YEAR	PREVIOUS YEAR
I. Opening Balances			**I. EXPENSES**		
a) Cash in hand	177496.63	128345.13	**a) Establishment Expenses**	54588009.79	43256063.53
			I) Institute		
b) Bank Balances			**b) Administrative expenses**		
			a) Institute	19016367.00	23984593.00
i) In current accounts	0.00	7273271.40	b)R&D[Rev] expenses	12223430.00	1572853.00
ii) In deposit accounts [Corpus Fund]	498215.71	20931307.92	c) Payments for current liabilities(gratuity/leave)	918958.00	1096659.00
iii) Savings accounts	25260003.44	34235962.93	**C. Capital expenditure**		
c) Advances & Others	89823209.43	88853165.03	a) Purchase of Fixed Assets	12755345.00	12493376.00
(As per annexure Attached)			b)Expenditure on Capital Work in Progress	2612000.00	963000.00
F.C. ACCOUNT			c) Acquirement of land (Lease money)		0.00
A) Cash in hand	18975.33	27798.33	**II Payments made against funds for various proj.**		
b) Cash at bank	1007474.07	339951.72	**Expenditure State govt. projects**		
c)FC Advances			a) Capital	3582195.00	1758036.00
II. Grants Received			b) Revenue;		
a) From Government of India			Establishment exp	11396807.00	6472262.23
i) Institute	119500000.00	99717650.00	Administration exp	20199228.00	17310458.00
ii) IERP Projects	0.00	0.00	**Expenditure FC projects**		
b) From Other agencies	30121358.00	21608818.00	**a) Capital**	0.00	2173027.00
c) From other sources [from FC]	5458037.14	7697323.55	**b) Revenue:**		
III. Income on Investments from			Establishment exp	227244.00	1019276.00
a) Corpus Fund	3329933.10	4725398.00	Administration exp	2240316.80	3551419.00
IV. Interest Received			**IERP grant released**	4425070.00	7007555.00
a) On Bank deposits savings a/c	1666168.00	1461771.10	**III Investments and deposits made**		
b)On term deposits a/c	6556804.00	0.00	Corpus Fund	3850000.00	29759000.00
c) Loans, Advances etc.	173402.00	143314.00	**IV Refund of Surplus money/Loans**		
			a] To the Government of India	217158.00	1361457.00
			b]To Others/ security/ caution money]		2500.00
V. Other Income			**V Other payments**		
(As per annexure Attached)	2717079.00	1724848.00	Other Payment to Instt. FC Proj.	11236.00	111422.00
VI. Amount Borrowed		0.00	Current liabilities		4568880.74
VII. Any other receipts.		0.00	**VI Closing balances**		
b] Other Receipt FC a/c	0.00	111422.00	**a) Cash in hand**	38644.53	177496.63
c) receipts current liabilities	3707453.95	0.00	**b) Bank Balance**		
d) IERP grants refunded by grantee Org.	0.00	262585.00	i) In Current account	0.00	0.00
e)Construction Fund		0.00	ii) In deposit accounts [Corpus Fund]	31666.81	498215.71
f) Corpus Fund FDR'S		0.00	iii) In savings accounts	33318861.60	25260003.44
g) Caution Money	7000.00	6500.00			
h) Security Deposit	10000.00	0.00			
i) EMD	68250.00	155000.00	**C) Advances and others**	104283937.01	89823209.43
			FC Project		
			a) Cash in hand	9004.33	18975.33
			b) Bank Balance	2110183.93	1007474.07
TOTAL	**290100859.80**	**289404432.11**	**TOTAL**	**290100859.80**	**289404432.11**

AUDITOR'S REPORT
As per our separate report of even date annexed.
For: Dewer Karnatak and Associates
CHARTERED ACCOUNTANT

(Sanjay Karnatak)
PARTNER
M.NO.501670
DATED : 06-11-2013
PLACE :ALMORA

(Dr. P.P. DHYANI)
DIRECTOR

[Dr. S.C.R. Vishvakarma]
D.D.O

[SURYA DUTT]
ACCOUNTS OFFICER

G.B. PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND

STATEMENT OF OPENING & CLOSING BALANCES

PARTICULARS	OPENING AMOUNT	CLOSING AMOUNT
Cash & Bank Balances		
Cash In Hand :		
Srinagar	278.85	461.85
Sikkim	7439.00	861.00
Kullu	74771.40	690.40
Itanagar	41907.66	29895.56
Grant in aid in transit (Biotech-XIII)	184000.00	184000.00
Cheque in transit: (NE Unit)	316605.20	0.00
Cheque in transit: (G Unit)	0.00	760274.74
Cash at Bank Balances		
SBI Almora A/c No.10861378091 (Corpus)	498215.71	31666.81
SBI Tadong A/c No 11226047758	240626.84	541576.85
SBI Kullu A/c NO. 10792147561	1880141.78	1747314.78
SBI Itanagar A/c No 10940060114	3357712.28	633276.58
SBI Srinagar A/c No 10972182864	679636.53	1334286.27
Advances		
House Building Advance	1779768.00	2307997.00
Motor cycle/Car Advance	134047.00	103975.00
Festival Advance	33000.00	40500.00
Computer Advance	27000.00	21000.00
Income tax deducted at source	191498.00	191498.00
Units of Institute:		
Sikkim Unit	-51387.82	-43427.83
HP Unit	-73110.00	8721.00
Garhwal Unit	0.00	46115.00
NE Unit	0.00	0.00
FC Advances:		
Elcom Technology Pvt. New Delhi	1084101.00	0.00
ICIMOD RSR (LOA-I)Director, Wild Life Dehradun	729000.00	729000.00
ICIMOD RSR (LOA-III)Director, Wild Life Dehradun	270250.00	270250.00
ICIMOD RSR (LOA-I)M/S TATA Motars N. Delhi	177.00	177.00
ICIMOD India Day Workshop Habitat World N.Delhi	70000.00	70000.00
ICIMOD India Day Workshop The Energy Resources instt. N. Delhi	75000.00	75000.00
E.T.& T.N.DELHI(INDO-CANADIAN SUMMER)	2880.00	2880.00
NRSA HYDERABAD(PARDYP)	32274.00	32274.00
Fixed Deposit		
Corpus Fund FDR'S	62028378.00	69558240.00
Interest Accrued on Corpus fund FDR	3679862.00	6556804.00
FDR (Margin Money/LC A/C)		
Institute	6364.00	500000.00
BIOTECH -XI	577.00	0.00
ISRO-JCK-EO (HP Unit)	580582.00	1035000.00
TOTAL:	**77881595.43**	**86770308.01**

G.B. PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND

Brought forward	**77881595.43**	**86770308.01**
Due Staff/ other IC A/c		
Dr. L.M.S. Palni	120000.00	0.00
Ms. Sarita Bagdwal	50000.00	0.00
Receivable from Sikkim Unit	800.00	800.00
STUP Consultant	(7435.00)	(7435.00)
M/S International Trade Links, Mumbai	0.00	34328.00
LICOR INC USA	54460.00	54460.00
Tuder Rose UK (Instt.)	88535.00	88535.00
S.K. Diesel Sales (Instt.)	66538.00	66538.00
Wipro GE Health Care (Instt.)	296534.00	296534.00
Elemonter Analyser (Instt.)	165000.00	0.00
VPKAS Almora (Instt.)	26560.00	26560.00
Saveer Biotech New Delhi	156334.00	0.00
Adv. to NIH Roorkee	100000.00	100000.00
Post Master G.P.O Almora	40566.00	40566.00
Employment News	48287.00	48287.00
Sigma Aldrich Chemicals	10590.00	10590.00
Siltap Chemicals Ltd (Biotech -III)	408.00	408.00
DST (LMS) ILTP NRSA Hyderabad	48000.00	48000.00
NRSA Hyderabad	35300.00	35300.00
R.K.Nanda & Sons	28517.00	28517.00
NICSI New Delhi	35106.00	35106.00
Security Deposit CET Sikkim Unit	11000.00	11000.00
NRSA Hyderabad (NNRMS Proj.)	1970000.00	234000.00
NRSA Hyderabad- Grant in Aid (NNRMS Proj.)	0.00	458441.00
NRSA Hyderabad (ISRO GBP SSS)	350000.00	350000.00
NRSA Hydrabad (DST-KK-I)	7400.00	7400.00
Vankta Enterprises (MOE&F NBA RSR)	0.00	7100.00
CCU New Delhi	1646753.00	10123178.00
NRSC Hyderabad (SERB GCSN)	0.00	200000.00
Security Deposit NE Unit	1750.00	1750.00
NCADMS, Itanagar (MOE&F CC-II)	160288.00	0.00
N.E. Regional Institute, Itanagar (MOE&F UNDP CCF)	815060.00	213403.00
EE R.E.S. Almora (MOE&F (BG) RSR	3402000.00	3402000.00
EE R.E.S. Almora Insitute	1571000.00	1571000.00
WWF New Delhi (UNDP-CEF-GOL) NE Unit	418070.00	-31930.00
Director State Forest Research Institute (UNDP-CEF-GOL) NE Unit	193.00	193.00
M/S Kasar Jungle Resort (ICTS RSR Wks.)	60000.00	0.00
M/S Mohan's Café (ICTS RSR Wks.)	25000.00	0.00
M/S Imperial Heights (ICTS RSR Wks.)	30000.00	0.00
M/S Paramount Pathfinders (ICTS RSR Wks.)	50000.00	0.00
E E R.E.S. Almora (HRDI I.D.B. Project)	59000.00	59000.00
TOTAL	**89823209.43**	**104283937.01**

G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
SCHEDULE FORMING PART OF BALANCE SHEET AS ON 31ST MARCH 2013.

SCHEDULE 8 - FIXED ASSETS
(DETAILS AS PER ANNEXURE ATTACHED)

(In Rupees)

S NO.	DESCRIPTION	GROSS BLOCK				DEPRECIATION				NET BLOCK	
		Cost as at beginning of the year	Additions during the year	adj/deduction during the year	Cost at the end of the year	depreciation for prior periods	depreciation for current year	adj/deduction for previous years	Total up to the end of the year	As at the current Year end	As at the previous year-end
	A. FIXED ASSETS:										
1	**LAND:**										
	a) Freehold	75639.23	0.00	0.00	75639.23	0.00	0.00	0.00	0.00	75639.23	75639.23
	b) Leasehold	4069026.00	0.00	0.00	4069026.00	271268.00	135634.00	0.00	406902.00	3662124.00	3797758.00
2	**BUILDING:**										
	a) On Freehold Land	214751988.00	0.00	0.00	214751988.00	33185174.21	3500457.40	0.00	36685631.61	178066356.39	181566813.79
3	**PLANT MACHINERY & EQUIPMENT**										
	a) Scientific Equipments	169814284.11	6424851.00	(988450.00)	175250685.11	81653082.14	8276104.04	(46951.38)	89976137.56	85368450.31	88161201.95
4	**VEHICLES**	8504819.30	0.00	988450.00	9493269.30	6284059.39	959993.40	111793.70	7355846.49	2137422.81	2220759.91
5	**FURNITURE FIXTURES**	24636380.40	1414031.00	0.00	26050411.40	15813539.03	1648991.04	0.00	17462530.07	8587881.33	8822841.37
6	**OFFICE EQUIPMENT**	24776345.35	2421446.00	0.00	27197791.35	12067846.65	2583790.18	0.00	14651636.83	12546154.52	12708498.70
7	**ELECTRICAL INSTALLATION**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	**FIRE FIGHTING EQUIPMENTS**	60962.00	0.00	0.00	60962.00	46331.15	2895.70	0.00	49226.85	11735.16	14630.86
9	**LIBRARY BOOKS**	93203371.50	6361320.00	0.00	99564691.50	39419211.01	4729322.85	0.00	44148533.86	55416157.64	53784160.50
10	**TUBE WELLS & W. SUPPLY**										
11	**OTHER FIXED ASSETS**										
	GLASS / NET HOUSE	3911549.00	0.00	0.00	3911549.00	2908796.85	185798.58	0.00	3094595.43	816953.57	1002752.15
	TOTAL OF CURRENT YEAR	**543804364.89**	**16621648.00**	**0.00**	**560426012.89**	**191649308.43**	**22022987.18**	**64842.32**	**213831040.69**	**346688874.96**	**352155056.46**
	PREVIOUS YEAR	**526621897.84**	**17706432.00**	**523964.95**	**543804364.89**	**171093713.67**	**21079959.71**	**523964.95**	**191649308.43**	**352155056.46**	**352155056.46**
	B CAPITAL W I P										
	Acquirement of land (Lease money)	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CCU Delhi	53735426.00	2612000.00	0.00	56347426.00	0.00	0.00	0.00	0.00	56347426.00	48500126.00
	ASSET UNDER INSTAL/TRANSIT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	**597539790.89**	**19233648.00**	**0.00**	**616773438.89**	**191649308.43**	**22022987.18**	**64842.32**	**213831040.69**	**403036300.96**	**400655182.46**

INSTITUTE SUPPORTING STAFF

HEAD QUARTERS	
Surya Kant Langayan	Accounts Officer
L.M.S. Negi	Office Superintendent (Admn.)
Sanjeev Higgins	Technical Gr. – III(2)
Preeti Tiwari	Technical Gr. – IV(1)
Sarita Bagdwal	Stenographer
Jagdish Kumar	Stenographer
Mamta Higgins	U.D.C.
Heera Singh	U.D.C.
K.K. Pant	U.D.C.
Hema Pandey	U.D.C.
S.K.Gururani	L.D.C.
Suraj Lal	L.D.C.
Jagdish Singh Bisht	Technical Gr. – II(1)
R.C.Bhatt	Driver
Chandra Lal	Driver
K.N.Pathak	Technical Gr. – I(3)
Pan Singh	Peon
G.D.Kandpal	Peon/Mali
Nathu Ram	Peon/Mali
Ganga Joshi	Peon
Kanshi Ram	Peon/Mali
GARHWAL UNIT	
D.P. Kumeri	L.D.C.
M.P. Nautiyal	Driver
J.M.S. Rawat	Driver
R.C. Nainwal	Field Assistant
R.P. Sati	Peon
HIMACHAL UNIT	
S.P. Maikhuri	Office Superintendent
Daulat Ram	Peon
SIKKIM UNIT	
R.K. Das	L.D.C
Jagnnath Dhakal	Technical Gr. – I(3)
P.K. Tamang	Technical Gr. – I(3)
Musafir Rai	Peon
Shyambir	Peon

INSTITUTE FACULTY

HEAD QUARTERS		
L.M.S Palni	Director	Plant Physiology; Biochemistry; Biotechnology
P.P.Dhyani	Scientist-G	Plant Physiology; Restoration Ecology
Kireet Kumar	Scientist-F	Environmental Engineering; Hydrology
S.K. Nandi	Scientist-F	Plant Physiology; Biochemistry
R.C. Sundriyal	Scientist-F	Plant Ecology; Rural Ecosystems (On Deputation)
Anita Pandey	Scientist-E	Microbiology
S.C.R. Vishvakarma	Scientist-E	Plant Ecology; Rural Ecosystems
B.P. Kothyari	Scientist-E	Plant Pathology; Restoration Ecology
D.S. Rawat	Scientist-E	Settlement Geography; Rural Ecosystems
R.S. Rawal	Scientist-E	High Altitude Ecology; Conservation Biology
G.C.S. Negi	Scientist-D	Forest Ecology; Watershed Management; EIA
R.C. Prasad	Scientist-D	Library & Information Science; Documentation
Subrat Sharma	Scientist-C	Agroecology; Remote Sensing / GIS
I.D. Bhatt	Scientist-C	Plant Physiology; Phytochemistry
R.K. Singh	Scientist-C	Information Technology
A.K. Sahani	Scientist-C	Social Science; Anthropology
Rajesh Joshi	Scientist-C	Mathematical Modeling
K.C. Sekar	Scientist-C	Plant Taxonomy; Animal Taxonomy
Shilpi Paul	Scientist-C	Molecular Biology; Plant Biotechnology
Vasudha Agnihotri	Scientist-B	Soil Science; Plant Analysis; Instrumentation
R.G. Singh	Tech. Grade IV (3)	Applied Arts; Photography, Social Science
B.S.Majila	Tech. Grade IV (3)	Forest Ecology; Restoration Ecology
Subodh Airi	Tech. Grade IV (2)	Forest Ecology; Biotechnology
HIMACHAL UNIT		
S.S. Samant	Scientist-E & In-charge	Plant Taxonomy; Conservation Biology
J.C. Kuniyal	Scientist-D	Development Geography; Waste Management
Ranjan Joshi	Scientist-C	Ecology Economics; Resource Valuation
R.K. Sharma	Scientist-C	Policy Analysis; Environmental Management
SIKKIM UNIT		
H.K. Badola	Scientist-E	Morphoanatomy; Conservation Biology
K.K. Singh	Scientist-D & In-charge	Plant Physiology; Stress Physiology
L.K. Rai	Tech. Grade IV (3)	Plant Taxonomy
Y.K. Rai	Tech. Grade IV (3)	Rural Ecosystems
GARHWAL UNIT		
R.K. Maikhuri	Scientist-E & In-charge	Plant Ecology; Rural Ecosystems
S.C. Joshi	Scientist-E	Plant Physiology; Stress Physiology
Paromita Ghosh	Scientist-C	Plant Science; Soil Science
S. Tarafdar	Scientist-C	Weather & Climate Change; Glaciology; Hydrology
NORTH-EAST UNIT		
P.K. Samal	Scientist-E & In-charge	Social Science; Anthropology
M.S. Lodhi	Scientist-C	Environmental Assessment
S.C. Arya	Scientist-B	High Altitude Ecology
S. Chaudhary	Tech. Grade IV (2)	Conservation; Biological Diversity