ANNUAL REPORT

2014-2015






G.B. Pant Institute of Himalayan Environment & Development

(An Autonomous Institute of Ministry of Environment Forests and Climate Change , Govt. of India)

Kosi-Katarmal, Almora - 263 643, Uttarakhand, India

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CONTENTS

FOREWORD

The beginning of a new year brings along with new challenges and new opportunities while serving in the Indian Himalaya Region (IHR). Since the inception in 1988–89, the Institute has made significant strides year-to-year in the direction of mandated Vision as per the Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt. of India. With increasing pace of globalization, the Institute has created a special niche among national and international research and development (R&D) communities. The progression has been multi-directional from research to development to dissemination, which attempts to address the diverse needs of several stakeholders, dependent on the Himalaya, its ecosystem services and natural resources sustainably.

During the reporting period, i.e. Year 2014-15, the year witnessed implementation of several new initiatives, execution of Memorandums of Understanding (MoUs), and other crucial steps to strengthen the on-going R&D programmes and activities. Furthermore, as new surge into the Institutional mechanism, the Institute initiated and implemented eight new initiatives in order to mobilize a variety of societal actors *viz*., students, researchers, academicians, farmers, citizens, policy-makers and others towards intensifying developmental processes on participatory approaches and capacity building *in tandem*. Targeting each critical section of the integrated Himalayan society, these initiatives resurge the identified segments as follows: (i) *Himalayan Research Fellowships* for promoting science culture by creation of dedicated future researchers; (ii) *Himalayan Young Researchers' Forum (Him-YRF)* for connecting researchers to bring transformation in research culture across the Himalaya; (iii) *Himalayan Research Mentors' Forum* for shaping and nurturing young minds in the Himalaya; (iv) *Himalayan Popular Lecture Series* for admiring actions and opinion for sustainable development of IHR; (v) *Himalayan People's Representatives Meet* for policy advocacy on sustainable development of the Indian Himalayan Region (IHR); (vi) *Himalayan Students' Nature Awareness Campaign* for facilitating development of a culture of creative nature-based learning; (vii) *Himalayan Farmers' Livelihoods Enhancement Drive* for empowering communities through new opportunities and skill building; and (viii) *Mountains Environmental Policies Repository* for creating an environment for mutual learning, experience sharing and repository. Implementation of such synchronized participatory efforts engages different societal segments with R&D activities of the Institute, which further enhances accessibility and acceptability of scientific results by the common man in lab as well as field settings along with environmental education.

In addition, latest environmental issues with specific R&D targets have also been addressed during the reporting year, these include: (i) addressing issues on ecological, social and policy implications of changing water resource scenario; (ii) analysing impact of climate change on biodiversity, ecosystem services and farming system; (iii) understanding pattern and process of biodiversity; and (iv) promoting conservation and sustainable use of biodiversity using biotechnological approaches. Moreover as on-going exercises, the Institute continues to strengthen environmental assessment of hydropower projects; field demonstrations; trials on wasteland rehabilitation; strategies for economic development and environment conservation following alternate livelihood options. Towards promoting research outreach, the Institute focuses on capacity building of a range of stakeholders on environment-friendly technologies through Rural Technology Centre (RTC) and its extension centre. On-site training programmes on biodiversity conservation, natural resource management, disaster management and implementation of national initiatives such as National Nature Camping Programme, Citizen Science, etc. keep the developmental cycle rolling and in action with active participation of diverse stakeholders.

Considering the tranboundary R&D drive as a key to reinstate conservation and sustainable utilization of bioresources, the Institute has implemented three distinct, landscape-based projects *viz*., Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI), Khangchendzonga Landscape Conservation and Development Initiative (KLCDI), and Landscape Initiative for Far Eastern Himalaya (Far-LIFE). Next, realizing the need and significance of collaborative research in such settings, the Institute entered into the MoUs with several national and international organizations. Acceptance of the Institute outcomes by way of the publications of research articles in peer-reviewed national and international journals has ranked the Institute the second rank for research in the IHR. Increased financial and collaborative support from diverse external agencies to conduct project-based research on priority issues is a testimony of enhancing recognition of the Institute's R&D capacities.

As a head of the leading Institute, it is my duty and a matter of pride in strengthening the existing programmes and formulating new ones to realize the goals envisaged in the Institute's Vision Document towards ensuring well-being of the Himalaya and its dependent communities. I am sure that with the persistent efforts of colleagues in the Institute HQs and Regional Units and support from the well-wishers, the Institute shall succeed sustaining the Vision foreseen for the Himalaya. Your valuable suggestions and critiques are always welcome to keep the Himalayan journey interactive, enlightening and ascending in all respects.

(P.P. Dhyani)
Director

MAJOR ACHIEVEMENTS

- Initiated development of "Nanda Van" at Almora for restoration of ecological balance in the degraded & fragile ecosystem by application of live demonstration of hill specific technology packages. The initiative is being implemented in partnership with the Nagar Palika, Almora, which has offered about 1.2 ha land to the Institute for this activity.

- Developed and demonstrated an innovative model on 2 ha of land at different villages of Garhwal region (1600-3800 m asl) for the first time on integration of medicinal plants cultivation (*Picrorrhiza kurrooa, Saussurea costus, Valeriana wallichii* and *Inula racemosa*) with horticultural crops (apple, plum, walnut, etc.) as a potential option to increase per unit area production and income particularly for high altitudinal region/villages located between 1600-3800 m asl where climatic conditions are favorable.

- Adopted four (4) disaster affected village clusters (each cluster with 2 villages) in Kedar valley for empowering human resource particularly women, unemployed youth and farmers for capacity building/skill development, income generation and natural resource management through on-site training, exposure visit and live demonstrations.

- Study intensified at Gangotri glacier and revealed that beginning of ablation period of snow showed shift from mid May to early May whereas accumulation of snow was found to be delayed from mid September to end of September.

- Study has been initiated on black carbon, other aerosols, and snow chemistry in the three important northwestern Indian Himalayan glaciers- Parbati, Hamta and Beas Kund.

- Towards assesing the field applicabiliy of tissue culture raised plants, over 250 saplings of *R.maddeni* were distributed to different stakeholders in Sikkim (i.e., State Forest Department, local inhabitants and NGOs) for plantation in different conditions and over 100 saplings were planted at office premises during World Environment Day.

- Long term monitoring site was established following GLORIA protocol in Chaudas valley, Uttarakhand. This is first of its kind site in Indian Himalaya. The intensive inventory of plant diversity of GLORIA summits has revealed a total of 161 species in Bhairav Ghati (BHT) summit. The Kharangdhang, Ganglakhan and Sekhuakhan summits recorded 120, 88 and 57 species, respectively.

- Three volunteer programmes were organized jointly with Earthwatch Institute India in May (06-09), August (20-27) and October (09-18) 2014; the volunteers were involved in collection of data on biodiversity including insect/pollinators diversity, ecosystem services and phenology.

- Nature activity camps were organized for the students of Uttarakhand and other stakeholders. Under KSLCDI, three concurrent Landscape Yatras (LYs) were organized in the vertical transect and it generated extensive information about the landscape and understanding of interfaces and transition of systems and their possible management, livelihood opportunities and challenges.

Publications:

1. Research Papers and Articles	- 108
2.Authored/EditedBooks/Booklets/ Bulletins/Monographs	- 06

EXECUTIVE SUMMARY

The institute 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 in the Institute. In this effort, special attention is placed on 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 conducted by 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 2014–15 is as follows.

WATERSHED PROCESSES AND MANAGEMENT (WPM)

The study on "Ecological, Social and Policy Implications of Changing Water Resource Scenario in Indian Himalayan Context" was conducted in the Kosi watershed of the Central Himalaya and generation of water quality data was initiated in this year. According to the survey, conducted in 101 villages (731 households) in four different altitudinal zones of Kosi watershed, the average per capita water consumption in Kosi watershed is 30.35 l/daywhich is lower than the national average of 40 l/day. Mean monthly water discharge of river Kosi at Betalghat site has been measured for the last one year (2014-15). R&D programme on "Farming Systems and Changing Climate Regime: Strengthening Food and Nutritional Security in the Himalaya", reveals that frequency for the light rainfall, moderate rainfall and total seasonal rainy days showed two maxima at around 227 m and 2100 m altitudes of North Western Himalayan region. Project on "Runoff modeling and simulation of sediment load of Gangotri Glacier system" reveals a decreasing trend in annual mean SCA for elevation zones II-VII with varying rates (zone II: -2.28%±2.49; zone III:-4.21%±3.17; zone IV:-4.41%±3.87; zone V: -4.82%±5.26; zone VI: -9.93%±6.27; zone VII: -6.95%±5.96); whereas SCA in zone I is found increased by 0.71%±3.33. A new project was started in the Gangotri glacier system on geodynamic and hydro-chemical study of the glaciers. GPS studies conducted through permanent stations indicate the precise position and velocity of these sites in ITRF08 reference frame. There is convergence of 5.7mm/y, 16.7mm/y and 18.1 mm/y between GBPK_KIT3, GBNL_KIT3 and GBSN_KIT3, respectively and 28.5 mm/y, 35.7 mm/y and 38.4 mm/y between GBPK_POL2, GBNL_POL2 and GBSN_POL2, respectively. R&D programme on "Study of heavy metal transfer from contaminated soil to food chain and their risk to human health in Himachal Pradesh" reveals that cauliflower, cabbage, radish and tomato grown locally and sold in open urban markets of Kullu Valley and its adjacent areas were found contaminated with Cu, Zn, Cd, Pb and Cr. Mean concentrations of Cu was found above the permissible limit of Indian standard in tomato and cauliflower, Cd and Zn in tomato at production sites; Cd in tomato and radish, and Pb in radish at market sites. A pot based study was carried out to assess the effects of sulfur and farm yard manure application, singly and in combination on Cd accumulation and consequent response of radish grown on Cd contaminated soil. The study revealed that farm yard manure application reduces Cd stress in test plants through altering their physiological and biochemical activities. To study "Responses of some high altitude crops to enhanced UV-B radiation and nutrient fertilization", a pot based experiment was carried out to study the responses of two cultivars of French bean

(cv. PusaHimlata and PusaParvati) on enhanced and ambient UV-B radiation. Growth parameters such as number of leaves, leaf area, root length, shoot length, total length, and numbers of root nodules of both the cultivars were reduced after 30 and 60 days of plant age; % decrease was more in PusaParvati as compared to PusaHimlata. Economic yield of PusaHimlata under enhanced UV-B radiation was higher due to development of strong cellular defense mechanism.

BIODIVERSITY CONSERVATION AND MANAGEMENT

Through its multilocational project on 'Understanding biodiversity patterns and processess under changing resource use and climate scenario in Indian Himalaya' intensive biodiversity data sets were generated under diverse aspects. While the studies in Kanawar Wildlife Sanctuary (HP) and Kanchendzonga Biosphere Reserve (Sikkim) contributed for strengthening information base on floristic diversity and community compositional patterns, the investigation in Hat-Kalika Watershed (Kumaun) improved understanding on resource use and availability patterns. The assessment of Probability of Use (PU) and Resource Use Index (RUI) helped in fixing priority to various species use in the watershed. More importantly the data sets generated on abundance and regeneration of these species in forests have helped in assessing the impact of biomass removal on such species. Establishment of Long Term Monitoring site in Uttarakhand following GLORIA protocol, for the first time in Indian Himalaya, has provided the base line information on plant biodiversity of four summit areas. The richness of species in these summits varied between 161 species in Bhairav Ghati summit to 57 species in Sekhuakhan summit. Besides the in house projects, various externally funded projects contributed for strengthening of biodiversity data-sets. The Global Pollination Project, which concluded during the year, provided useful information on insect visitors/pollination on insect visitors/pollinators of mustard, cucurbit, apple and large cardamom crops. Plant-insect interaction inventory was prepared to assess the most preferred teraging resource. The detailed investigation on Large cardamom pollination revealed that the increasing density of bumble-bee (*Bombas* sp) resulted in significant higher yield of the crop ($r=0.352$; $p<0.05$). Also, increasing density of all bees lead to significant ($r=0.324$; $p<0.05$) in crop field. Through all India coordinated research project on Sacred Grove and Ecosystem Services Assessment, floristic diversity data sets for 33 sites (21 undisturbed, 12 disturbed) in Himachal Pradesh were generated and 229 species of vascular plants (89 families, 175 genera) recorded. Data sets of selected Sacred Groves w.r.t. carbon sequestration potential were further strengthened. Land Use Land Cover mapping of Cold Desert Biosphere Reserve (HP), Nanda Devi Biosphere Reserve (UK) and Dibru Saikhowa biosphere Reserve (Assam) have been completed and different GIS Layers prepared. Towards mapping community perception and vulnerability assessment of biodiversity and natural ecosystems four representative sites (i.e. Parbati valley, Upper Beas, Great Himalayan National Park, and Saroj valley of Anni watershed) in Himachal Pradesh were selected and investigated. At the Landscape level, studies in Kailash Sacred Landscape (KSL), and Kanchedzonga Landscape (KSL), both part of India were further strengthened. While partnership arrangements and identification pilot sites for study was accomplished in KSL, feasibility and Conservation and Development Strategy documents were prepared for Kanchedzonga Landscape. Equal emphasis was given to the demonstration activities. Strengthening of arboreta, herbal gardens and medicinal plant nurseries continued through introduction of new accessions at Kosi-Katarmal, Almora, Uttarakhand, Mohal, Doharanala and Kasol, Himachal Pradesh and Pangthang, Sikkim. A total of 79 cultivars of apple collected from Utttarkhand, Jammu and Kashmir and Himachal Pradesh have been planted at two different sites as National Apple Germplasm Repository viz., Government Inter College, Majkhali and Suryakunj, GBPIHED, Almora. Twenty five accessions were added in the Lead Botanical Garden. The accession numbers given to six species are *Polygonatum cirrhifolium* (GBP 3204), *Malaxis muscifera* (GBP 3205), *Meizotropis pellita (*GBP 3206), *Quercus lanuginosa (*GBP 2512), *Castanopsis tribuloides (G*BP 2511) and *Mahonia jaunsarensis* (GBP 3901). Under KSLCDI Biodiversity Management Committees (BMCs) have been

developed in collaboration with Uttarakhand Biodiversity Board and process of preparing People's Biodiversity Register has been initiated. For making polyhouses, polythene sheet (20x6m) was provided to 44 families. These families belonging to Gondhla and Jispa (12), Khangsar and Goshal (8) and Jagla (4) villages in Lahaul Valley of Himachal Pradesh. Demonstration was also given for the construction of polyhouse. As dessimination activity, farmers ***interaction*** meeting was organized at Mamlay watershed-Sikkim (South) on 21 October 2014 and total 50 participants were represented. The major focus of the event was to discuss the local issues and priority actions as: promotion of vermi-compost and bio-pesticides, reassessment of the watershed, assessment of diseases and pest of crops at seasonal level, crop rotation, availability of disease free seedling of large cardamom, popularization of organic products, awareness on ecosystem services and sustainable use of natural resources. Three concurrent Landscape Yatras (LYs) were organized in the vertical transect and generated extensive information about the landscape and understanding of interfaces and transition of systems and their possible management, livelihood opportunities and challenges. Showcasing of KSLCDI at Jeoljibi International Trade Fair (November, 14-17, 2014) generated mass awareness about the project and its components both in India and Nepal part of Kailash Sacred Landscape.

ENVIRONMENTAL ASSESSMENT & MANAGEMENT (EAM)

During 2014-15 this Theme undertook R&D on six projects; two being inhouse and four externally funded. The inhouse project on 'Strategic Environmental Assessment (SEA) of hydropower projects in the Himalayan Region' was undertaken on Sutlej basin in Himachal Pradesh and the Ranganadi basin in Arunachal Pradesh in order to undertake in-depth studies on cumulative impacts of all installed, under construction and proposed hydropower projects in each basin focussing on social, environmental and cross-sectoral developmental activities. The second in-house project on 'Climate change impacts on ecosystem services in the Indian Himalayan Region' aims to study tree phenological observations as an early indicator of climate change on four dominant forests between an altitudinal gradient of 300-2100 m asl in the Central Himalaya. Besides, tourist recreational services as an important ecosystem service (ES) is being monitored along a famous tourist corridor. Among the externally funded projects 'Indicators of climate change in context to the Himalayan forest ecosystems along an environmental gradient' deals with the indications of climate change (CC) in relation to the forest ecosystem; 'Gaseous air pollution in the background site of sprawling urban environment of Himachal Pradesh' pertains to aerosols (i.e., gaseous pollutants, columnar aerosol and black carbon aerosol) and their impacts on temperature rise, radiative forcing and climate change; 'Aerosol climatology over the northwestern Indian Himalayan region, Himachal Pradesh' assesses aerosol optical depths (AODs) at ultra-violet, visible and near infrared spectrums (380-1025 nm) in clear, partially clear and hazy sky day conditions; and 'Black carbon and other aerosols loading, and their impact on melting of the Parbati Glacier in the northwestern Himalaya, India' appraises role of black carbon and other aerosols on snow and ice chemistry of the Glacier.

SOCIO - ECONOMIC DEVELOPMENT (SED)

The Indian Himalayan region (IHR) is a unique zone of convergence of diverse ecosystems, natural resources, cultures and plethora of ethnic communities. However, the continued population growth and consequential poverty are fast depleting the finite natural resource base of the region breaking down the indigenously evolved resource use patterns. The capacity of the IHR is fast approaching many of its limits and gradually being unable to provide enough support to livelihoods of the people residing in the region. Therefore, during the reporting year, the SED Theme continued to focus on ecologically appropriate and socio-culturally acceptable initiatives and interventions that have potential to reduce poverty in this ecosystem through promotion of innovative livelihoods and skill enhancement of the local communities in rational and judicious use of local resources for their social and economic development. Some of the prioritized activities and region specific sub-activities that were focused included ecotourism, innovative livelihood options, appropriate technology

and delivery systems, capacity enhancement, etc., that have potential to benefit the economically disadvantaged communities of the IHR. During the reporting year, the projects and activities on priority areas that were initiated earlier continued, i.e. (i) Eco-tourism as a potential tool for biodiversity conservation and sustainable livelihood in Indian Himalayan Region (in Himachal Pradesh, Uttrakhand, Sikkim, Arunachal Pradesh states), (ii) Preparation of wildlife management plan / biodiversity conservation plan for Trans Arunachal Highways, and (iii) Multi-locational approach on capacity building on enhanced agricultural production, entrepreneurship development and self employment in the Himalayan region (Himachal Pradesh, Uttrakhand, Sikkim and Arunachal Pradesh states). The SED Theme during the reporting year had given due consideration to landscape and ecosystem approaches for managing biodiversity and promoting livelihood in the transboundary regions on the lines of advocacy by Convention on Biological Diversity. Under the major transboundary initiative called Landscape Initiative for Far Eastern Himalaya (Hi-LIFE), the Theme conducted regional and national consultation workshops to prepare technical documents such as 1. Feasibility Assessment Report-India, 2. Conservation and Development Strategy (CDS) and Comprehensive Environmental and Socio-economic Monitoring Strategy (CESMS) in consultation with subject experts from India, China, Myanmar and Nepal, which all shall be guiding documents in institutionalizing Hi-LIFE as a marked initiative in managing biodiversity and promoting livelihood in the Far Eastern Himalaya Landscape. The Feasibility Assessment Report indicates that there are ample opportunities in the Hi-LIFE to implement the decisions of the Convention on Biological Diversity to bring in collaborative efforts in addressing the poverty, enhancing conservation, and strengthening the policy and institutions.

BIOTECHNOLOGICALAPPLICATIONS

The focus of the theme is to document, characterize, conserve and utilize ecologically and economically important Himalayan bioresources using biotechnological approaches. In this context, *Nardostachys jatamansi*, *Ginkgo biloba*, *Trillium govanianum,* and *Aconitum ferox* were used for estimation of phytochemicals and antioxidant properties. Presence of optimum amount of phytochemicals and antioxidant properties is an indicative that these species can be promoted for the use of natural antioxidant in addition to their traditional medicinal uses. Characterization of different Podophyllum species using molecular markers has been done, and some podophylotoxin pathway specific genes were identified. Similarly, efforts are being made to develop propagation protocols using conventional and *in vitro* methods for large-scale multiplication and production of quality planting material. *In vitro* propagation was established for *Nardostachys jatamansi*, *Rhododendron maddenii*, however, preliminary standardization has been completed for *Gingko biloba*, *Aconitum ferox*, and *Trillium govanianum*, etc. Conventional propagation of different high value plants have been done through seed germination and vegetative propagation techniques. Tissue culture raised plants of *R. maddeni* were distributed to different stakeholders towards demonstration in the field conditions. Besides, the ecological niche modelling for some threatened medicinal plants, i.e. *Podophyllum hexandrum*, *Paris polyphylla*, *Angelica glauca*, and *Dactylorhiza hatagirea* were done to identify possible habitats of their occurrence so that further reintroduction of the species can be done. Another component of the theme is to characterize microbial diversity of extremophiles, thermophiles and psychrophiles in IHR. A hyperthermophilic bacterium, isolated from autoclaved sediments collected from a hot spring site in District Chamoli of Garhwal Himalaya, has been characterized. The growth curves, drawn at different temperatures, showed clear preference for high temperature for production of cell biomass. Following polyphasic approach, the bacterium was identified as *Geobacillus stearothermophilus*. Elasticity in morphological structures and the production of thermostable enzymes at elevated temperatures by the bacterium are likely to play important role in conferring resilience to bacterium for survival and multiplication under high temperatures. Twenty five species of cold, pH and salt tolerant *Penicillium*, isolated from soil samples from the high altitudes in IHR, have been

characterized. Characters like tolerance for low temperature, wide range of pH, and high salt concentration, and enhancement in sporulation and production of secondary metabolites such as watery exudates at low temperature were attributed to the ecological resilience possessed by these fungi for survival under low temperature environment of mountain ecosystem. A project on characterization of pyschrotolerant fungi with particular reference to lignin degradation under mountain ecosystem is underway in an ICMR-funded project. Species of *Aspergillus*, *Penicillium* and *Trametes* are being studied for their ability to produce laccases under different physico-chemical and cultural conditions. Analysis of leaf extracts of *Ginkgo biloba* with reference to antimicrobial phytochemicals has been carried out in a CSIR-funded project. A DST-funded network project is underway on "Ecophysiological and microbiological studies in relation to climate change along an altitudinal gradient". Pure cultures of bacteria, actinomycetes and fungi are being maintained in a Microbial culture collection established in Microbiology Laboratory and regularly being accessioned by various national laboratories and institutes. Various trainings workshops and exposure visits are being carried out throughout the year to sensitize the diverse group of stakeholders towards sustainable utilization of Himalayan bioresources.

KNOWLEDGE PRODUCT AND CAPACITY BUILDING

Knowledge is one of the key factors in solving development problems and initiate effective action. The Himalayan mountains communities have acquired an immense knowledge of their natural environment. However, the accumulated knowledge is rapidly disappearing from the region.The focus of knowledge products and capacity building (KCB) programme is an enhancement of institutional outreach based on its research outcome such as (i) state-of-art methodological approaches for knowledge based products development, (ii) develop connecting links between knowledge providers, knowledge seekers and users to effectively utilize available knowledge resource/products to deal with prominent environmental issues, (iii) blending of traditional ecological knowledge with scientific knowledge for their livelihood improvement, natural resource management and sustainable development. Current thrust of the KCB Theme is on comprehensive documentation of indigenous knowledge related to natural resource management, agronomic practices and traditional health care systems, synthesizing existing traditional knowledge and scientific knowledge to develop improved and best practices as knowledge products for sustainable development of the Himalaya. Other areas of interest include ecological analysis, economic assessment of cropping pattern, nutraceutical potential and climate change adaptation and mitigations. Popularization of bioprospecting and value addition in traditional and wild bioresources for enhancing the livelihood of the marginal communities, networking with various stakeholders (policy makers, professionals and practioners) in different fields to share knowledge products for the benefits of the user groups and enhancement of capacities and skills of people in harnessing the potential of knowledge system for socio-economic development and environmental conservation and management are other activities undertaken in this theme.

1. INTRODUCTION

During the year 2014-15, 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, viz., 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 Forests & Climate Change (MoEF & CC), Govt of India, and the projects financed by external funding agencies (National and International). The Institute also supports activities of various partner Institutions situated in different Himalayan states through Integrated Eco-development Research Programme (IERP). The Science Advisory Committee (SAC) 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 the XIIth plan period (2012–2017). 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 of time, relevant detailed documents will be published and made available for the public. The progress made during the year 2014–2015 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 outputs of various R&D activities.

2. MILESTONE EVENTS

Khangchendzonga Landscape Conservation and Development Initiative (KLCDI)

The Sikkim Unit of the Institute organized a consultation workshop for development of a regional cooperation framework (RCF) under Khangchendzonga Landscape Conservation and Development Initiative (KLCDI), on April 9, 2014 at Gangtok. The objective of the consultation was to highlight the progress of the Feasibility Assessment Report (FAR) on KLCDI (India) seeking further inputs and suggestions for finalizing the FAR, especially for its presentation by GBPIHED in regional workshop in Thimpu-Bhutan in April 2014. The consultation was organized to highlight the progress on Feasibility Assessment Report KLCDI, India, for the proposed KL comprising Sikkim and part of West Bengal (Darjeeling and Jalpaiguri districts). Over 40 participants representing academicians and researchers, government institutions, local/regional NGOs, regional and international institutions, and ICIMOD and GBPIHED attended the workshop and participated in deliberations and extensive/intensive discussions on different issues.

Kailash Sacred Landscape Yatra (KSLY)

As an innovative approach for connecting with land and people, and also as an effective tool for maintaining science-policy-practice interface, three concurrent Landscape Yatras (LSYs) by multidisciplinary teams were organized in the vertical segment of landscape. These Yatras have yielded significant information on: (i) understanding of interfaces and transition of systems and their possible management; (ii) livelihood opportunities and challenges; and (iii) bottlenecks in natural governance and Natural Resource Management systems. The Yatra findings were shared with the higher bureaucrats of the MOEF&CC and Uttarakhand State Government with an aim to explore possibilities for policy interventions. As an innovative approach and tool to connect 'yatries' with the land and people in the course of journey (Yatra) through a landscape, KSLCDI-GBPIHED organized Landscape Yatra-LSY (Journey though Landscape). These yatras were synchronized with the decadal yatras for PAHAR's Askot-Arakot Abhiyan, 2014. During the course of yatras, detailed interactions were conducted on: (a) Interfaces and transitions of systems and their possible management, (b) Local governance and Natural Resource Management and, (c) Livelihood opportunities and challenges in the landscape.

Capacity Building of Women and Local Villagers

A two-day training programme under the ICSSR, New Delhi-sponsored programme on "Capacity development for women and local villagers of the disaster-affected areas of the Kedar valley" was jointly organized during May 23–24, 2014 in the Kalimath valley at village Kaviltha by the G.B. Pant Institute of Himalayan Environment and Development, and the Department of Political Science, HNB Garhwal University, Srinagar (Garhwal). The main aim of this programme was to solicit the opinions of the local residents for developing appropriate strategies for sustainable development of disaster-affected areas of the Kedar valley. It also aimed to seek suitable options for strengthening the economic condition of the disaster-affected areas. It also sought to train them in the simple and easy scientific techniques as well as to disseminate information about the possibilities of employment by the proper use of the locally available natural resources, particularly in the field of agriculture, horticulture, animal husbandry, and cultivation of medicinal plants. The training programme was attended by about 112 people from 22 villages of Kalimath valley, and representatives from - line departments of district administration, academic institutes like HNBGU and P.G. College Augustamuni, and the NGOs. People's perception on livelihoods and development options were noted in details to formulate strategies for sustainable development of disaster-affected Kalimath and Kedar valley.

World Environment Day (WED)

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 "*Think, Eat and Save*" on June 5, 2014. 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, microbiology 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

Sikkim Unit, at its Pangthang campus, has also organized the World Environmental Day. The day commenced with a group plantation of multi-purpose trees 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 the Garhwal Unit and NE Unit of the Institute to mark the World Environment Day. Open discussion was held among the scientists and participants, covering different issues related to climate change impact, biodiversity loss, land degradation, forest degradation, human integrity, cultural and religious entity and how to cope with adverse situation in future with respect to environmental conservation so that appropriate strategies could be developed for conserving environment sustainably.

Technology Training Programme

GBPIHED-NE Unit Conducted Field training programme on simple low-cost technologies for trainees of Arunachal Pradesh Rural Bank – Rural Self Employment Training Institute (Doimukh, Arunachal Pradesh), on July 29, 2014. The programme was conducted basically to boost up entrepreneurship development and to enhance the skill and capacity of the trainees, those were drawn from unemployed educated youths and NGOs and for strengthening their capacity. The trainees were given hands –on-training on number of technologies either developed or modified by the Institute at the Multi Technology Demonstration Centre (MTDC) at Midpu, Doimukh, Arunachal Pradesh. The technologies included Production Enhancement Technologies (Bio-composting, Vermi composting, Liquid mannuring, Polyfilm technology, Polyhouse, Legume intercropping, and Trellises), Soil Erosion Control Technologies (Contour hedgerow technology and Modified Jhum), Water Management Technologies (Haandi or pitcher irrigation system), Post Harvest Technologies (Zero energy cool chamber), Energy/Fuel Saving Technologies (Bio-briquetting technology) and Nursery Techniques (Bamboo propagation). Towards entrepreneurship development, the trainees were advised to constitute SHGs to make savings first on the principle *"savings first – credit later"*.

Organization of Popular Lecture

The Institute at its HQs Kosi-Katarmal and all five units (Garhwal Unit, Srinagar; HP Unit, Mohal-Kullu; Sikkim Unit, Pangthang; NE Unit, Itanagar; and Mountain Division, New Delhi) under the initiative "Popular Lecture Series" organized Popular Lectures of eminent persons during different occasions on real time problems. Some of these includes, Human-wildlife conflicts (Dr. S.S. Garbyal, Director General Forest and Special Secretary, MoEF&CC), Do we struggle for development (Prof. Tamo Mibang, Vice Chancellor, Rajiv Gandhi, University Arunachal Pradesh), The evolution of conservation of biodiversity in the Sikkim Himalayas and introspection on the prevailing socioeconomic and environmental scenario (Shri K.C. Pradhan, Former Chief Secretary, Govt. of Sikkim), Save the unique agro-biodiversity for future agroecosystems sustainability (Shri Vijay Jardhari, Environmentalist, Tehri Garhwal), Environmental Issues and Concerns in Particular Reference to the Himalaya (Shri B.S. Parsheera, Former Secretary, Ministry of Home Affairs, Department of Official Language, Govt. of India), Natural Disasters and Human Tragedy (Prof. K.S. Valdiya, Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR, Bangalore), Vulnerability of Himalayas and Current Challenges (Shri Chandi Prasad Bhatt, Padam Bhusan, Gopeshwar Chamoli), etc.

Scientific Advisory Committee (SAC) Meeting

XXth Meeting of the SAC of the GBPIHED was held (August 6-7, 2014) under the Chairmanship of Prof. SP Singh, Former Vice Chancellor, H.N. B. Garhwal University, Srinagar. Prof DC Upreti; Dr Arun K Sharma; Dr SK Srivastava (BSI Nominee); Er Kireet Kumar (GBPIHED Nominee); Dr HK Badola (GBPIHED Nominee); Dr JC Kuniyal (GBPIHED Nominee); and Dr PP Dhyani, Director, GBPIHED were present in the meeting. Prof. DM Banerjee and Director, Wadia Institute of Himalayan Geology (WIHG) could not attend the meeting. The meeting started with welcome address by Director of the Institute, Dr. PP Dhyani and confirmation of minutes of XIXth SAC Meeting. Dr PP Dhyani, welcomed the Chairperson and the Members of the SAC for the 20th meeting of SAC. He recalled and thanked all the former Directors of the Institute and the Chairpersons and SAC members for their contribution towards shaping and strengthening the R&D programmes of the Institute. After introducing the Chairperson and the Members of the newly constituted SAC to the House, he briefed the SAC about its mandate. He further informed about the pre-SAC deliberations held with the Chairman, SAC on March 14, 2014. It was also mentioned that the indicative developmental questions provided by the Chairperson have been duly considered by the Institute faculty for possible inclusion/addressing through ongoing R&D programmes/projects in the Institute. It was emphasized that this SAC meeting, being first in the current plan period, holds special significance for streamlining and strengthening the Institute's R&D

programmes. The Director introduced agenda for the SAC meeting and urged the SAC to critically evaluate the on-going programmes and provide constructive suggestions and guidelines for further improvement. He stressed that the Institute is committed to achieve its mandate through high quality development research. Upon the request from the Director, the Chairman released ENVIS Bulletin prepared by the ENVIS Center on Himalayan Ecology at the Institute. Following to this, Dr PP Dhyani, made a comprehensive power-point presentation to cover: (i) Institute's mandate, structure, and functioning, (ii) R&D thrusts and programmes for the XII plan period, and (iii) major progress and achievements during 2012-13 and 2013-14. Besides the ongoing R&D programmes of the Institute, he specifically highlighted the eight new initiatives of the Institute (1. Himalayan Research Fellowships; 2. Himalayan Young Researchers' Forum; 3. Himalayan Research Mentors' Forum; 4. Himalayan Popular Lecture Series; 5. Himalayan Peoples' Representatives Meet; 6. Himalayan Students' Nature Awareness Campaign; 7. Himalayan Farmers' Livelihoods Enhancement Drive; 8. Mountains Environmental Policies Repository), which have been launched to engage with wider stakeholder constituencies. The Director informed the SAC that besides 9 in-house R&D projects GBPIHED is currently executing 54 externally funded projects (47 National funds; 7 International funds). Among others, the Director emphasized on: (i) extramural funding being made by the Institute for location-specific researches by diverse organizations under Institute's Integrated Eco-development Research Programme (IERP); (ii) strengthening of global collaborations particularly through involvement as Country Coordinator on Indian part for one Global Pollination Project (GPP) and three transboundary landscape conservation and development initiatives; (iii) publication of 348 Research papers/articles (with total impact factor of 70 Journals - 88.07) and 25 Books/booklets/monographs during last two years; (iv) establishment of Mountain Division as the 5th Unit of GBPIHED; (v) Outreach and capacity building programmes of the Institute that are being organized particularly through Rural Technology Centre(s). This was followed by individual presentation by the Institute scientists on different in-house projects. The members of the SAC keenly observed and discussed on the 5-years rolling plans of each in-house project. The Chairman and SAC members expressed satisfaction on the progress of various R&D projects and mentioned that the quality of presentations has improved considerably. Besides, members of SAC visited the Surya-kunj Nature Interpretation and Learning Centre and the Rural Technology Centre. In addition, to give an overview of the activities to SAC members, three brief presentations were made in this session: (i) "Pertinent development questions raised by SAC Chairman" by Er. Kireet Kumar, (ii) "A report of Silver Jubilee Celebrations in the Institute" by Dr. S.K.Nandi, and (iii) "Vision 2040 of the Institute" by Dr. R.C. Sundriyal. The SAC appreciated the progress made by the Institute in last 25 years. They also provided inputs on development questions and suggested that these questions should be addressed through high quality research. The SAC members were also requested to provide their valuable inputs for the development of "Vision 2040 document" of the Institute.

Citizen Science Programme

Two Citizen Science Programmes for Volunteers were organized from August 20-27, 2014 and October 9-18, 2014. In the first group, 07 participants from Shell Company representing different countries (Nigeria, UK, Brazil, Poland, Scotland and USA) and in second group 16 participants from AMCOR (10 participants), Shell (04 participants) and Public Team (02) representing Germany, Indonesia, Australia, Turkey, France, Ukraine, Belgium, India, UK, Canada, Netherlands & USA participated. The programme comprised of 4 modules. Module 1 dealt with Introduction of Participants, Organizations and Programme briefing; Module 2, deliberation and training; Module 3, learning sessions; and Module 4, field surveys and data generation. The volunteer groups generated information on qualitative and quantitative assessment of biodiversity, ecosystem services, phenology, etc. The volunteer Groups were given exposure to the various Institute facilities and feedback of the programmes were taken.

National Consultation on Brahmaputra-Salween Landscape

North East Unit, Itanagar convened the Second National Consultation on Brahmaputra-Salween Landscape Conservation and Development Initiative (BSLCDI) on November 17-18, 2014 at Itanagar, which was funded by International Centre for Integrated Mountain Development (ICIMOD), Kathmandu. The Consultation was inaugurated by Shri Mutchu Mithi, Hon'ble MLA & Parliamentary Secretary, Horticulture, Govt. of Arunachal Pradesh as Chief Guest. Shri Sonam Chombay, Secretary Planning and Shri CD Singh, Director, SFRI, Govt. of Arunachal Pradesh were Guests of Honour. The participants to the consultation also included policy makers, administrators, subject experts from diverse organizations across the country such as IIRS

(Dehradun), RFRI (Jorhat), Tata Institute of Social Science (Guwahati), Rajiv Gandhi University, NERIST, BSI, ZSI, State Institutions like SFRI, SIRD, International organizations like ICIMOD, various line departments of Govt. of Arunachal Pradesh and NGOs like WWF-India (Tejpur), Aaranyak (Guwahati, INSPIRE Network for Environment. Dr. P.K. Samal, Scientist Incharge of the Institute, while welcoming the participants, appraised them on the rich biodiversity of the Brahmaputra-Salween Landscape and the numerous conservation and development challenges that landscape is currently facing. To address some of these issues, the Brahmaputra Salween Landscape Conservation and Development Initiative (BSLCDI) is being launched by ICIMOD for which GBPIHED has been identified by Govt. of India as the focal institute in lndia. Ms. Bandana Shakya, Associate Coordinator of BSLCDI in ICIMOD appraised the participants on the goals and objectives of the transboundary programme of ICIMOD observing that there is a need of collaborative efforts to support conservation of rich and unique biodiversity and to address the poverty through conservation linked development strategies. Also, there is an effort required to develop complementary actions among countries sharing the landscape to help the communities adapt to changing climate regime and to enhance the resilience of both ecosystems and people in the landscape. The goal of the Consultation was to deliberate on preparation of country (India) specific two technical documents, i.e., BSL-India Conservation and Development Strategy (CDS) and BSL-India Comprehensive Environmental and Socioeconomic Monitoring Strategy (CESMS) to be prepared for implementation of BSLCDI. A number of technical sessions were held that deliberated on key actions and priority areas keeping in view conservation and development challenges and issues; implementation strategies, mechanisms, monitoring and evaluation; biodiversity management and development practices including existing policy measures and enabling mechanisms at Regional, National, State and Local level; priority actions for improving long-term environmental monitoring (LTEM); identification of regional interventions to support LTEM; timeline and institutional mapping (skills and resources) and possible role and responsibility with respect to monitoring, conservation and development.

Workshop on Youth and Climate Change

Three days workshop on "Youth and Climate Change in the Indian Himalayan Region" was organized by the GBPIHED, Himachal Unit, Mohal-Kullu in collaboration with Central Himalayan Environment Association (CHEA), Nainital, Uttarakhand from 1-3 December, 2014. 50 Participants including 40 young researchers and Experts/Resource Persons from different Government Organizations and NGOs across the Himachal Pradesh participated. The programme was started with Sarswati Vandana, followed by the welcome address and brief presentation on Institute infrastructure and R&D activities by Scientist In-charge, GBPIHED, Himachal Unit, Mohal-Kullu. Dr. Pushkin Phartiyal, Executive Director, CHEA, told about the CHEA and objectives of the Workshop. Chief Guest Prof. S. K. Sharma, FNASc, Emeritus Scientist (Former Vice Chancellor, CSKHPKV, Palampur, Former Director, NBPGR, New Delhi) addressed the participants on Climate change in the IHR. He highlighted the various factors responsible for the climate change and stressed that immediate mitigation measures are required. On the second day, Dr. S.S. Samant delivered Key lecture on Biodiversity and climate change, Dr. J.C. Kuniyal on Environment pollutions, impacts and implications on climate change, and Dr. H.K. Sharma on Bee keeping and pollinations under changing scenario in the IHR. In the post-lunch session, Ms. Bhawana Luthra interacted with participants on Adaptation to climate change and mainstreaming adaptation in development planning; applying a climate lens in development planning and practice and Group work/ World Café: Youth action to deal with Climate Change in Himachal Pradesh. Dr. Pushkin Phartiyal delivered lecture on importance of the Networking among youth to respond to challenges of climate change through leadership & effective communication in the research. The day ended with 'Nature walk to observe the climate change in Kullu Valley. 3rd day started with recap of the 2nd day by participants. After this Dr. Lal Singh, Director, Himalayan Research Group delivered comprehensive lecture on Technology based livelihoods for rural youths in the IHR. This was followed by Group discussion and finalization of Group Work. In the Valedictory Session, Group Leaders gave presentations on the assigned tasks. The workshop showed significant improvement in the knowledge of the participants about climate change. The participants highly appreciated the Workshop and desired frequent organization of such events in future.

Science motivation Programme

Five days training programme was organized between 1-5 December 2014 at Garhwal Unit of G.B. Pant Institute of Himalayan Environment & Development (GBPIHED) sponsored by National Council of Science & Technology Communication (NCSTC), Department of Science & Technology (DST), Govt. of India with the following objectives:

(a) to carry forward scientific spirit, popularize knowledge of science, promulgate scientific thinking and conduct activities related to science and technology among the students, (b) to conduct exposure visits for students to various research and development (R&D) institutions, high-tech laboratories and field demonstration sites, and (c) to encourage students to opt for science courses and select their future careers in the field of science and technology. About 40 students (5 from each of 8 schools) located in Srinagar town and adjoining areas and 20 faculty members from different academic and R&D organizations covering a wider range of subjects under umbrellas as mentor experts to facilitate interactions and discussions between the students, eminent scientists, researchers and teachers.

Regional Consultation on BSLCDI

Fifth Regional consultation to develop Programme design and Implementation Plan for Brahmaputra-Salween Landscape Conservation and Development Initiative (BSLCDI) was held on 15-18 December 2014 at Kathmandu, Nepal. The Regional Consultation was organized by ICIMOD, Kathmandu in collaboration with GBPIHED (India), KIB (China) & MOECAF (Myanmar). The objective of this regional consultation was to consolidate programme design based on the understanding created among partner countries on landscape elements of the landscape, and to develop the Implementation Plan for BSLCDI for the upcoming five-year period based on shared regional priorities as well as country-specific priorities outlined in the respective country specific strategies. Regional action plan with a thorough understanding of the Results Chain and Impact Pathways for the Initiative was developed. After threadbare discussion, the partner countries agreed to change to the name of the Initiative, i.e., Brahmaputra-Salween Landscape Conservation and Development Initiative (BSLCDI) to Landscape Initiative for Far Eastern Himalaya (Hi-LIFE) in the Consultation.

Governing Board Meeting

The 37th Governing Board Meeting of G. B. Pant Institute of Himalayan Environment and Development (GBPIHED) was held on February 27, 2015 at the Ministry of Environment, Forest & Climate Change, New Delhi, under the Chairmanship of Shri Ashok Lavasa, Secretary, Ministry of Environment, Forests & Cliamate Change, Govt. of India, New Delhi. The meeting was attended by Shri S.S. Garbyal, DG Forest & Special Secretary, MoEF&CC; Shri Hem Pande, Addl. Secretary, MoEF&CC; Shri S. Mohanty, Addl. Secretary & Financial Advisor, MoEF&CC, Dr. J.R. Bhatt, Scientist G & Advisor, MoEF&CC; Prof. S.P. Singh, Dr. R.R. Rao, Dr. D.M. Banerjee, and Dr. P.P. Dhyani, Director, GBPIHED (Member Secretary). Secretary, DBT, New Delhi; Chief Secretary, Uttarakhand; Dr. Y.V.N. Krishna Murthy could not attend the meeting. Shri C.M. Sharma, Deupty Secretary, MoEF&CC, Er. Kireet Kumar, Scientist G (GBPIHED) and Dr. R.S. Rawal, Scientist F (GBPIHED) also attended the meeting. The Governing Board approved the draft Annual Report and Statement of the Accounts for the year 2012-13 and 2013-14 and discussed about the R&D activities of the Institute.

GBPIHED Society Meeting

The 18th Society Meeting of GBPIHED was held on March 2, 2015 at the Ministry of Environment, Forest & Climate Change, New Delhi under the Chairmanship of Hon'ble Minister of State (Independent Charge), Environment, Forest & Climate Change, Govt. of India, Shri Prakash Javedkar (President of the GBPIHED Society). At the outset President Shri Prakash Javedkar extended warm welcome to all the members of the Society, which was followed by confirmation of the minutes of the 17th Society Meeting. Following this, Dr. P.P. Dhyani, Director, GBPIHED, made a detailed presentation on the progress of the Institute. Among others, this meeting was attended by Shri Ashok Lavasa, Secretary, MoEF&CC; Shri S.S. Garbyal, DG (Forests) & Special Secreatary, MoEF&CC; Shri Hem Pande, Addl. Secretary, MoEF&CC; Dr. K.K. Katoch, Vice Chancellor, CSK Himachal Pradesh Agricultural University, Palampur; Shri Y.S. Shullai, Chief Wildlife Warden, Meghalaya; Dr. G.A. Kinhal, Director, IIFM Bhopal; Dr. G.S. Rawat, Scientist G, WII Dehradun; Dr. J.R. Bhatt, Scientist G & Advisor, MoEF&CC; Dr. P.K. Mishra, Director, IISWC, Dehradun; Dr. Ashok A. Sonkusare, Deputy Advisor (S&T), NITI Ayog, Dr. Mahi Pal, Director, Ministry of Rural Development; Dr. Vinod Kumar, Director, UCOST Dehradun; Dr. V.R.S. Rawat, Scientist, ICFRE Dehradun; Dr. Sandeep Chauhan, BSI, MoEF&CC; Dr. P.P. Dhyani, Director, GBPIHED (Member Secretary); Shri C.M. Sharma, Deputy Secretary, MoEF&CC, Er. Kireet Kumar, Scientist G (GBPIHED) and Dr. R.S. Rawal, Scientist F (GBPIHED). The Society approved the draft Annual Report of 2010-11, 11-12, 12-13 & 13-14 and Statements of the Accounts of GBPIHED and discussed about various R&D issues of the Institute.

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 diversities. Traditionally, the system is strongly rooted upon the concept of recycling of resources within; however, the system is undergoing rapid breakdown because of the 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, migration and its socio-economic and cultural implications, etc. The development in the IHR so far has also involved conflict between man and nature. 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 ecological 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 like hill-specific Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA), aerosols and climate change impacts, disaster mitigation and management, 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, 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 systematic approach. This group also envisages activities on the enhancement of Institutional outreach based on its research products such as state-of-the-art methodologies/approaches, models and policy briefs, etc. Besides the above, capacity building through specifically designed modules, training programmes, library and IT services, which also help significantly in human resource development, are among 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 plants, animals and microbial populations, and is considered a "hot-spot" of biodiversity; it also caters and contributes significantly to support livelihood and contribute to the economic well-being of the people. However, the changing world scenario stresses on 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 and 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 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 Indian Himalayan Context (2012-2017, *In-house*)

Availability of water is on decline in the IHR, both in terms of quality and quantity. The condition is specifically severe in the rain-fed watersheds. Growing scarcity of water (due to changing demand and supply factors) has resulted into changes in other components (biotic and abiotic) of the environment in the region. Therefore, the watershed development projects are now focused towards intensifying land uses using available water and the betterment of neglected ecosystem services through integrated planning with the advance uses of GIS based models and applications. This project is also focusing on the interface of water demand and availability along with its future scenario at the basin scale. The demand side includes demand from major land uses to ensure water sustainability in the fragile Himalaya. The study area is Kosi Watershed, encircling a principle tributary of River Rāmgangā (West) System, from its north most point at Pinath (NW of Kausani) to Ramnagar (NW in district Nainital). Geographically, the catchments has its spatial extension between $29^0\ 22'\ 41.60''$ and $29^0\ 52'\ 20.81''$ N latitudes and $79^0\ 02'\ 38.21''$ and $79^0\ 51'\ 15.08''$ E longitudes, covering 1868.64 km^2 area. The absolute relief of the catchment ranges between 349 m and 2758 m from the mean sea level.

Objectives

- To identify, analyze and assess potential indicators depicting changes in water resource scenario under changing climate regime and its interaction with consumptive and non-consumptive uses at watershed scale.
- To investigate the implications of changing surface water regime and delineate the critical ecosystem components susceptible to change.
- Analyses of the consequences of the changing water resources on society and adaptation measures 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

- According to the survey, conducted in 101 villages (731 households) in four different altitudinal zones of Kosi watershed, the average per capita water consumption in Kosi watershed is 30.35 l/daywhich is lower than the national average of 40 l/day. The average water consumption per livestock is 32.38 l/day. The zone wise analysis reveals that the per capita water consumption is low in zone IV (> 1800 m asl) and zone III (1200 – 1800 m asl) i.e. 19.95 l/day and 20.64 l/day, respectively. The people residing in these zones are entirely dependent on the natural springs for water. The values for zone I (< 800 m) and zone II (800 – 1200 m) are 41.32 l/dayand 39.47 l/day, respectively, somewhat close to the supply norms. The average water consumption per livestock is less than the national average (47 l/day) in all four zones (Fig 1).

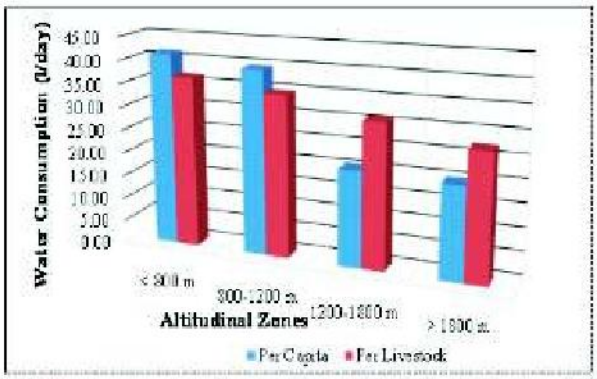


Fig. 1. Water consumption per capita and per livestock (l/day)in four altitudinal zones of Kosi watershed

- Mean monthly water discharge of river Kosi at Betalghat site has been measured for the last one year (2014). The discharge was high in the month of July and August (during monsoon season) i.e. 14.43 cu m/sec and 14.99 cu m/sec, respectively. November 2014 depicts the lowest mean monthly discharge of 1.77 cu m/sec during the year.
- Grid (5 Km x 5 Km) based distributive underground water samples from 110 sites were collected (Fig 2). Water was tested for various quality parameters like pH, Electric conductivity (EC), Total Dissolve Sediments (TDS), Salinity, Total Hardness (TH), Calcium Hardness, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Chloride (Cl), Sodium (Na^{+}), Potassium (K^{+}), Fluoride (F^{-}), Sulphate (SO_4^{2-}), Total Suspended Sediments (TSS) and Alkalinity. Data was analyzed for different seasons.

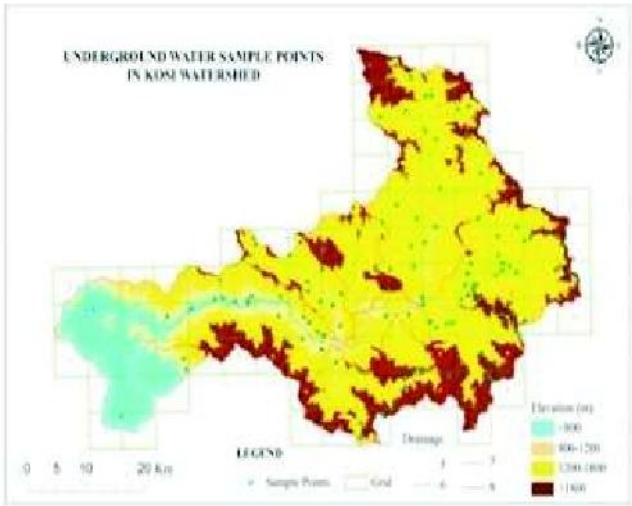


Fig. 2. Groundwater sampling points in Kosi watershed

Farming Systems and Changing Climate Regime: Strengthening Food and Nutritional Security in the Himalaya (2012-2017, *In-house*)

The Indian Himalayan Region (IHR) is a distinct and eco-sensitive geographical region where about 70% of the population is rural and dependent mainly on rainfed agriculture, horticulture and animal husbandry. Here farming systems are complex; crop husbandry, animal husbandry and forest 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. Due to the increasing global surface temperature, the rainfall distribution pattern is changing throughout the world. The monsoon Asia, particularly the Indian subcontinent, is no exception to this varying rainfall pattern. 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, harvest as also the pest activity. In IHR farmers have developed locally suitable practices to cope with the harsh environment of the hills. These practices are continuously upgraded to meet new demands changing local environment. This study

examines the changes in farming system, soil nutrient status and climatic changes in Kosi watershed, intra seasonal oscillation (ISO) of ISMR across the Himalayas and Economic and biochemical yields of few selected vegetable crops grown in the Kullu Valley, Himachal Pradesh. Since, monsoon rainfall is a regional scale phenomenon and the localized trend analysis of rainfall is inadequate to represent trend of the entire Himalayan region.

Objectives

- To study changes in mountain farming systems due to socioeconomic factors.
- To study changes in mountain farming systems due to ecological factors including climate change.
- To develop future farming scenario based on above (1 & 2).
- To develop appropriate strategies and action plans for sustainability of mountain farming system.

Achievements

- Altitudinal variation of intra seasonal oscillation (ISO) of Indian summer monsoon rainfall (ISMR) over the IHR was investigated with multitude of approach using field station data of 133 stations across the IHR for the period of 1995-2004. Frequency for the light rainfall, moderate rainfall and total seasonal rainy days showed two maxima at around 227 m and 2100 m altitudes of North Western Himalayan region. However, for the Eastern Himalayan region, where the station observations are available up to around 1800 m, all the different rainfall classes along with the variation of total seasonal rainy days were found to have maxima at around 1100 - 1400 m height.
- At Dhaniyakot about 34% agriculture land was cropped with cash crops (potato, pea, onion, cauliflower and tomato) and remaining land was under traditional food crops. At Kantli, potato and pea were cropped for home consumption on very small areas. Rain fed condition and smaller land holding don't allow farmer for large scale cash cropping.
- During two consultations meeting held in Kosi watershed ~80.70% farmers perceived the changes in mean temperature, out of which about 75.9% perceived rise in mean temperature and 4.8% perceived decrease in mean temperature (Table 1). Majority of farmers (92.8%) believed that the annual rainfall has decreased; about 9.6% believed that rainfall has become more erratic as compared to 30 years ago. About 39.8% of farmers have made changes in crop sowing timing, 34.9% have started using insecticides, and 25.3% farmers have replaced traditional seeds with high yielding varieties of same crops as adaptation measure to climate change.

Table 1. Farmers Perception about climate change (Total respondents 83)

S. No.	Questions and people's perceptions	% Respondent	Studies/ published data supporting farmer's perception
1	Change in mean temperature		Increase of mean annual temperature (Gaira et al., 2014) Rises in both maximum and minimum temperature (Joshi & Kumar, 2013)
	(A) Yes	80.7	
	i. Temperature increase	75.9	
	ii. Temperature decrease	4.8	
	(B) No	19.3	
2	Changes in mean precipitation		Increasing trends in pre-monsoon rains; decrease in monsoon and winter rains (Joshi & Kumar, 2013) No change in extreme events (Mukherjee et al., 2014)
	(A) Yes	92.8	
	i. Decrease in rainfall	92.8	
	• Increase in intensity of rainfall	22.9	
	• Erratic rainfall	9.6	
	(B) No	7.2	

Sources: Gaira, et al. (2014). Current Science, 106 (12): 1735-1738; Joshi, S. and K. Kumar (2013 In: Climate Change and Himalaya- Natural Hazards and Mountain Resources (Sundaresan et al. eds.), pp: 138-148, Scientific Publishers, India; Mukherjee et al. (2014). Theor. Appl. Climatol. DOI 10.1007/s00704-014-1273-1

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)

This project proposal is designed to delineate the deformation field in the Himalayan urban centers, including some notable land slip zones with high resolution, GPS data across Himalaya using 6 continuously operating GPS systems at Almora, Gangtok, Nainital, Kullu, Ziro and Srinagar-Garhwal. Study is also designed to constraint on the deformation rate (strain) in the Uttarakhand Himalaya based on GPS measurements taken by reoccupying the existing GPS campaign stations along the Gori and Kali valleys from the foothills to the trans-Himalaya. The project also aims at testing whether the Lesser Himalaya and Siwalik Himalaya deform coherently with respect to the main Himalayan thrusts.

Objectives

- To maintain and operate existing permanent GPS stations at Kullu (HP), Almora (UK), Nainital (UK), Srinagar (Garhwal, UK), Pangthang (Sikkim), and Ziro (AP) focusing on quantification of the tectonic deformation field by experimentally determining the displacements of these fixed sites (urban centers) 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 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 Ziro (GBZR) (Fig.3) is being done with reference to other campaign sites. Field GPS campaign for 10 sites along Gori valley and 10 sites along Kali valley in Kumaun Himalaya have been completed and data processed using GAMIT/GLOBK software. Coordinates and baseline of all campaign sites are determined with mm accuracy.

Fig. 3 Permanent GPS reference station Old Ziro (A.P.)

- The precise position and velocity of the permanent sites in ITRF08 reference frame are being determined. Preliminary observations show that the velocity of IISC and HYDE is ~ 52 mm/year, and velocities of GBPIHED's permanent stations GBSK, GBPK, GBNL, GBSN, GBKL and GBZR are ~ 46 mm/year, 47 mm/year, 47 mm/year, 47 mm/year, 40 mm/year and 45 mm/year, respectively.
- There is convergence of 5.7mm/y, 16.7mm/y and 18.1 mm/y between GBPK_KIT3, GBNL_KIT3 and GBSN_KIT3, respectively and 28.5 mm/y, 35.7 mm/y and 38.4 mm/y between GBPK_POL2, GBNL_POL2 and GBSN_POL2 respectively (Table 2).

Table 2. Baseline changes for the year 2012-2014

Stations	Baseline 2012 (m)	Baseline 2014 (m)	Baseline change 2012-2014 (m)
GBPK_IISC	1845790.057	1845790.060	0.0029
GBPK_KIT3	1568521.453	1568521.447	-0.0057
GBPK_POL2	1509568.886	1509568.886	-0.0285
GBPK_LHAZ	1110483.231	1110483.240	0.0083
GBPK_HYDE	1355461.275	1355461.273	0.0083
GBNL_IISC	1817190.034	1817190.035	0.0009
GBNL_KIT3	1576439.572	1576439.556	-0.0167
GBNL_POL2	1531364.185	1531364.149	-0.0357
GBNL_LHAZ	1128991.477	1128991.482	0.0051
GBNL_HYDE	1327243.259	1327243.253	-00060
GBSN_IISC	1898824.080	1898824.084	0.0037
GBSN_KIT3	1463504.258	1463504.240	-0.0181
GBSN_POL2	1427962.708	1427962.670	-0.0384
GBSN_LHAZ	1196110.747	1196110.756	0.0090
GBSN_HYDE	1412954.603	1412954.602	-0.0006

Geodynamics and Hydro-chemical Studies of Gangotri Glacier System, Garhwal Himalaya (2013-2016, DST, New Delhi)

The Himalayan glaciers are retreating rapidly like many other parts of the Globe. The recession and overall decrease in the volume of glacier is adding to the total area of erosion every year. It generates large amount of suspended sediment load, which is carried from the glacierized basin. The geodynamic changes in Glacier basin are also responsible for multidimensional changes in glacier ecology. This proposal stems from the effort made by the Institute to understand the ecosystems of Gangotri, Thelu and Raktvarna valleys under the completed DST projects. The baseline data was collected on different bio-physical elements of the glacier valley. The present proposal envisages analyzing long term dynamics of Gangotri glacier system and its impact on bio-physical and chemical components of glacial environment. The underlying hypothesis is whether or not the present dynamics of glacier (to be measured by precise snout monitoring using GPS) significantly affects the physical environment (i.e. geo-hydrology and micro-

climate), and glacier chemistry. The result of this study are expected to yield helpful information for understanding the role of glacier dynamics in present context of climate change and development of water management plan for downstream usages such as hydropower and irrigation.

Objectives

- Assess impacts on geo-hydrological features by monitoring of snout and glacier surface using precision surveys for retreat/ flow assessment.
- Investigate hydrology and quantification of suspended sediments of the meltwater stream of tributary glaciers/ streams to evolve the erosion rates and its possible relation with glacier dynamics.
- Study of temporal and spatial solute dynamics of glacier and to explore the relationship between solute dynamics and glacier dynamics.

Achievements

- The variable rate of recession of the snout of Gangotri glacier is possibly due to excessive forcing of melt water from the tributary glaciers (Raktverna and Chaturangi). Further studies in the upper part of glacier valley will be necessary to confirm the recession pattern of Gangotri (Fig 4).

Fig. 4. Sign of excessive melting and erosion in northern portion of Gangotri Glacier

- During this ablation season for glacier chemistry 120 diurnal water samples were collected from Gangotri glacier and its tributary glacier (Chaturangi). The collected water samples was filtered and further analysis shows the average suspended sediment (SS) concentration during the monitoring period for Chaturangi and Gangotri glacier was 0.26 and 5.864 mg/l, respectively (Fig. 5a & b).

- CO_2 level was also measured in Gangotri and Chaturangi glacier using LiCor CO_2 gas analyzer along the valley at eight points. The values of CO_2 varied from 250.54 ppm to 284.62 ppm.

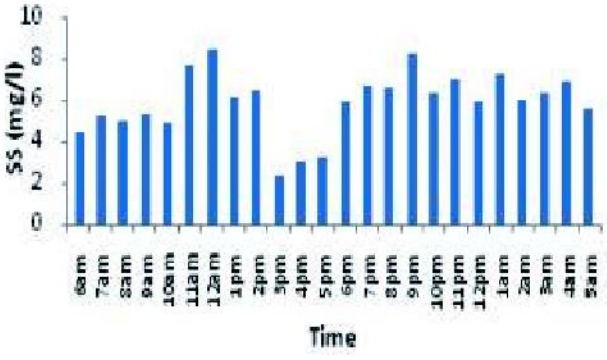


Fig.5a. Suspended sediment in mg/l at Gangotri glacier

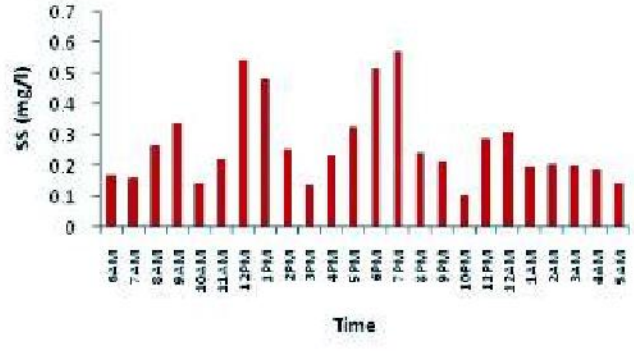


Fig. 5b. Suspended sediment in mg/l at Chaturangi glacier

Run off Modeling and Simulation of Sediment load of Gangotri Glacier Systems (2011-2014, DST, New Delhi)

Glaciers, an important component of earth system, control the river hydrology of the mountainous and the areas downstream. In the Himalaya, about 1400 km^3 of snow and ice is sheltered which spreads over nearly 33,200 km^2 area in higher altitude above the 4300-5800 m. Nearly 1,20,00,000 million cubic meter of water flowing down the Himalayan rivers, has potential of generating 28 million kilowatts of electricity and 2,46,600 million m^3 of water for irrigation, annually sustains almost 60% of population in Indo-Gangetic plains. 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. Suspended sediment forms a part of glacier erosion. Estimates of sediment yield are required in a wide spectrum of problems such as design of reservoirs & dams, transport of sediment and pollutants in rivers, lakes, design of stable channels, dams and debris basins, protection of fish and wildlife habitats, determination of the effects of watershed management, and environmental impact assessment which are considered essential for the land and water management. 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.

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 MODIS Terra and Aqua satellite derived snow cover area (SCA) analyses for Gangotri glacier systems for 2002-2012 period shows decreasing trend in annual mean SCA for elevation zones II-VII (3834-6834m) with varying rates (zone II: -2.28%±2.49; zone III:-4.21%±3.17; zone IV:-4.41%±3.87; zone V: -4.82%±5.26; zone VI: -9.93%±6.27; zone VII: -6.95%±5.96); whereas SCA in zone I (>6834m) is found to be increased by 0.71%±3.33 (Fig. 6).

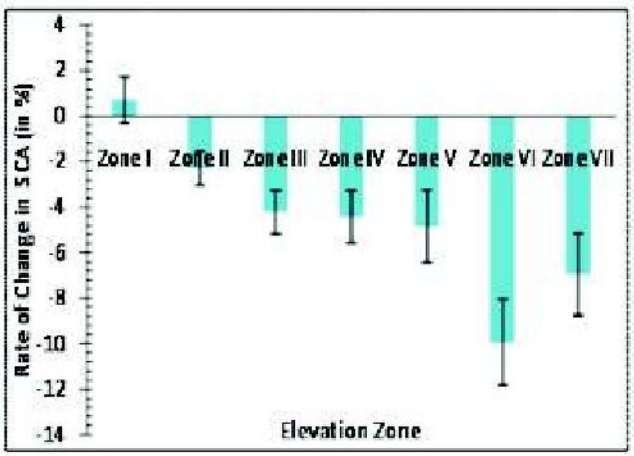


Fig. 6 Annual rate of change in snow cover area from 2002-2012

- Modeling experiments were performed to simulate stage-discharge-suspended sediment concentration (SSC) for Gangotri glacier using Artificial Neural Network (ANN) technique. The best modeling structure for estimation of daily SSC with a combination of 3-previous day's stage, discharge and SSC values (S_{t-1}, Q_{t-1}, H_{t-1}, S_{t-2}, Q_{t-2}, H_{t-2}, S_{t-3}, Q_{t-3}, H_{t-3}) as input to ANN model was developed.
- The results of hysteresis generated by ANN model shows its appropriateness over the conventional sediment rating curve (SRC) method (Table 3) for simulating suspended sediment load in glaciated catchments.

Table 3. Comparative performance of SSC simulation by ANN models and SRC method

Modeling approach	Statistical parameters for performance evaluation			
	RMSE (g/l)	MAE (g/l)	Relative Error	R^2
ANN using discharge (Q) and sediment (SSC)	1.8	1.3	7.8%	0.79
ANN using stage (H), discharge (Q) and sediment (SSC)	1.6	1.1	4.4%	0.81
SRC using discharge (Q) and sediment (SSC)	6.4	3.3	23.2%	0.25

Study of Heavy Metal Transfer from Contaminated Soil to Food Chain and Their Risk to Human Health in Himachal Pradesh (2012-2015, DST-YS)

Human concerns on heavy metal contamination of vegetables are growing due to their health causing effects and non-biodegradable nature. Vegetables, rich source of minerals, vitamins, antioxidants, etc. are getting contaminated with heavy metals due to overuse of pesticides, contaminated irrigation water, chemical fertilizers, solid waste composts contaminating essential (Cu, Zn, etc.) and non essential heavy metals (Cd, Pb, Ni, Cr, etc.). Consumption of such contaminated vegetables can pose health threats to the human population. There are scarcities of data on heavy metal contamination of vegetables and associated human health as well as techniques for

reducing their contamination levels in food chain. 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 and Kullu Valley in particular with following objectives.

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 of Kullu.
- To quantify the dietary intake of heavy metals through contaminated vegetables and their health risks to local consumers of Kullu.
- To assess the influence of organic matters and sulfur on soil bioavailability of heavy metals and their accumulation in vegetable crops grown on heavy metal contaminated soil.

Achievements

- Cauliflower, cabbage, radish and tomato grown locally and sold in open urban markets of Kullu Valley of Himachal Pradesh and its adjacent areas were found contaminated with Cu, Zn, Cd, Pb and Cr. Their concentrations (mg/kg dw) in above vegetables ranged between 1.9-72.1, 6-96.4, 0.06-5.7, 0.01-7.6 and 0.28-16.10, respectively (Table 4).
- Cu concentration in both tomato and cauliflower, Cd and Zn in tomato at production sites had exceeded permissible limit, whereas Cd in tomato and radish and Pb in radish exceeded the safe limit at market sites. The mean concentration of Cd in all the test vegetables collected from both production and market areas had exceeded the safe limit set by EU and FAO/WHO.
- A pot based study was carried out to assess the effects of sulfur and farm yard manure application, singly and in combination on Cd accumulation and consequent response of radish (*Raphanus sativus* L. var. White icicle) grown on Cd contaminated area. The study revealed that farm yard manure application can be used to reduce the effects of Cd polluted soil on yield of crops (Fig. 7).

Table 4. Heavy metal concentration (on mg/kgdry weight basis) in vegetables sold locally in urban market areas of Kullu valley, Himachal Pradesh

Vegetables	Values	Cu	Zn	Cd	Pb	Cr
Tomato	Mean Range	16.24 (30) 7.55-28.35	32.14 (30) 7.55-64.50	1.50 (30) 1.15-2.58	1.24 (24) 0.79-2.04	4.36 (3) 4.30-4.40
Cauliflower	Mean Range	27.85 (33) 7.34-38.88	41.46 (30) 15.25-79.50	0.76 (33) 0.11-1.50	2.10 (24) 0.01-6.74	5.63 (6) 5.05-6.20
Cabbage	Mean Range	10.92 (33) 1.85-22.30	37.55 (33) 6.00-70.50	0.95 (33) 1.60-2.65	1.79 (24) 0.23-4.45	4.05 (6) 1.05-7.08
Radish	Mean Range	19.48 (33) 3.84-56.90	49.40 (33) 28.04-87.68	2.31 (33) 0.06-5.69	2.60 (24) 0.01-7.60	5.80 (6) 2.75-8.85
Indian Standard		30	50	1.5	2.5	20
EU Standards		-	-	0.2	-	-
WHO/FAO Standards		40	60	0.3	0.3	-

Values in parenthesis indicate the numbers of samples analyzed.

Fig.7. Photograph showing growth performance of radish (*Raphanus sativus* L. var. White icicle) plants grown on soil (control) and Cd contaminated soil, amended with sulfur (S) and farmyard manure (FYM), singly and in combination.

Responses of Some High Altitude Crops to Enhanced UV-B Radiation and Nutrient Fertilization (2013-2016, DST-WS, New Delhi)

Depletion in ozone layer resulting from contamination with anthropogenic emissions of chlorofluorocarbons, nitrogen oxides and methyl bromides leads to an increase in UV-B radiation on the earth's surface. During the last few decades, there has been considerable concern over the depletion of stratospheric ozone layer caused by contamination

with man-made pollutants. Reductions in stratospheric ozone because of various anthropogenic activities are therefore important as it leads to corresponding increase in UV-B radiation (280–320 nm) reaching the Earth's surface. Enhanced ultraviolet-B (UV-B) radiations due to depletion of stratospheric ozone layer affect agriculture crops in many ways either directly or indirectly. In IHR, the UV-B radiation is increasing due to increased deforestation, forest fire and transportation. Increased UV-B radiation may significantly alter plant ecosystems by reducing productivity of several economically and ecologically important plants. Limited reports on the effects of enhanced UV-B radiations of agricultural crops of Himachal Pradesh are available. Therefore, the present study on the response of some agricultural crops of Himachal Pradesh to enhance UV-B radiations and nutrient fertilization is being carried out with following objectives.

Objectives:

- To study growth, biomass accumulation patterns and yield responses of crop plants exposed to ambient and enhanced UV-B radiation.
- To study interspecific and intraspecific variations in response pattern of test plants to enhance UV-B radiation with respect to protein, antioxidants, enzymes and nutrient levels.
- To evaluate changes in quality of produce of test crop plants and antioxidant potential due to enhance UV-B radiation.
- To assess the effects of organic and inorganic fertilizers on UV-B induce toxicity in crop plants.

Achievements

- A pot based experiment was carried out to study the responses of two cultivars of French beans (*Phaseolus vulgaris* L. cv. PusaHimlata and PusaParvati) to enhanced and ambient UV-B radiation (Fig. 8).
- Economic yield of Phaseolus vulgaris cv. PusaHimlata grown under enhanced UV-B radiation was found higher as compared to that of Phaseolus vulgaris cv. PusaParvati (Table 5).
- Another pot based experiment is initiated to study the responses of two cultivars of pea *(Pisum sativum* L. cv. Lincoln and Early Giant) to enhanced and ambient UV-B radiation grown under mountain ecosystem.

Fig. 8. *Phaseolus vulgaris* plants exposed to enhanced ultraviolet-B radiation through UV-B 313 flouroscent lamps (Phillips, India

Table 5. Growth response of *Phaseolus vulgaris* exposed to supplemental UV-B under mountain ecosystem

Age/Growth response	*P. vulgaris* cv. PusaHimlata		*P. vulgaris* cv. PusaParvati	
	Control	Treatment	Control	Treatment
30 DAG				
No of leaves (plant^{-1})		9.80*±0.66	12.60±1.25	8.60*±1.07
Leaf area (cm^2 plant^{-1})	59.45±5.92	50.02^{ns}±4.78	54.59±6.67	38.06*±3.14
Number of nodules (plant^{-1})	18.20±1.32	8.4**±0.51	13.40±1.08	6.60**±0.69
Root length (cm plant^{-1})	5.28±0.29	4.38^{ns}±0.71	6.84±0.37	6.0^{ns}±0.30
Shoot length (cm plant^{-1})	21.32±1.05	18.48*±0.73	25.60±1.00	20.90*±0.834
Total length (cm plant^{-1})	26.60±.90	22.86*±0.95	31.84±1.17	26.90**±0.59
60 DAG				
Number of leaves	24.60±1.36	18.20*±0.80	64.00±4.30	43.00*±2.09
Leaf area (cm^2)	91.61±2.45	72.49***±2.28	63.07±1.67	41.96***±1.66
Number of nodules	12.80±1.16	5.40**±0.68	9.00±0.71	3.60**±0.51
Root length (cm)	11.08±1.23	7.34*±0.56	14.80±0.67	11.32**±0.35
Shoot length (cm)	32.54±1.23	28.04^{ns}±1.72	94.94±4.88	67.86**±2.80
Total length (cm)	43.62±1.31	35.38*±1.25	109.74±4.93	79.18**±2.62
Economic yield	0.21±0.004	0.18*±0.004	0.18±0.004	0.11***±0.002

Values are mean ± SE of five replicates. DAG: Days after germination, Levels of significant: ***= p≤ 0.001, **= p≤ 0.01, *= p≤ 0.05, ns= not significant.

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 utmost important for developing appropriate short and long term management plans. The long-term research sites and programmes provide appropriate information on how biodiversity changes, and are important in distinguishing anthropogenic and natural changes. Among the landscapes of the world, the Indian Himalayan Region (IHR) is most vulnerable due to various anthropogenic activities coupled with the changing environmental conditions. Therefore, it requires immediate actions towards assessing status, changing patterns and processes of biodiversity components, as well as their conservation and socio-economic values; evaluating and comparing ecological integrity, stability and resilience of ecosystems and their components; and analyzing impacts of climate and resource use changes on the biodiversity components and assessing its socio-economic consequences. In addition, development of packages of practices for maintenance and optimal use of sensitive biodiversity components and improving bio-resource based livelihood options for native communities; establishment of demonstration models, development of dissemination packages on cultivation and establishment of *ex situ* gene banks of elite planting materials; and creation of awareness among the stakeholders about the potential benefits and benefit sharing mechanism of biodiversity are essentially required. Besides these, establishment of Himalayan Biodiversity and Climate Change Knowledge Network (HBCC-KN) to build on existing knowledge and enhance information generation through robust globally accepted protocols, and development of management and sustainable use plans with policy briefs are essentially required. During the plan period studies have been initiated on these lines, so that above issues could be addressed and appropriate management plans of biodiversity could be prepared and implemented through different organizations. Realizing the importance of biodiversity for sustainable development and environmental conservation, the Biodiversity Conservation and Management (BCM) Theme envisages the following objectives: (i) to generate robust datasets on status, changing patterns and processes of biodiversity components, as well as their conservation and socio-economic values of the Indian Himalayan landscapes, (ii) to evaluate and compare ecological integrity, stability and resilience of ecosystems and their components in the Indian Himalayan landscapes, (iii) to analyze impacts of climate and resource use changes on the biodiversity components, and assess its socio-economic consequences, (iv) 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, (v) to establish demonstration models, develop dissemination packages on cultivation/plantation and establish *ex situ* gene banks of elite planting materials, (vi) to inculcate awareness among the diverse stakeholders about the potential benefits and benefit sharing mechanism of biodiversity, (vii) to establish Himalayan Biodiversity and Climate Change Knowledge Network (HBCC-KN).

Understanding Biodiversity Patterns and Processes Under Changing Resource Use and Climate Scenario in Indian Himalaya – Ecological and Social Implications (2012-2017, In-house)

The biodiversity of Indian Himalayan ecosystems is depleting fast due to habitat degradation caused by various anthropogenic activities coupled with the changing environmental conditions. 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 and their conservation and socio-economic values; evaluating and comparing ecological integrity, stability and resilience of representative ecosystems and their components; analyzing impacts of climate and resource use changes on the biodiversity components, and assessing its socio-economic consequences so as to draw realistic and widely accepted action agenda for the conservation and sustainable use of its biological diversity under changing climate and land use. Keeping in view the importance of biodiversity of the temperate, sub-alpine and alpine regions and its vulnerability to the global climate change, the study has been initiated in the temperate, subalpine and alpine landscapes of Himachal Pradesh in the North Western Himalayan biogeography province. Establishment of long term monitoring sites to ensure uninterrupted flow of information, identification of most resilient habitat and formulation of Himalayan biodiversity and climate change network (HBCC-KN) are among major outcome of the study.

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

Kanawar Wildlife Sanctuary, Himachal Pradesh

- Total 19 sites were sampled in the Kanawar Wildlife Sanctuary between 1,706-2,005m. The shady moist forest habitat represented maximum sites, followed by dry forest, bouldary and rocky habitats. Maximum sites were represented in South-West, North-West, North-East, and East aspects (03, each), followed by South-East and North-East (02, each) aspects and only one site from South West aspect.
- Total 14 forest tree communities were identified based on Importance Value Index and relative density. Total tree density ranged from 210.0-707.5 Ind ha^{-1} and total basal area 1.871361-51.577 m^2ha^{-1}. Shrub and herb density ranged from 130.0-706.67 Ind ha^{-1} and 16.05-41.5 Ind m^{-1}, respectively (Fig. 9).
- 292 species of vascular plants i.e., Angiosperms (272 species), Gymnosperms (8 species) and Pteridophytes (12 species). Among the angiosperm families, Asteraceae (28 spp.), Rosaceae (18 spp.) and Ranunculaceae (12 spp.) were dominant. 135 species were economically important, and used as medicine (69 spp.), wild edible/food (35 spp.), fodder (70 spp.), fuel (32 spp.), timber (06 spp.), religious (09 spp.), fiber (04 spp.), making agricultural tools (07 spp.) and some other purposes (12 spp).
- Species diversity index (H') for trees ranged from 0.747-2.885, saplings, 0.562-2.087, seedlings, 0.479-1.299, shrubs 0.021-4.138, and herbs 2.07-3.29, respectively. Concentration of dominance (Cd) for trees ranged from 1-0.183, saplings, 0.134-0.625, seedlings, 0.297-1352.87, shrubs 0.212-1 and herbs 0.044-0.267, respectively.
- The forest communities were represented by evergreen coniferous communities (*i.e., Cedrus deodara and Pinus wallichiana*); broad leaved evergreen communities (*i.e., Quercus gluca*) evergreen coniferous mixed community (*i.e., Pinus wallichiana-Cedrus deodara* mixed and *Cedrus deodara-Pinus wallichiana* mixed). Species richness is highest in *Pinus wallichiana* among the forest community followed by *Cedrus deodara*.
- Soil samples of 23 sites were analyzed for physico-chemical properties. Soil moisture content ranged from 5.86-9.556, pH 5.94-6.55, total nitrogen 1.4-2.29% and organic carbon 0.69-6.23%.

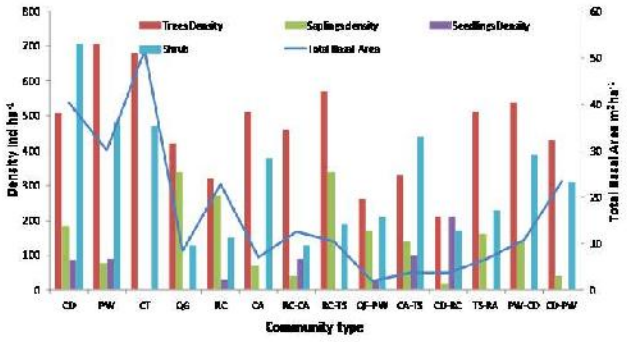


Fig.9. Total density of trees, saplings, seedlings, shrubs and Total Basal Area of forest communities in Kanawar Wildlife Sanctuary. Abbreviations used: CD=*Cedrus deodara;* PW=*Pinus wallichiana;* CT=*Cupressus torulosa;* QG=*Quercus glauca;* RC=*Rhus chinensis;* CA=*Celtis australis;* TS=*Toona serrata;* QF=*Quercus floribunda;* RA=*Rhododendrone arboreum.*

Headquarters, Uttarakhand

- Long term monitoring site, first of its kind was established following GLORIA protocol. The intensive inventory of plant diversity of GLORIA summits has revealed a total of 161 species in Bhairav Ghati (BHT) summit. The Kharangdhang (KHA), Ganglakhan (GAN) and Sekhuakhan (SKN) summits recorded 120, 88 and 57 species, respectively (Fig. 10). While comparing the number of species among the summits, the lower elevation represented highest number of species.
- Extensive resource use studies in Hat Kalika watershed revealed that *Pinus roxburghii* was the most collected fuel wood from forests with an annual mean collection 1077 kg/hh/yr and probability of use 0.69 The major fodder included *Grewia oppositifolia, Bauhinia variegata, Celtis australis, Ougeinia oojeinensis,Quercus glauca, Q. leucorichophora, Q. lanuginosa, Ficus palmata and F. roxburghii*. Among these, *Q. luecorichophora* was the most preferred fodder species. Fuel wood consumption was highest 18 kg/hh/day in Pali village in winter season.

Fig. 10. Species diversity in GLORIA site, Pithoragarh

Kanchendzonga Biosphere Reserve, Sikkim

- Quantitative assessment of vegetation and prioritized faunal elements using standard protocol was targeted for Yuksom- Mt. Black Kabur transact (1780m-4810m); nine sites were investigated from 2600-4010m and total 39 woody species were recorded. Family Ericaceae appeared as the most diverse family. Importance Value Index (IVI) identified *Rhododendron setosum/Juniperus recurva/Rhododendron anthopogon scrub (4010.2m), Rhododendron lanatum /Rhododendron thomsonii/Prunus cerasoides* (3995.11m), *Rhododendron lanatum/Abies densa/Micromeles thomsonii* (3806.22m), *Rhododendron grande/Abies densa/ Rhododendron lanatum* (3675.2m), *Abies densa/ Rhododendron falconeri/Betula alnoides/ Rhododendron barbatum* (3367.7m), and below 3367.7m, mixed broad leaves forests.
- Woody species diversity, tree species richness and species evenness was quantified in respective study sites along 2600-4010 m. Negative correlation (r= -0.790; $p<0.05$) was obtained between woody species richness and altitude (Fig. 11).
- Observations were also made on pheasants' availability, abundance, encounter rates and their habitat interaction pattern. Significant positive correlation (r=1.000; $p< 0.01$) was found between the encounter rate of Blood Pheasants and their average altitudes of availability in sub-transects, as well as perfect significant negative correlation (r=-1.000; $p< 0.01$) was observed between the frequency of Blood Pheasants and species richness during summer season.

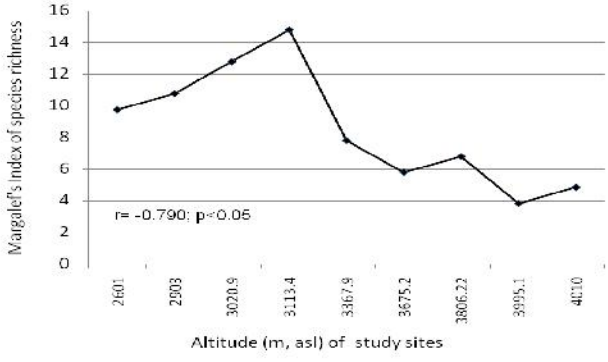


Fig. 11. Woody species richness and altitudes of study sites in Yuksom-Mt Black Kabur transect in Khangchendzonga Biosphere Reserve (west Sikkim)

West Kameng, Arunachal Pradesh

- Phytosociological survey was conducted in (Pine Grove) Lyango Forest of Ziro area in Lower Subansiri District of Arunachal Pradesh by using the standard ecological methods. Total 9 sites were sampled in different altitude, aspects, slopes and habitats and 31 species were recorded. The sites were represented by Shady, Moist, Riverine and Dry habitats (Table 6). Among the sites, species richness ranged from 9-15. Among habitats, the species richness ranged from 9-24, and found maximum (24) in Shady habitat, followed by 19 in Dry habitat.
- Among habitats, the Density (Ind ha^{-1}) ranged from 6.60-12.70, found maximum 12.70 Ind ha^{-1} in Dry habitat, followed by 9.20 Ind ha^{-1} in Shady habitat. Species Diversity (H') ranged from -1.94 to -2.60 and found maximum -2.60 in Shady habitat, followed by-2.32 in Riverine habitat.
- Total 9 communities were delineated from the forest area. Amongst communities, the species richness ranged from 9-15; density (Ind ha^{-1}) 520-1520 and Species Diversity (H') 1.28 to 2.43.

Table 6. Site and habitat characteristics of the Lyango Forest of Ziro area in Lower Subansiri District of Arunachal Pradesh

Site	Habitat Type	Altitude (m)	Location	Aspect	Slope (°)	Boulder %	Dominant Species
1	Shady	1734	N 27°37'36.5", E 93°51'28.4"	NW	40	2	*Santi, Michelia champaca, Angiopteris evecta, Teby*
2	Moist	1714	N 27°37'35.6", E 93°51'25.4"	NW	15	2	*Saari, Michelia champaca, Angiopteris evecta, Quercus floribunda*
3	Shady	1659	N 27°37'36.6", E 93°51'21.7"	N	30	2	*Santi, Angiopteris evecta, Rihing, Michelia champaca*
4	Riverine	1650	N 27°37'36.1", E 93°51'16.6"	SW	15	20	*Tanyi, Michelia champaca, Santi, Teby*
5	Dry	1666	N 27°37'35.2", E 93°51'14.1"	SW	10	20	*Tanyi, Michelia champaca, Tako, Quercus floribunda*
6	Shady	1685	N 27°37'34.2", E 93°51'8.5"	NW	40	10	*Rihing, Tanyi, Quercus floribunda, Quercus semecarpifolia*
7	Shady	1636	N 27°37'34.7", E 93°51'8.3"	SE	30	15	*Tanyi, Rihing, Quercus floribunda, Michelia champaca*
8	Riverine	1639	N 27°37'33.1", E 93°51'6.4"	SW	20	10	*Quercus griffithii, Rihing, Michelia champaca, Saari*
9	Dry	1609	N 27°37'13.8", E 93°51'58.6"	SE	15	5	*Pinus wallichiana, Quercus floribunda, Rihing, Quercus semecarpifolia*

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 (2012-15, Sainj Hydro-Electric Project, Himachal Pradesh Power Corporation Ltd., Himachal Pradesh)

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. have created a tremendous pressure on the biodiversity in the IHR. This has resulted in decreased population of many ecologically and economically important species. A large number of Hydro-Electric Projects have been constructed, 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 Sainj Valley. It is located in the periphery of Great Himalayan National Park. The adjacent areas towards the Great Himalayan National Park (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 GHNP in particular and flora and fauna of the local area in general is urgently required.

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, 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

- 417 species of vascular plants belonging to 86 families and 228 genera, and representing herbs (276 spp.), shrubs (85 spp.), trees (43 spp.) and ferns (13 spp.) were recorded from Sainj Valley. Families, Asteraceae (28 spp.), Lamiaceae (19 spp.), Rosaceae (13 spp.), Poaceae (08 spp.) and Urticaceae (06 spp.) were species rich. Amongst genera, Polygonum (04 spp.) and *Anaphalis, Cornus, Jasminum Rhamnus, Rubus, Asplenium and Pteris* (03 spp. each), respectively represented the maximum species.
- 229 species were identified as medicinal, 68 wild edibles/food, 71 fodder, 51 fuel, 16 religious, 8 fibre, 9 making agricultural tools, 10 timber, 8 dye yielding and 12 miscellaneous purposes.

- 49 sites representing different aspects and habitats between 1,510– 3,820 m were surveyed and sampled for the quantitative assessment of floristic diversity. 32 forest tree communities were recorded. Maximum sites (06) were represented by *Pinus wallichiana* community, followed by *Quercus semecarpifolia* (04 sites), *Abies pindrow, Cedrus deodara, Hippophae salicifolia and Prunus cornuta* (03sites each) and *Corylus jacquemontii-Juglans regia* mixed (02sites) communities.
- The total tree density ranged from 190.00- 840.00 Ind ha^{-1}; total basal area 3.08-124.28 m^2 ha^{-1} Maximum total tree density recorded in *Quercus semecarpifolia-Picea smithiana* mixed (840.00 Ind ha^{-1}) community, followed by *Taxus baccata* subsp. *wallichiana* (780.00 Ind ha^{-1}) community. Total basal area (124.24 m^2 ha^{-1}) was recorded maximum in *Quercus semecarpifolia* community, followed by *Cedrus deodara* (81.67 m^2 ha^{-1}) community. Total saplings density ranged from 60.00-370.00 Ind ha^{-1} and total seedlings density 60.00-610.00 Ind ha^{-1}.
- Species richness (145 spp.) was maximum in *Quercus semecarpifolia* community; followed by *Fraxinus micrantha-Juglans regia-Hippophae salicifolia* mixed (110 spp.) community. It was lowest in *Rhododendron campanulatum-Rhododendron anthopogon* mixed community (16 spp.). The richness of trees was highest in *Prunus cornuta, Quercus semecarpifolia,* and *Cornus macrophylla-Pinus wallichiana-Betula alnoides* mixed (9 spp., each) communities, followed by *Fraxinus micrantha-Juglans regia-Hippophae salicifolia* mixed and *Quercus semecarpifolia-Rhododendron arboreum-Acer caesium* mixed (8 spp., each) communities.

Population Assessment, Standardization of propagation protocols and Establishment *(ex situ and in situ)* of Selected Species as a part of Biodiversity Conservation Plan under Sainj Hydro Electric Project in Himachal Pradesh (2012-15, Sainj Hydro-Electric Project, Himachal Pradesh Power Corporation Ltd., Sarabai, Kullu)

The IHR with its unique topography, diverse habitats and varied altitudinal range (200-8000 m) supports representative, natural, unique and socio-economically important floristic diversity. The high anthropogenic pressures coupled with changing environmental conditions have resulted in rapid depletion of economically important species in the region. In addition, a large number of Hydro-Electric Projects have been constructed, under construction and proposed for construction on the rivers originating from the Himalaya. The Sainj Hydro-Electric Project (100 MW) is under construction in Sainj river. Due to construction of dam, roads, etc. the habitats of some of the economically important species have been destructed. Considering the high rate of habit degradation and population depletion of economically important species in their natural habitats, it becomes essential to adopt *in situ* and *ex situ* conservation measures. Therefore, the present study has been initiated for the population assessment, standardization of propagation protocols, promoting mass multiplication, hardening and *in situ* and *ex situ* conservation of seedlings and plantlets of *Desmodium gangeticum, Delphinium denudatum* and *Polygonatum verticillatum.*

Objectives

- To assess the populations of *Desmodium gangeticum, Delphinium denudatum and Polygonatum verticillatum*
- To develop conventional and *in vitro* propagation protocols of *Desmodium gangeticum*, *Delphinium denudatum, Polygonatum verticillatum* and monitoring their responses in different experimental conditions
- To promote mass multiplication, hardening and establish the seedlings and plantlets of *Desmodium gangeticum, Delphinium denudatum, Polygonatum verticillatum* in ex situ and in situ conditions
- To create awareness among the inhabitants for conservation and harnessing the benefits of *Desmodium gangeticum, Delphinium denudatum, Polygonatum verticillatum*

Achievements

- Review of literature for the selected species was done. Populations of the selected species were identified. Four sites containing populations of *Polygonatum verticillatum* were sampled using quardrat method between 2,046– 2,200 m in the surrounding areas of Sainj Hydro-Electric Project in Sainj valley. The moisture content of these sites ranged from 19.92-31.24%.
- Amongst the *Polygonatum verticillatum* populations, the total trees density ranged from 127-190 Ind ha^{-1}; total shrubs density, 1090-1690 Ind ha^{-1} and total herb density, 38.15-54Ind m^{-2} and relative density (%) of *Polygonatum verticillatum* was 1.38-7.99%.
- Concentration of dominance (Cd) of trees ranged from 0.30-0.69; shrubs 0.06-0.08 and herbs 0.05-0.07, and species diversity (H') for trees ranged

from 0.48-1.27; shrubs 2.68-2.82 and herbs 2.99-3.19.

- Young plantlets of *Polygonatum verticillatum* along with tubers were collected from four populations and planted in herbal garden at Mohal.

Mapping Community Perceptions on Climate Change and Vulnerability Assessment for Biodiversity and Natural Ecosystems in the Selected Sites of Kullu District, Himachal Pradesh (2014-15, Swiss Development and Cooperation, New Delhi)

The community living in mountain ecosystems in the developing world is particularly vulnerable to climate change as a result of their high dependence on natural resources for their livelihoods, comparatively higher exposure to extreme events, and widespread poverty and marginalization. Already there is evidence of change related to global warming in mountain areas, for example, temperatures rising at disproportionately higher rates at higher altitude, changing precipitation patterns, glacier recession, and the thawing of permafrost, with mountain areas becoming relative 'hotspots' of climate change. These changes have potentially serious consequences for mountain ecosystems and people, as well as for the areas downstream. However, little is known about the impacts of climate change on the livelihoods of mountain communities, their perception of these changes, or their capacity to adapt to climatic variability and change. The biodiversity is facing tremendous pressures due to various anthropogenic activities, natural calamities and changing environmental conditions. Therefore, mapping community perceptions and vulnerability assessment of biodiversity are essential for developing analytical framework and methodology for assessing environmental and socio-economic changes affecting the livelihoods of rural, natural resource dependent communities living in mountainous environment. It will also provide guidelines for the better understanding of driving forces which shape mountain communities' vulnerabilities, and places a special focus on the capacities inherent to these communities for coping with and adapting to environmental and socioeconomic changes.

Objectives

- To map community perceptions on hazard risks and climate change adaptations
- To assess vulnerability of biodiversity and natural ecosystems

Achievements

- Four representative sites (i.e., Parbati Valley, Upper Beas Catchment- above Manali, Great Himalayan National Park (GHNP), and Seraj Valley- Anni watershed) in Kullu district, Himachal Pradesh have been selected for mapping community perceptions and vulnerability assessment of biodiversity and natural ecosystems.
- For the Community Perception study, a standard questionnaire containing information on the name of village, respondents of the family members, their education, occupation-income, migration, agriculture and horticulture, vegetables, communication means, soil-types, energy sources, land use patterns, irrigation, hazard managements, biodiversity, tourism, factors affecting their common livelihoods, etc. were developed. In each site, representative panchayats/villages have been selected along the topographical gradient. In Parbati valley 24 panchayats were selected and in each selected village, about 30% households were surveyed and analyzed for various parameters.
- Total 627 species of representing 86 trees, 105 shrubs, 327 herbs and 9 ferns were recorded from GHNP (252 spp.) and Parbati Valley (375 spp.). Total 62 sites (42 in Parbati Valley & 20 in GHNP) were sampled for the quantitative assessment of vegetation. 15 communities representing 7 aspects and 6 habitats from GHNP and 14 communities representing 6 aspects and 4 habitats from Parbati valley were delineated.
- In GHNP, total tree density ranged from 250 – 500 Ind ha^{-1} and Total Basal Area 32.05 – 124.30 m^2 ha^{-1}, total shrub 300 – 830 Ind ha^{-1}; total herb density 13.55 – 35.90 Ind/m^2; Species diversity (H') 0.00-0.46 and Concentration of Dominance (Cd) 0.83 – 1.00. In Parbati valley, total tree density ranged from 270 – 530 Ind ha^{-1}, Total Basal Area 44.33 – 136.27 m^2 ha^{-1}, total shrub density 670 – 1000 Ind ha^{-1}, total herb density 9.90 – 23.70 Ind/m^2; Species diversity (H') 0.13 – 0.68 and Concentration of Dominance (Cd) 0.71 – 0.94).

Assessment and Quantification of Forest Ecosystem Services with Special Emphasis on pollination in the Indian Himalayan Agro-Ecosystems (2012-15, Earth Watch Institute, India)

The Himalayan region is one of the 34 Global Biodiversity hotspots. The IHR forms a major part of this hotspot. The region represents tropical, sub-tropical, temperate, sub-alpine, alpine and Tundra ecosystems/biomes. These ecosystems provide provisioning (e.g., fresh water, NTFPs and timber), cultural (e.g., recreation and spiritual), regulating (e.g., carbon sequestration, hydrological) and supporting (e.g., biodiversity, nutrient cycling, pollination)

services to the 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

- Qualitative assessment of the vegetation was carried in 10 locations and among 20 sampled plots in upper Beas valley; also assessment of bee flora in the selected orchards and surrounding areas was done. Total 176 species of plants representing trees, shrubs and herbs including ferns were recorded. Out of which, 62 were found to be bee/pollinators resources based on the visitation of bees/pollinators on the flowers of these plants.
- Amongst the tree communities, total tree density ranged from 5.29 *(P. wallichiana)* - 8.41 *(C. deodara)* (ind/100 m^2) and total basal area 32.67 (P. roxburghii) – 62.37 *(C. deodara-P. smithiana mixed)* m^2ha^{-1}, total shrub density ranged from 6.34 - 24.6 ind/100 m^2 and total herb density among ranged from 30.68 - 69.63 Ind m^{-2}. The soil samples (25 Nos.) collected from the sampled sites were analyzed for pH, EC, moisture content, organic carbon & nitrogen. The pH ranged from 5.12-6.32, moisture content 4.30-31.29%, organic carbon 0.27-4.73% & nitrogen 0.09-1.19%.
- Insect/pollinators diversity was enumerated through scan sampling around the apple orchards in each season. Total 8 groups of pollinators i.e., European bee, Indian bee, syrphids, bumble bees, drone flies, blue bottle flies, butter flies, other wild bees, etc. were found. Maximum diversity was found in Nashala & Raugi orchards during apple flowering. Pollinator density was recorded as insect visitation per 100 flowers. Amongst sites, maximum density of bees was found in Bashkola followed by Dhamadhar, Raugi, Nashala, Mehliseri, Hirni & Karadsu. For the assessment of preferential floral species of insects, plants in the flowering stage were selected at different orchards & then were observed for 15 minutes for the insect visitations.
- Phenological observations were recorded on leaf fall, leaf bud initiation, flower bud initiation and leaf initiation and pink flower bud initiation, flower opening, fruit setting and fruit maturation in the marked Apple, Plum and Pear trees of the six selected orchards of the upper Beas Valley.
- The Participatory Rural Appraisal exercise and questionnaire survey was conducted in seven villages to generate information on the ecosystem services (regarding medicinal plants, wild edibles, fodder, fuel and timber plants, plants used for making agriculture tools, regarding horticultural and agricultural crops, vegetables and condiments grown, fiber plants etc.) flowing from forest and agro ecosystem to the inhabitants of the villages.

Headquarters

- Phytosociological study was carried out in the same plots which were taken for forest carbon sequestration and forest biomass estimation and a total of 38 quadrates were laid. All data were analyzed for different phytosociological attributes. The species richness and biodiversity values were recorded higher in Oak forests than Pine forests. Species evenness and biodiversity index values were higher in Oak forests than Pine forests. Species richness was recorded maximum in the herb layer of Oak forests (12.32) and minimum in the shrub layer of Pine forests (3.0). The mean cbh value in oak forests is 48.32±1.39 and 41.34±2.05 in Pine forests. The average tree layer density was recorded 568±1.45 Ind/ha in Oak forests and 280±2.29 Ind/ha in Pine forests. Shrub layer average density in the Oak forests was recorded 54 Ind/ha and in the Pine forests 44 Ind/ha.
- In Almora site, similar exercise was carried out for mustard and cucurbits. Bees were found major visitor of cucurbits and on the basis of insect visiting per 100 flowers, pollinator density of bees, Bumble bees and other wild bees were found significantly ($p < 0.05$) higher in Dhari. The possible reason for maximum density at Dhari could be the presence of bee boxes. Total 7 types of insects (i.e,. bee, bumble bee, other wild bee, ant,

beetle, houseflies and wasp) were found. The maximum diversity was found in Bimola site and minimum in Mahatgaun. Pollinator density was recorded as insect visitation per 100 flowers. Among all the sites, density of bees was found significantly ($p < 0.05$) higher in Dhari. The possible reason of higher pollinator density in Dhari site could be the non-availability of other blooming foraging resources in the nearby region and the mustard was only source of foraging resources during the time of its flowering, while in other sites, there were so many weeds as foraging resource at the time of flowering of mustard that might have diverted the bees and other pollinators.

- In Almora site, plant-insect interaction inventory was made to assess the most preferred foraging resources for all the insects which used to visit on the selected crops. Number of bees increased significantly ($p < 0.05$) with the number of plants per quadrat and number of wild bees increased significantly ($p < 0.05$) with the number of open flowers. Among the different sites, houseflies found significantly ($p < 0.05$) higher in Sheetlakhet. The reason might be houseflies preferred an altitudinal range of 2000-2500 m amsl. Among the three different colour bowls (Blue, White and Yellow), total 30 bowls (10 bowls of each colour) were placed in each site. The different insect groups were shown specific colour preferences in bowl trap and among the three different colours, butterflies showed significantly ($p < 0.05$) higher preference for yellow bowls.
- 115 species of bee forage were recorded throughout the year from the Kosi-watershed. Maximum flora was recorded in summer (April - 70) and minimum in winter (December - 23). Most of the insect supporting forage species (14 species) were found in wasteland, field margins on the hedge (12 species) and adjacent forest (12 species). Out of 87, 52 specimens belonged to Hymenopteran group, which consisted of 40 species of bees and 12 species of wasps. 11 specimens were belonged to Dipteran group, which consisted of 7 species of hoverflies and 4 species of syrphides and 24 specimens belonged to Lepidopteron group in which 20 species were butterflies and 4 species moths. 47 specimens were identified. Total 25 bees were identified up to the family level. 2 Dipterans and 20 Lepidopteron group were identified

Sikkim Unit

- For the insect pollinator assessment Scan/Visual Sampling, Sweep net sampling and Bowl trap methods were followed. Proportionate density of pollinators per 100 flowers of large cardamom and variations across sites (i.e. S 1: within village boundary; S2: under forest canopy; and S3: close to natural forest).
- Abundance of bumble-bee per 100 flowers of large cardamom and variations across sites (i.e. S 1: within village boundary; S2: under forest canopy; and S3: close to natural forest) was observed significantly ($p<0.01$) for the year 2014. The highest frequency observed in S3 (i.e. 23 bumble bee/100 flowers) as compared to S1 (i.e. 15 bumble bee/100 flowers) and S2 (i.e. 13 bumble bee/100 flowers)
- Abundance of honeybee per 100 flowers of large cardamom and variation across time-frames (T1: 22-31 May, T2: 1-10 June; T3: 11-20 June; T4: 21-30 June) was observed significantly ($p<0.01$) for the year 2014. The highest frequency observed in between 1-10 June (i.e. 8 honey bees/100 flowers) as compared to T1: 22-31 May (i.e. 7 honey bees/100 flowers), and T3 and T4 (i.e. 3 honey bees/100 flowers).
- Impact of pollinator density on yield of large cardamom crop: Increasing density of bumble-bee (Bombus sp.) resulted in significantly ($r=0.352$; $p <0.05$) higher yield of the crop. Increasing density of all bees lead to significant ($r = 0.324$; $p<0.05$) increase in crop yield.
- For estimating the foraging resources within the large cardamom plantation, among the different foraging plants (herbs and shrubs), *Cestrum fasciculatum* species observed the best foraging plant (i.e. 20 bumble bees/100 flowers of *C. fasciculatum*) across the year.
- Farmers interaction meeting was organized at Mamlay watershed-Sikkim (South) on 21 October 20014 and total 50 participants were participated. The major focus of the event was to discuss the local issues and priority actions as: promotion of vermi-compost and bio pesticides, reassessment of the watershed, assessment of diseases and pest of crops at seasonal level, encouraged crop rotation, provided disease free seedlings of large cardamom, publicity of organic products, awareness on ecosystem services and sustainable use of natural resources, promote flowering plants around the agricultural farm, and develop the skill of youth and connect with ecotourism.

Assessment of Ecosystem Services in Sacred Groves of Himachal Pradesh, North Western Himalaya (2012-17, MoEF&CC, New Delhi)

The IHR which form major part of the Global Biodiversity Hotspots represents 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 in the form of Biosphere Reserves, National Parks and Wildlife Sanctuaries has been established across the IHR. In addition, the native communities of the region practice an age old tradition of conserving trees and forests near their settlements and alpine meadows as part of their culture and religious belief. These are known as Sacred Groves. They believe that their deities live inside these sacred groves and these deities would be offended if any damage is caused to the plants and animals. Usually Traditional Sacred Groves (Forests) and Temple Groves are found in the region. Of the 13,270 sacred groves documented from India, 5,627 sacred groves are known from the IHR. The state Himachal Pradesh, also known as "Deobhumi" supports about 5,000 Sacred Groves. But, these Sacred Groves have not been explored for the various ecosystem services provided by them. Therefore, present study has been initiated on this line.

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 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 33 sites were sampled for floristic diversity. Of these, 21 sites were undisturbed and 12 disturbe. Maximum sites (10) were represented by Shady moist habitat, followed by Dry (7), Moist (6), Shady (5), Bouldary (4) and Riverine (1). Ten (10) sites were represented in North East aspect, 06 in East, 05 in North West, 04 in South & North, 03 in South East, and 01 in South West aspects. The slope varied from 10-60.
- Total 229 species of vascular plants belonging to 89 families and 175 genera were recorded. Of these, from Jamdagni Rishi Sacred Grove 62 species, Sangchul Rishi Sacred Grove 85 species, Hadimba Devi Sacred Grove 105 species, and Kalinag Sacred Grove 88 species were recorded.
- In Jamdagni Rishi Sacred Grove total 62 species from undisturbed site and 42 species from disturbed site were recorded. The total tree density in undisturbed site ranged from 320 – 940 Ind ha-1 and Total Basal Area, 18.24 – 51.57 m2 ha^{-1} and in disturbed site, total tree density ranged from 130 – 290 Ind ha^{-1} and Total Basal Area, 3.52 – 24.03 m^2 ha^{-1}. In Sangchul Rishi Sacred Grove total 85 species from undisturbed site and 79 species from disturbed site were recorded. In undisturbed site, total tree density ranged from 262 – 410 Ind ha^{-1} and Total Basal Area, 9.26 – 24.15 m^2 ha^{-1} and in disturbed site total tree density ranged from 130 - 170 Ind ha^{-1} and Total Basal Area, 1.47 – 1.55 m^2 ha^{-1}.
- In Hadimba Devi Sacred Grove from undisturbed site 105 species and disturbed site 85 species were recorded. In undisturbed site, total tree density ranged from 270 – 330 Ind ha^{-1} and Total Basal Area, 43.01 – 169.89m^2 ha^{-1} and in disturbed site total tree density ranged from 220 – 250 Ind ha^{-1} and Total Basal Area, 37.25 – 151.61 m^2 ha^{-1}. In Kalinag Sacred Grove from undisturbed site 88 species and disturbed site 55 species were recorded. In undisturbed site total tree density ranged from 300 – 430 Ind ha^{-1} and Total Basal Area, 42.29 – 180.80 m^2 $ha^{-1}$and in disturbed site total tree density ranged from 280 - 400 Ind ha^{-1} and Total Basal Area, 32.78 – 38.47 m^2 ha^{-1}.
- Carbon Sequestration was estimated in Bhrigu Rishi and Vasukinag Sacred Groves. 2 undisturbed and 1 disturbed site were sampled in Bhrigu Rishi and Vasukinag Sacred Grove. Both in Bhrigu Rishi and Vasukinag Sacred Grove, the first plot showed highest no. of trees, Total Basal Area, above ground biomass, carbon content (50% AGB), below ground biomass, and Carbon content (50% BGB).The details of above ground biomass, below ground biomass, and carbon content in the forest stand of Bhrigu Rishi and Sangchul Rishi Sacred Groves is presented (Table 7).

Table. 7. The details of above ground biomass, below

ground biomass, and carbon content in the forest stand of Bhrigu Rishi and Vasukinag Sacred Groves

Sacred Grove	Plot No.	No. of trees	Total Basal Area 400 m^2)	Above ground biomass (kg/400 m^2)	Carbon content (50% AGB) (kg/400 m^2)	Below ground biomass (kg/400 m^2)	Carbon content (50% BGB) (kg/400 m^2)
Bhrigu Rishi (UD)	1	17	6.12	79784.88	39892.44	23137.62	11568.81
	2	11	6	28027.44	14013.72	8127.96	4063.98
Bhrigu Rishi (D)	1	8	0.61	7581.46	3790.73	2198.62	1099.31
Vasukinag (UD)	1	15	6.29	42276.88	21138.44	12260.30	6130.15
	2	15	4.64	32056.32	16028.16	9296.33	4648.17
Vasukinag (D)	1	11	3.53	24188.91	12094.45	7014.78	3507.89

Abbreviations used: UD= Undisturbed; and D= Disturbed

Kailash Sacred Landscape Conservation and Development Initiative (2013-16, ICIMOD, Kathmandu)

The Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI) is an attempt on the part of the three neighboring countries to join hands to help preserve the unique biological diversity, the many ecosystem goods and services, and the value-based cultural heritage while developing the livelihoods of the local communities of one of the most revered and sacred transboundary landscapes in the world. The Kailash Sacred Landscape (KSL) spreads over an area of over 31,000 km^2 in remote portions of the Tibet Autonomous Region of China (TAR) and contiguous areas of far west Nepal and north east part of Uttarakhand State in India. At the heart of this landscape is the sacred Mount Kailash, revered by millions of people in Asia and throughout the world. The landscape, however, is environmentally fragile and geopolitically sensitive. The region and its people are highly vulnerable to climate change and environmental degradation, as well as threats associated with ongoing globalization and development processes. Therefore, the project has been initiated to address above issues.

Objectives

- To strengthen transboundary regional cooperation by institutionalizing the elements of the regional cooperation framework
- To establish sustainable ecosystem management approaches and practices at all levels mainstreamed into national policies and plans in the context of climate change adaptation in the KSL
- To build the capacity of key institutions for long-term environmental monitoring and socioeconomic research for better planning and decision making
- To contribute to establishment of a regional knowledge sharing platform to support evidence-based decision making at regional and national level

Achievements

- Towards building collaborative efforts GBPIHED has established formal implementation partnership with Uttarakhand State Biodiversity Board (UKBB) for implementation of activities of project Component 3-Access and Benefit Sharing, Uttarakhand Forest Department (UKFD) towards actions on identified activities of Component 2-Managing Ecosystem for Sustaining Services and Component 4- Long-term Conservation and Environmental monitoring, Himalayan Gram Vikas Samiti (HGVS) for community mobilization and preparation of participatory plans for water conservation and management.
- Following richness, representativeness, uniqueness criteria across physical, biological and social systems, three watersheds, two (i.e. Hat-Kalika, Chandak-Aunlaghat) in the horizontal transect and one (Himkhola-Kharangdang) in the vertical transect have been identified as the pilot sites for the project interventions in the landscape (Fig. 12).
- Through specific emphasis on stakeholder's consultations in the landscape needs and priorities have been assessed and documented. Also, the awareness and information generation campaigns have resulted in agri-biodiversity documentation of the landscape.
- Three concurrent Landscape Yatras (LYs) were organized in the vertical transect have generated extensive information about the landscape and understanding of interfaces and transition of systems and their possible management, livelihood opportunities and challenges.
- Six Biodiversity Management Committees (BMCs) have been developed in collaboration with Uttarakhand Biodiversity Board and process of preparing People's Biodiversity Register has been initiated.
- Showcasing of KSLCDI at Jeoljibi International Trade Fair (November, 14-17, 2014) generated mass awareness about the project and its components both in India and Nepal part of Kailash Sacred Landscape (Fig. 13).

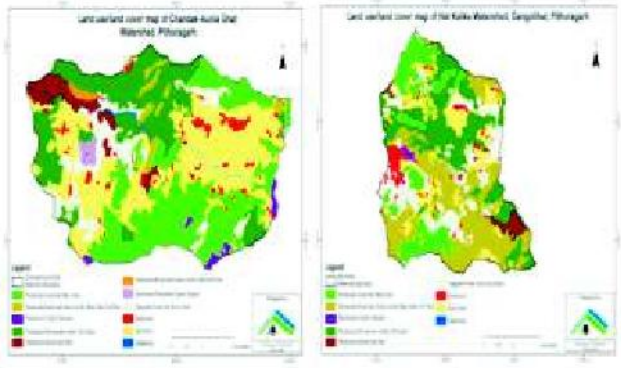


Fig. 12. Maps of the KSLCDI

Fig. 13. Showcasing of KSLCDI

Status Assessment of Endemic Threatened and High Value Medicinal Plants of Cold Desert Areas in Indian Himalayan Region (2013-16, CSIR New Delhi)

Cold Deserts are characterized by extremely low temperature (-45°C) and low rainfall ranging between 500-600 mm annually. In India, the Cold Desert lies in the rain shadow of the main Himalayan range and is usually described as "Trans Himalayan zone". Within Indian limits bulk of the cold desert lies in Ladakh region of Jammu & Kashmir, Lahaul & Spiti, and Kinnaur (Pooh sub division) in Himachal Pradesh and small portions of Uttarkashi (Nelang valley), Chamoli (Mana and beyond, and Niti beyond Malari) and Pithoragarh (Darma, Johar and Vyas) districts in Uttarakhand and in small portion of Sikkim (The Lanchun valley and The Lachen chu valley). The Uttarakhand Cold Desert is represented by the upper parts of Uttarakhand, a unique cold arid ecosystem that has largely escaped the attention of the ecologists, geographers and natural resource managers owing to the remoteness, inaccessibility and harsh climatic conditions. Therefore, the study has been initiated to explore the floristic diversity including endemic and threatened plants of the Uttarakhand Cold Desert.

Objectives

- To survey and document endemic and threatened medicinal plants of Indian Cold desert area
- To analyze and map their distribution pattern
- To evaluate the status of endemism, threatened categories and conservation status
- To build awareness and provide training to local people and relevant stakeholders on identification / importance and conservation needs of endemic, threatened and medicinal plant species

Achievements

- From Johar valley, 104 plants were collected in different altitudinal range 3200m (Burfu) to 3600 m (Milam glacier). Six sites namely, Burfu (3200 m), Belju (3300 m), Milam Bugyal (3400 m), above Milam (3500 m) and Milam glacier (3600 m) were identified for population assessment studies. Of the 104 species, 58 species (55.77%) are medicinal and used in different medicinal system and out of them 13 species (12.5%) are under Threatened categories. The valley is dominated by Asteraceae (13.74%), followed by Rosaceae (10.69%) and Poaceae (6.87%).
- On reviewing the population status of threatened medicinal plants, highest density was observed for *Thymus linearis* (6.7 ind/m^2) and least for *Aconitum heterophyllum* and *Rheum moorcroftianum* (0.1 Ind/m^2). *Danthonia schneideri* (8.50 Ind/m^2) and *Poa alpina* (4.2 Ind/m^2) were the most dominant species in the region.
- From Byans valley, 71 plants were collected in different altitudinal range 3200 m (Gunji) to 4500 m (Jeolinkong). Of the 71 species, 48 species (67.61%) are medicinal and used in different medicinal system and out of them 16 species (22.54%) are under Threatened categories. The dominant families were Rosaceae (14.08 %), followed by Salicaceae, Brassicaceae and Caprifoliaceae (7.04%).
- During population assessment of threatened plants of the region, the highest density was recorded (1.10 ind/m^2) for *Bergenia stracheyi* and least density (0.1 ind/m^2) for *Aconitum heterophyllum.*

Promoting Bioresource Based Livelihood Opportunities for the Tribal Community in Lahaul-Spiti, Cold Desert Area of Trans Himalaya (2012-2015, ICAR; TSP Project)

The Lahaul-Spiti District of Himachal Pradesh is inhabited mostly by Tribal population. It is located in the north eastern part of the State, and is scarcely

populated. Due to remoteness, the area is known as "Forbidden land in the Himalayas". The total Schedule Caste population is 2,605 (7.34 %) and Schedule Tribe 24,238 (72.95 %). The area is under developed and faces many problems due to its remoteness. Therefore, the project has been initiated in Lahaul Spiti district for the development of tribal communities.

Objectives

- To investigate the existing potential of wild edibles and medicinally important plants in the landscape
- To explore possibilities for value addition, through processing and product development of potential wild edibles and plants of medicinal value
- To enable target groups, through awareness and capacity building programmes to harness the economic potential of bio-resources, including wild edibles and medicinal plants

Achievements

- Provided training to Tribal People of Khangsar, Jagla, Phukatal, Jispa and Goshal villages of Lahaul, Himachal Pradesh on "Preparation of different pickles, jam, squash & murabba by using local vegetables, fruits and wild edibles" at Panchayat Bhawan, Khangsar, Lahaul, Himachal Pradesh from 02.11.2014 to 05.11.2014. Mr. Jay Krishna Sharma, MD, Pooja Dhoop Avam Hawan Samigri Udoyag, Bhuntar, Kullu, H.P. was the Resource Person. Total 296 tribal people were trained. Among the participants, 52% (154) were male and 48% (142) female. In Gondhla village, the female participation was high (67%) in comparison to male (33%; Fig. 14).
- Polythene sheet (20x6m) was provided to 44 families for making the polyhouse. These families belong to Gondhla and Jispa (12), Khangsar and Goshal (8) and Jagla (4) villages. Demonstration was given for the construction of polyhouse.

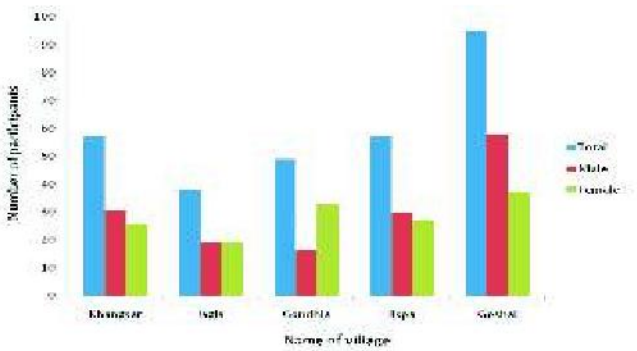


Fig. 14. Village wise participants of the training programmes in Lahaul Valley

Assessment of Molecular and Biochemical Diversity for Conservation and Effective Utilization of *Roscoea spp.* in West Himalaya (2014-2017, DST-YSS)

In terms of setting priorities for conservation, especially with regard to successful reintroduction of the populations in the wild, studies on genetic diversity are being increasingly used. Among various factors, population size and habitat distribution greatly affect the level and distribution of genetic variation. So understanding the genetic consequences of such changes in population structure and their effects on the conservation value are major research challenges. Similarly, analysis of biochemical parameters are most often results in evaluation of genotype – phenotype relationship and in accumulation of useful information for selection of desired combinations in further breeding studies. Realizing such gaps, present study attempts to analyze the extent of diversity in molecular and biochemical attributes and their association in two selected high value endemic medicinal plants i.e., *Roscoea procera and R. alpina* in the Himalayan region.

Objectives

- To understand patterns of morphological, genetic and biochemical variability within and among populations of selected species
- To determine the level of polymorphism within and among populations and between species using different molecular markers
- To establish association of different molecular markers with morphological and biochemical traits
- To develop detailed conservation and sustainable utilization plan of the species

Achievements

- The total phenolic content in rhizomes among populations varied significantly ($p<0.01$) ranging from 2.11 mg (Ranikhet) to 3.56 mg GAE/ g dw (Mussoorie-II). While analyzing the phenolic content in different forest types, populations growing under oak-mix forest (2.98 mg GAE/g dw) and open grassy land (2.99 mg GAE/g dw) showed comparatively higher total phenolic content than oak and pine forests. Moreover, population with West (3.51 mg GAE/g dw) and South-East (3.30 mg GAE/g dw) sun-facing aspects contained higher phenolic level.
- Among 7 studied compounds, gallic acid exhibited highest level (72.02 mg/100 g dw), followed by catechin (12.05 mg/100 g dw) and p-coumaric acid (0.138 mg/100 g dw). Gallic acid ranging from 37.01 mg (Buranshkhanda) to 100.81mg /100 g dw (Ranikhet) was the major phenolic acid detected in

the rhizome of *R. procera.* The catechin content ranged from 6.50 mg ((Majkhali) to 25.50 mg/100 g dw (Mussoorie-I). On the other hand p-coumaric acid was detected only in few populations (0.52 mg to 0.95 mg/100 g dw) of *R. procera*. Among the forest types, gallic acid was found higher levels in oak mix forest (86.01 mg/g dw).

- Antioxidant capacity in the methanolic extract of *R. procera* measured by three *in vitro* antioxidant assays, i.e. ABTS, DPPH and FRAP assay showed significant variation ($p<0.01$) among the populations (Fig. 15). The activity in ABTS radical scavenging assay ranged from 1.26 mM (Dol) to 1.69 mM AAE/100 g dw (Surkanda) with the mean of 1.47 mM AAE /100 g dw. The DPPH scavenging assay showed significant ($p<0.01$) variation among populations ranging between 0.65 mM (Nainital) to 0.87 mM AAE/100 g dw (Choubatia) with an average of 0.75 mM AAE/100 g dw Similarly, using the FRAP assay, the value ranged from 0.78 mM (Nainital) to 1.29 mM AAE/ 100 g dw (Manjkhali) with an average of 1.01 mM AAE/100 g dw.

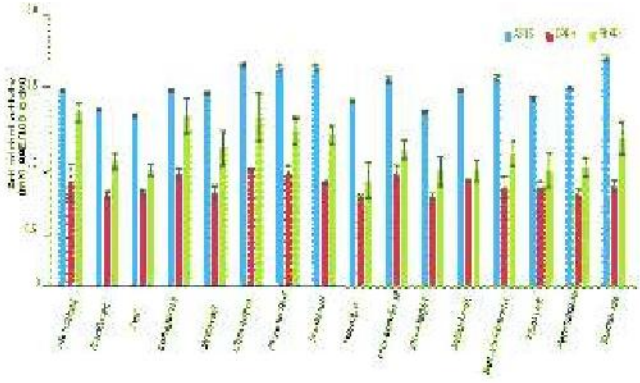


Fig.15. Antioxidant activity analyzed in 16 different populations of *R. procera* using 3 different *in vitro assays*

Creating a Genomics Platform for Apple Research in India (2010-15, DBT New Delhi)

Apple is one of the major cash crops of the North Western and Western Himalaya. The identification of germplasm, phenotyping of the cultivars, generation of passport data, clonal propagation of cultivars, mapping populations and exchange of material of apple in these biogeographic provinces have not been carried out so far. Therefore, multi-Institutional project has been initiated which involved CCMB, Hyderabad, University of Jammu, Jammu, University of Kashmir, Srinagar, Dr. Y. S. P. Univ. of Horticulture and Forestry, Solan, and GBPIHED, Kosi-Katarmal, Almora to address the above issues.

Objectives

- To identify the germplasm and phenotyping of cultivars in Uttarakhand
- To generate passport data and its transmission to Jammu
- To establish clonal propagation and maintain mapping population
- To exchange the material with Kashmir University and Y.S. Parmar University

Achievements

- Extensive survey were conducted in Almora, Nainital, Pauri, Tehri, Uttarkashi, Pithoragarh and Chamoli district of Uttarakhand. A total of 62 apple cultivars were collected and identified.
- For the generation of passport data, photo-documentation of 50 genotypes has been completed and 12 genotypes are under progress.
- 79 cultivars of apple collected from Utttarkhand, Jammu and Kashmir and Himachal Pradesh has been planted at two different sites as National Apple Germplasm Repository viz., Government Inter College, Majkhali and Suryakunj, GBPIHED, Almora.
- Leaf sample of 62 genotypes identified in different locations of Uttarakhand has been sent to Jammu University and CCMB, Hyderabad. Exchange of apple cultivars scions with Y. S. Parmar University, Solan (H.P.) & Kashmir University has also been undertaken.

Impact of Anthropogenic and Climate Induced Perturbations on Regeneration Potential of Oak forests in Kumaun Himalaya (2014-19, DST-INSPIRE)

Oaks (*Quercus spp.*) are among the dominant broad leaved forests of Himalaya, ranging from the sub-tropical to the sub-alpine zones. In Kumaun, west Himalaya the oak forests are extensively distributed between 1000 - 3600 m. These forests are known as the common source of fodder, leaf litter, firewood and timber. Therefore, their occurrence is affected by human interventions. Among human influence, commercial exploitation, agricultural requirements, forest fire, and grazing pressure are the important sources of disturbance. In many of the ecosystems, problems with oak regeneration exist and it adversely affects various complex stages of regeneration like acorn production and germination, seedling establishment and

development, and ultimately recruitment patterns. Interest in Oak (*Quercus spp.*) regeneration has prompted the implementation of a large number of research studies over the last several decades. The present study is an attempt to furnish information that deals with the overview of regeneration pattern in oak forests around Nainital in Kumaun, western Himalaya and also considers the role of anthropogenic factors in changing the forest composition and patterns of species distribution as with the increasing biotic stress, the oak forests have been depleted rapidly in recent.

Objectives

- To assess species diversity, composition and population structure of four representative oak species forests.
- To investigate recruitment patterns in selected forests across disturbance intensities and along climate range.
- To understand germination responses of selected oak species in laboratory and nursery conditions.
- To detect change in diversity and recruitment trends through comparison of data sets with earlier reports (2- 3 decade old).
- To suggest strategies for management of diverse oaks based on the study outcomes.

Achievements

- The literature review conducted reveals that *Quercus leucotrichophora* is regenerating fairly in mixed and moderately disturbed forests otherwise shows low regeneration in its own forests when disturbance is severe and may be degenerating on account of increasing biotic pressure.
- The study provides quantitative information of five different forest types of Kumaun Himalaya (Fig. 16). The tree density ranged from 325-2534 ind ha^{-1}, sapling density 258.33-1733.17 ind ha^{-1}, seedling density in summer 1066.67-3591.83 ind ha^{-1}, seedling density in rainy from 1225-3765.25 ind ha^{-1}, seedling density in winter 683.33-2575 ind ha^{-1}, total basal area 25.29- 109.37 m^2 ha^{-1} and shrub density 700-5149.92 ind ha^{-1}.
- *Quercus leucotrichophora* forest reflects improved regeneration over the last three decades. The study suggests that if the biotic stress and natural disturbances are minimum, the rapid regeneration of *Quercus* spp. would be possible.

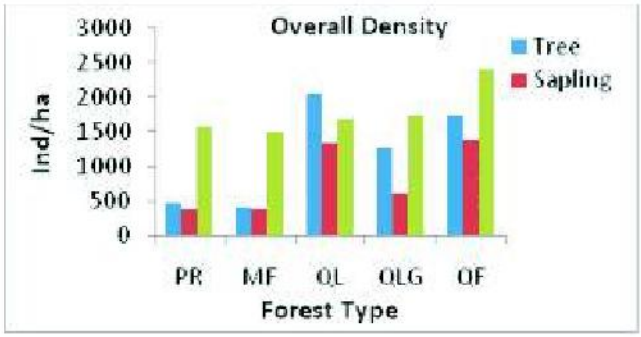


Fig. 16. Overall tree, sapling and seedling density in *Pinus roxburghii* (PR), Mixed oak (MF), *Quercus leucotrichophora* (QL), *Quercus lanuginosa* (QLG) and *Quercus floribunda* (QF) forest of Kumaun region

Augmenting Lead Botanical Garden at G.B. Pant Institute of Himalayan Environment & Development for *Ex-Situ* Conservation And Knowledge Dissemination on Threatened And Endemic Plants Of Central Himalayan Region - Phase II (2013-16, MoEF&CC, New Delhi)

Large numbers of plant species are facing threat of extinction due to habitat destruction and anthropogenic pressure. Hence, conservation of plant diversity assumes greater importance. Recognizing the scope and potential of 'Suryakunj', the Ministry of Environment and Forest, GoI, in 2008 identified it as a lead garden for *ex situ* conservation and knowledge dissemination on representative threatened and endemic (T&E) plants of Western Himalaya. The garden has emerged as a strong onsite training and demonstration center, which houses a number of threatened and endemic species. Surya-Kunj plays a very crucial role as centre for rescue; recovery and rehabilitation of threatened and endemic plants and valuable plant genetic resources. It also serves as medium for spreading conservation, education and awareness.

Objectives

- To conduct researches for understanding bottlenecks to propagate, multiply and rehabilitate selected threatened and Endemic (T & E) species of Western Himalaya
- To develop technology packages for propagation, multiplication and rehabilitation of selected T & E species
- To develop knowledge products including factsheets, field manual for identified T & E species
- To build capacity of diverse stakeholders in *ex situ* conservation, rehabilitation and recovery programmes

- To develop material for environmental awareness, lectures/ workshops with respect to *ex situ* conservation, etc.

Achievements

- Twenty five accessions were added in the Lead Botanical Garden. The accession numbers given to six species are *Polygonatum cirrhifolium* (GBP 3204), *Malaxis muscifera* (GBP 3205), *Meizotropis pellita* (GBP 3206), *Quercus lanuginosa* (GBP 2512), *Castanopsis tribuloides* (GBP 2511) and *Mahonia jaunsarensis* (GBP 3901). 19 species are yet to be identified.
- Seed germination protocol for *Meizotropis pellita*, an endemic plant was developed under different growth environments and 95% germination was achieved in glasshouse condition. This value was higher than control where only 50% germination was recorded (Fig. 17).
- Infrastructure, cafeteria with dinning and kitchen facility to NILC was developed. Research equipments and interactive learning and presentation system were procured and installed.

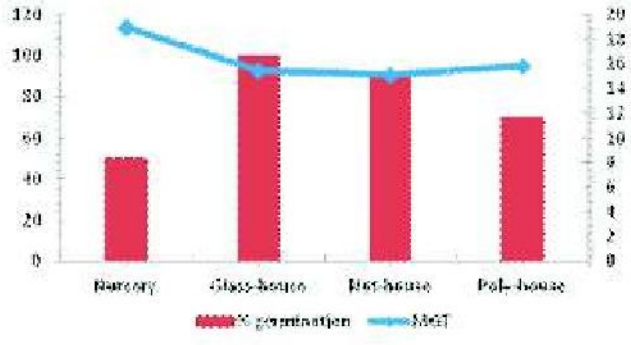


Fig. 17. Effect of different growing conditions on the germination behavior and mean germination time of *Meizotropis pellita*

Inventorization and Monitoring of Biosphere Reserves in India using Remote Sensing and Geographical Information System Technology (2010-14, MoEF&CC, New Delhi)

The Biosphere Reserves (BRs) are internationally designated landscape/seascape units under UNESCO's flagship Man and the Biosphere (MAB) Programme for building harmonious relationship between human activities and ecosystem conservation. They are representative of characteristic ecosystems in a biogeographic region and consider human communities as an integral component. The BRs aim; a) ensuring *in situ* conservation at all levels of biodiversity ranging from genes to ecosystems in totality as part of wider ecosystem; b) widening the understanding through research and monitoring of components of ecosystems; and c) achieving integrated development (improved quality of life for indigenous communities living in and around) of the area. In order to cover a wide representation of characteristic ecosystems from diverse biogeographic zones/provinces in the country, the Ministry of Environment & Forest (MoEF), GOI, has till date established 19 BRs and nearly 10 sites have been proposed as potential BRs. 7 BRs (i.e., Nilgiri, Sunderbans, Gulf of Mannar, Nanda Devi, Nokrek, Simlipal, Pachmarhi) have been included in WNBR. Through analysis of BR designation in the country, it is revealing that over the years India has responded proactively towards increasing BR network (number and coverage area) in the country. In view of the importance of BRs, studies using RS/GIS and adequate management plans are essentially required.

Objectives

- To create Natural Resources (Land use/ cover, water, soil, slope, etc.) and social database using latest RS images of existing BRs in India with a focus on preparing Land use land cover maps
- To study the temporal changes in land use dynamics (at 5 year interval starting from 1990 or date of notification) as an impact of BR management
- To make recommendations, based on outcomes of objectives, for effective management of BRs focusing on redefining zones/boundaries
- To develop and test RS/GIS based approaches for assessment and valuation of ecosystem services in a selected BR of the Himalayan region

Achievements

- Mapping of Cold Desert Biosphere Reserve in Himachal Pradesh has been completed and GIS database has been created. The Land Use Land Cover of CDBR (Fig.29) classified total area into 10 classes. Each and every class was identified on the basis of signature and ground truthing.
- The LULC map shows that in CDBR, vegetation covers only an area of about 247.3 km^2 (3.19%) and all non-vegetation classes cover 7522.67 km^2 (96.81%) area, out of which largest portion of land (78.16%) is rocky and barren due to almost complete sequence of exposed sediments from the Pre-Cambrian era to the Cretaceous period (Fig. 18).
- Land use/land cover mapping of 1990 and 2005 for Nanda Devi Biosphere Reserve has been completed and GIS layers for BR has been completed.

- Landscape analysis, along the time series of Dibru-Saikhova Island in the Dibri-Saikhova Biosphere Reserve was done for policy inputs.

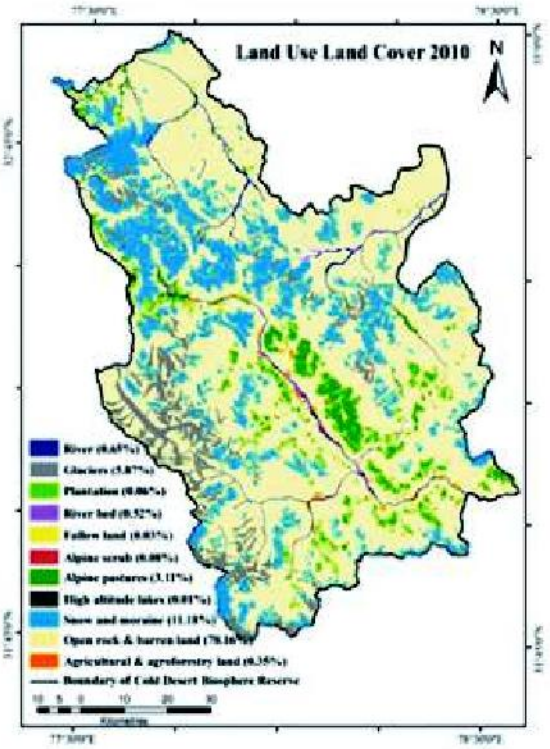


Fig. 18. Land use and land cover map of Cold Desert Biosphere Reserve

NMSHE Task Force (3): Forest Resource And Plant Biodiversity (2014-2019; Department of Science and Technology, Govt. of India)

The National Action Plan on Climate Change (NAPCC), which includes a comprehensive set of mitigation and adaptation measures, aims to promote India's development objectives while yielding co-benefits for addressing climate change effectively. The NAPCC, among others, recognizes the Himalayan ecosystem as vital for preserving the ecological security of the country. Also, it underlines intense vulnerability of this ecosystem towards both anthropogenic and environmental perturbations. With this realization, NAPCC sets out 'Sustaining the Himalayan Ecosystem' (NMSHE) as one and the only area-specific missions among the eight National Missions. This mission envisages measures for sustaining and safeguarding the glaciers and mountain ecosystems. Considering the relevance of mandate, G. B. Pant Institute of Himalayan Environment & Development (GBPIHED) has been identified as coordinating institution for task force 3: Forest Resources and Plant Biodiversity. The project covers three major aspects of Mission Approach – (a) enhanced monitoring through observational and monitoring network, (b) promoting community based management, and (c) strengthening regional cooperation.

Objectives

- Development of coherent database for forest resources and plant diversity of Indian Himalayan Region.
- Establishment of effective monitoring system for forests resources and plant diversity in relation to changing climate.
- Validation of Climate Model Projections with reference to forest resources and plant diversity in Indian Himalayan Region.
- Sensitization and capacity building of inhabitants towards climate change adaptation and mitigation.

Achievements

- Establishment of Task Force Secretarial (TFS) and effective networking with partners from GBPIHED regional Units for development of a strategy for PAN Himalaya coverage.
- Detailed Programme Report (DPR) prepared and submitted to Department of Science and Technology (DST), Delhi.
- Ensured procurement and installations of equipments, and preliminary survey in potential long term sites.
- Prepared and submitted the information under Forest Resource and Plant Biodiversity components for inclusion under Himalayan Health Status Report to be prepared by DST, Delhi.
- Secondary data and literature/information has been collected w.r.t climate change adaptations in Himalayan Region, and a report on 'Adaptation and Policy Research' on climate change is in progress.
- Two sites have been identified; one is for intensive long term monitoring in Kali river basin in the Pithoragarh district of Uttarakhand (Western Himalaya) and second an extensive inventorization site is Bhagirathi basin in Uttarakashi district (Central Himalaya). Infrastructural needs identified/planned for establishment of field bases.

Summary of Completed Project / Activity

Ecological evaluation, Mapping and Conservation Prioritization of Floristic Diversity of the Spiti Valley in a Proposed Cold Desert Biosphere Reserve in Trans Himalaya (2011-14, MOEF&CC, New Delhi)

The study was conducted in Spiti Valley to; assess the floristic diversity of the Spiti Valley in a proposed Cold Desert Biosphere Reserve; (ii) study the status and distribution pattern of the native and endemic species; (iii) assess the utilization pattern of floristic diversity and document indigenous knowledge and traditional practices by the tribal communities; (iv) assess the floristic diversity for threat categories; and (v) prioritize habitats, species and communities for conservation, and economically important species for the socio-economic development of the Tribal Communities. The outcomes of the study are as follows.

- Total 360 species belonging to 60 families and 270 genera were recorded. Of these, 7 species were trees, 30 shrubs and 323 herbs. Among the angiosperm families, Poaceae (86 spp.); Asteraceae (49 spp.); Fabaceae (36 spp.); Polygonaceae and Brassicaceae (24 spp., each); Scrophulariaceae (20 spp.), Boraginaceae and Lamiaceae (19 spp., each) and Rosaceae (16 spp., each); Caryophyllaceae and Gentianaceae (13 spp., each); Cyperaceae (12 spp.) and Ranunculaceae (11 spp.) were dominant. Among the genera, *Astragalus* (17 spp.), *Artemisia* and *Potentilla* (13 spp., each), *Poa* (10 spp.), *Polygonum* (9 spp.), *Nepeta* and *Pedicularis* (7 spp., each) and *Allium*, *Chenopodium* and *Saussurea* (5 spp., each) were dominant. Fourteen (14) families i.e., Campanulaceae, Capparaceae, Convolvulaceae, Cupressaceae, Cuscutaceae, Equisetaceae, Hippuridaceae, Iridaceae, Juncaceae, Lilliaceae, Linaceae, Oleaceae, Orobranchaceae and Tamaricaceae were monotypic, represented by one species only .
- 91 species were native to the Himalayan region, the remaining species were non-natives; represent different domains of the world. 03 species were endemic and 28 species near-endemic.
- 265 species (Angiosperms: 262; Gymnosperms: 02; and Pteridophytes: 01) were economically important, used as medicine (225spp.), wild edible/food (56 spp.), fodder (35 spp.), fuel (16 spp.), religious (15 spp.), Agricultural tools (07 spp.), timber (5 spp.), insect repellant (02 spp.) and other species for various other purposes.
- Among 73 plant communities recorded from 173 sites represented 12 habitats and 08 aspects between 2620-4559 m. Of these 46 were represented by shrubs and 27 by herbs. Density data of shrub ranged from 40- 3003 Ind/ha and herb density 2.93- 89.94 Ind/m^2 and the highest density (3003 Ind/ha) of shrubs was recorded for Hippophae rhamnoides subsp. Turkestanica community and lowest (40 Ind/ha) for Tamaricaria elegans community. Similarly, the highest density (89.94 Ind/m^2) of herbs was recorded for Potentilla anserina - *Potentilla argyrophylla* - *Poa lahulensis* mixed community and lowest (2.93 Ind/m^2) for Ephedra intermedia community.
- Species Diversity (H′) for shrubs ranged from 0.00- 1.72, and herbs, 0.44-4.29. The highest diversity (1.72) of shrubs was recorded for *Cotoneaster gilgitensis* community and lowest (0.00) each for *Tamaricaria elegans, Potentilla arbuscula* and *Myricaria germanica* communities. The highest diversity (4.29) of herbs was recorded for *Hippophae rhamnoides subsp. turkestanica* community and lowest (0.44) for *Myricaria germanica community.*

- Concentration of Dominance (Cd) of shrubs ranged from 0.24-01, and herbs 0.01-0.75. The highest Cd (01) of shrubs was recorded for *Myricaria germanica, Potentilla arbuscula* and *Tamaricaria elegans communities* and lowest (0.24) for Kraschenkovia lanata - *Hippophae rhamnoides subsp. turkestanica- Myricaria germanica* and *Hippophae rhamnoides subsp. turkestanica- Caragana versicolor- Ephedra gerardiana* mixed communities. The highest CoD (0.75) of herbs was recorded for *Juncus thomsonii – Carex nivalis-Primula rosea* mixed community, and lowest (0.01) for *Astragalus stobiliferus – Ephedra intermedia* mixed community.
- Among Shrub communities, Species richness for shrubs ranged from 1-14, and herbs 2-122. Among herb communities, Species richness for herbs ranged from 5-23.
- Overall in the study sites, the soil moisture content ranged from 0.04-47.6%, pH, 5.48-8.85, total nitrogen 0.07-1.33%, organic carbon 0.08-5.25% and organic matter, 0.13-9.05%.
- Long term monitoring of the prioritized species, habitats and communities for understanding the dynamics of vegetation has been suggested.

Summary of Completed Project / Activity

Conservation and Management of Pollinators for Sustainable Agriculture, through an Ecosystem Approach (GEF, UNEP, FAO funded)

Realizing the importance of pollinators; its implications on global food security and human livelihoods, seven counties (Brazil, Ghana, India, Kenya, Pakistan, Nepal and South Africa) have come together with FAO to address the threats to pollinators and expand global understanding, capacity and awareness about conservation and sustainable use of pollinators for agriculture. Several agro-ecosystems with at least one representative pollination dependent crop have been selected to assess the pollination deficit /trend across the above seven countries and to assess its economic value. The project was also aimed to develop suitable policy guidelines for interventions adequately supported with the scientific datasets for long term sustainability of agriculture with improved food production and livelihoods.

Himachal Unit, Kullu

- Pollination Deficit Protocol of FAO, Rome was followed to undertake the pollination deficit studies in 20 apple orchards of Kullu Valley, Himachal Pardesh. The orchards were selected at a distance of 2 km each in distinct geographical locations, Production-Pollinizer ratio, and vegetation type representing different treatment combinations i.e., far and near to natural habitats with and without the provisioning of bee hives of apple orchards.
- Under the pollination deficit protocol, Flower phenology, PAN trap, Visual and Sweep Net samplings methods were implemented for the assessment of status of apple pollinators. Total 32 species of apple pollinators representing to Honey bee, Solitary Bees, Wild bees , Bumble bee, Carpanter bee, Hober flies, Syrphid & Drone flies and Butterfiles have been recorded from the different apple orchards of the upper Kullu Valley, Kullu under the Scan, Sweep and PAN trap experiments.
- Across the treatment combinations, overall observations indicated that higher population density of Indian Honey Bee (*Apis cerana)*, solitary bees (*Andrean, Ceratina* sp.) and Bumble bee (*Bombus* sp.) were reported from the orchards near to natural habitat. The orchards located distant to natural habitat areas were reported to less diversity of Indian Honey bee, Bumble bee and Solitary/wild bees. No bumble bees were reported from the orchards located distant to natural habitat. Syrphids, drone flies and other pollinators were recorded in higher numbers as compared to orchards far from natural habitat.
- The provisioning of supplemented pollinators (Bee hives) positively affected the productivity of apple orchards both in terms of quality and quantity. The study also indicated the near to natural habitat orchards as non pollination deficit whereas distant to natural habitat orchards as pollination deficit sites on the basis of pollinators diversity, availability of food resources, pollination friendly practices and overall impact of habitat quality on crop productivity.
- Developed crop specific pollinator's calendar and database of < 75 bee/pollinators specific plants species of pollen and nectar potentially useful for conservation of bees and other pollinators of the Kullu Valley.
- Developed 03 profiles of progressive farmers employing good agricultural practices for pollinator conservation and sustainable crop production in the STEP Site.
- Identified and documented 07 pollination friendly practices implemented by farming community for the pollination management and better fruit crop production of apple and other temperate fruits and vegetables.
- Developed Pollinators Management Plan for sustainable production of apple and other temperate fruit and vegetables crop in the Kullu Valley by incorporating the trends of GPP studies as well as identified need base issues emerged during the course of farmers/ stakeholders meetings.

- Developed understanding of farming community for adoption of organic practices, conservation of bee flora, reduced use of insect pesticides, and use of bee hives for the pollination management of apple.
- Conducted standard questionnaire based socioeconomic surveys among the villagers and farming community falls under the STEP Site to know the status of knowledge base of farming community on various aspects of pollinators, pollination and sustainable crop production through conservation of pollinators and their habitats.
- Organized STEP – partners meeting (01), Training of Trainers (TOT) on Pollination and Pollinators (01), Interactive Workshop/Meetings with diverse stakeholders (farmers, fruit growers association, NGO and students and teachers on Biodiversity Conservation, Pollinators, Pollination and Crop Production (04), Village Level Meetings (02), National Steering Committee and National Project Coordination and Advisory Committee Meetings of Global Pollination Project (01 each), International Steering Committee Meeting of Global Pollination Project (01) and Meeting related to the Policy and Planning of Pollinators in the Kullu Valley (01). During the project meetings stakeholders were made aware about the role of beneficial insects towards the pollination management and sustainable crop production. Farming community was also made aware for visual identification of key pollinators by slide show, photographs and handouts.

Headquarters, Uttarakhand

- Pollination deficit protocol was tested in mustard and cucurbits in Upper Kosi Watershed. Insect diversity including pollinators and bee flora was assessed.
- Training was organized for the parataxonomists. Field guide for parataxonomist to identify visiting insects/pollinators (46 species) of the *Brassica campestris* (Mustard) was prepared.
- Curriculum on pollination for diverse stakeholders was developed. It included understanding pollination in Indian Himalayan Region, concepts, methodologies and introductory manual for training of trainer programme, pollination and pollinator management.
- STEP site was thoroughly surveyed for identifying farmers with pollination friendly activities in practice. Profile of Mr. Prem Ballabh Pandey of village Dhari and Mr. Nand Kishore Mungali of village Manan were identified and subsequently profile was developed.
- GPP-India- web portal was developed and launched during the 2nd National Steering Committee Meeting of GPP-India at Kullu in 21 Feb, 2012. Pollination flyer, GPP folder, Panel, Docket, Diary and Posters were developed for distribution & dissemination.
- Pollinator android application (s) i.e., pollinators field guide (20 Bee species & 20 Butterfly species) were prepared. Repository of more than 200 insects was prepared and maintained for future reference at the institute's Lead Center. Identification of insects is in progress.
- College students were involved in implementation of Pollination Deficit Protocols and Socio-economic evaluation of pollination friendly activities, so far 16 students have been trained. More than 13 trainings have been conducted where >1000 participants were given training on various aspects of pollination.
- Pollination Management Plan for STEP site Kosi-watershed was developed. Pollination Bibliography of 137 references on various aspects of target crop pollination was developed.

Sikkim Unit

- Mamlay watershed is selected as a project site, which is situated at the southern part of Sikkim state and extends from 27°12'3" to 27°16'14" N and 88°19'2" to 88°23'30" E, covering an area of 32 sq km. Watershed comprises of 9 blocks cover up 34 villages. The population density of the watershed is 135 people per km^2. Nearly 95% of the total population of watershed is concentrated in lower and middle hill slopes, and the remaining 5% in upper hill slope. Subsistence agriculture is a major occupation of the farmers for sustaining the livelihood.

- Large Cardamom (*Amomum subulatum* Roxb.), Zingiberaceae, is one of the main perennial cash crops cultivated in the sub-Himalayan state of Sikkim between an elevation 600-2000m. The capsule or fruit is used as spices due to its pleasant aromatic odor, obtaining 3% essential oil with high cineole content. Presently, the state has 26,734 ha of land under large cardamom plantations which has an average yield of 4,358 MT per annum provided 13.6 million USD to the state in 2007. Large cardamom is cultivated in the agroforesty system contributing to the mitigation of climate change due to its higher primary productivity rates and carbon fixation rates in the region as high value and low volume crop. Moreover, the crop preferable to grow under Himalayan alder (*Alnus nepalensis* D. Don) is more profitable in terms of fertility enhancement of crop field.
- *Socio* economic survey was conducted in the "Mamlay watershed" through the involvement of local farmers and students. Total 28 household' survey was completed in the 7 villages of the watershed. The prescribed format of socio-economic was followed by the team after long training and demonstration. Gathered information from the filled formats, the input and out put amount were analyzed in the two distinct groups i.e. monoculture (crop in the open field) and agro-forestry system. The difference between input and output amount (Rs.) were calculated and revealed that the large cardamom farming system observed much more profitable (i.e. Rs. 33228/) than monoculture (i.e. Rs. 5400/-).
- Under the agro-forestry system an approx. 80 x 80 m^2 demonstration plot were selected and planted 1000 seedlings of large cardamom in the watershed. To promote pollination services, total 11 flowering species were planted within and around the plot for providing variety of forages resources to pollinators. Also, 20 seedlings of *Alnus* tree were planted within the plot for i) providing shade of the large cardamom and soil nutrient and ii) managing wild bee nest sites.
- A "Strategy and Consultative" meeting was organized at GBPIHED, Sikkim Unit, Pangthang (Sikkim) under Global Pollination Project (GPP). Various experts and yiled workers were participated the meeting. The meeting was carried out in two sessions i.e. i) integrate the existing knowledge base on pollination services and ii) draft a plan for conservation and management of pollinators at regional level under round table discussion. Under the integral knowledge base several deliberations were made under the points i.e. i) different facts of pollinator and pollination process on the global, ii) pollinators of cardamom crop, and iii) gathering the integral values of pollination services for a sustainable agriculture in the Sikkim Himalaya.
- Under a draft a plan on mechanism on conservation and management of pollinators in Sikkim which was carried out in several aspects of pollinator and pollination events in and out of Sikkim. In the several presentations a move was set on making a road map ahead on pollinator aspect by way of drafting a policy on pollinators. All the participants joined hands during the round table discussion and certain goals were set up for policy draft and subsequently followed up by step-up mechanism taking in queries the form of why and how, when, who, status details, effects and SWOT, ecological risks, risk policy, implementation costs monitoring, binding force and options for the future. A total of two goals with six sub-goals (i.e. 1. research and 2. strengthening rural economy/role of pollinators) were derived from the deliberations and these were brain-stormed to get the results for the above mentioned fields.

Summary of Completed Project / Activity

Khangchendzonga Landscape Conservation and Development Initiative in India (ICIMOD funded)

- Focusing on cultural, geographical and resource use similarities in three countries, Bhutan, India and Nepal and for promoting sustainable resources use for improved livelihood, Khangchendzonga Landscape Conservation and Development Initiative (KLCDI) programme was initiated by ICIMOD, Nepal, offering an opportunity where partner countries may work together for utilizing strength of the region within a complex climate driven array. Surrounded along the southern stretches of Mount Khangchendzonga, the proposed Khangchendzonga Landscape (KL) includes eastern Nepal, Indian state of Sikkim, parts of north Bengal, and extending to Toorsa Strict Nature and connecting to Jigme Dorjii National Park (Bhutan). Three countries have agreed to collaborate and set the desired targets to help preserve the unique biological diversity and ecosystem goods and services, while simultaneously developing livelihoods of the local communities. On Indian part, following an approval of Ministry of Environment, Forests and Climate Change (MoEFCC), Govt of India, entrusting GBPIHED the responsibility as lead organization, a letter of agreement (LoA) was signed (15.11.2013) between GBPIHED, India (Dr PP Dhyani, Director) and ICIMOD, Nepal (Dr D. Molden, Director General) to initiate a preparatory phase on KLCDI. The GBPIHED, Sikkim Unit was asked to execute the task. Under preparatory phase, important deliverables to support implementation of the long run programme were: i) boundary delineation, ii) team building, iii) preparing feasibility assessment report, Conservation and Development Strategy (CDS) and Implementation plan, and iv) contributing in preparing Regional Cooperative Framework (RCF).
- The boundary delineation was accomplished through extensive consultations with diverse group of the stakeholders and using the criteria, (i) physical and cultural, (ii) biological, and (iii) planning and management. Delineated KL- India identified 14126.36 Km^2 geographical area (26°29'13.56" to 28° 7'51.6" latitudes and 87°59' 1.32" to 89°53' 42.96" longitudes), along 40m to 8586m asl, comprising Sikkim and Darjeeling, Jalpaiguri and Alipurduar districts of West Bengal. As per MoEFCC (GoI) suggestions in high-level meeting (30.1.2014), it excluded blocks along the borders of Bangladesh. Involvement of multidisciplinary government and NGO organizations and building up an effective team for implementing KLCDI was ensured through organizing several consultations and interactions. Outputs used for preparing major desired documents and planning. A baseline document, Feasibility Assessment Report (FAR) of KL-India was prepared using inputs from extensive exercises of experts, review of literature, analysis of primary/secondary data. Additionally, national consultations (28-29/1/2014; 9.4.2014; Gangtok), Stakeholder's consultation (28.2.2014: Sukna-WB) were organized seeking inputs to FAR preparation. FAR contained 11 chapters with tangible information of KL-India, included physical, biological, management resources, and policy issues and gaps of KL-India.
- Conservation and Development Strategy (CDS) is developed for 20 years through team building process by organizing several national, regional and local level consultations. These include a series stakeholders' consultations (4 nos; 6-9/9/2014: transboundary area with Bhutan- Jalpaiguri/ Alipurduar, support-HNAF-Siliguri;, 01 at Barsey-W Sikkim: 5.11.2014, support-TMI-India; 01 at Dzongu: 8.11.2014, support-MLAS-Dzongu, and 02 in transboundary area of Singalila and Mahananda range: 12-13/11/2014, support- CMD-Kalimpong). Also, participation in regional workshops (Pokhara-Nepal, 27-29/8/2014; Chalsa, Jalpaiguri, 4-5/1/2015) helped. Moreover, national Consultation cum write-shop (3-4/12/2014, Gangtok) and Sikkim experts/partners' brainstorming (GBPIHED, Sikkim: 7.1.2015) were organized. The implementation plan is prepared for 5 years through different consultations/interaction with the partner organizations, including over viewing plan development process, activities and approach. The plan included representative thematic areas/sites for implementation of the activities in KL-India and projected budget. To strengthen the trans-boundary cooperation among participating countries at regional scale, the team of KL-India had immensely contributed in developing Regional Cooperative Framework through their participation in various events

Theme

Environmental Assessment and Management (EAM)

The growing population and their continuously increasing demand together have led to 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 arise. The day-to-day upcoming developmental activities need a fresh re-look in an integrated manner with a view to sustainable development. Forests, ecosystem services and conservation have always been among the core issues in the mountain agenda. The IHR is likely to be adversely affected due to land use / land cover change for practising a variety of economic activities for livelihood options and upcoming threats of climate change, its adaptation, resiliencies and mitigation. The shrinking of forest resources, its functioning and ecosystem services (ES) are of utmost importance to address. The conversion of forest land into 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 the net present value of forests. The environmental issues like strategic environmental assessment of hydropower projects, and CC and ES have been the primary focus to improve better livelihood options. However, the adverse impacts due to developmental activities such as aerosols (gaseous, particulate, liquid) and its impact on temperature rise are needed to be assessed for sound policy making. The "Environmental Assessment and Management" (EAM) theme, therefore, addresses, monitors, assesses and analyses physical, chemical, biological and cultural components of environment, concerned with the developmental activities/ interventions/ projects/ policies/ plans in the Indian Himalayan Region (IHR). The R&D activities in the theme aim to assess and analyse impacts, set priorities, identify gaps, develop early mitigating approaches and to find new technology to achieve a goal of sustainable development.

The EAM Theme has successfully achieved its targets during 2013–2014. The on-going activities under the theme focused on seven projects, two of them being supported as in-house projects while remaining were externally funded. The project on "Strategic environmental assessment (SEA) of hydropower projects in the Himalayan Region" is being implemented to carry out integrated and cumulative impact assessment of all hydropower projects in Sutlaj (Himachal Pradesh), Alkananda (Uttarakhand) and Ranganadi (Arunachal Pradesh) basins with an aim to develop a broad framework for installation of hydropower projects in a given river basin. Remote Sensing and Geographic Information System (RS & GIS) along with field verification tools are being used. The project on "Climate change impacts on ecosystem services in the Indian Himalayan Region" aims to investigate four dominant forest types of the Central Himalaya for the change in their structure and functioning *vis-à-vis* with a focus on its impact on ecosystem services. The phenological investigation on dominant species is being made as an early indicator of climate change. Other projects in the theme comprise "Indicators of climate change in context to the Himalayan forest ecosystems along an environmental gradient", "Gaseous air pollution in the background site of sprawling urban environment of Himachal Pradesh",

"Aerosol climatology over the northwestern Indian Himalayan region (Himachal Pradesh)", and "Black carbon and other aerosols loading, and their impact on melting of the Parbati glacier in the northwestern Himalaya, India"; these R&D works were pertaining to aerosols (i.e. gaseous pollutants, columnar aerosol and black carbon aerosol) and their impacts on temperature rise, radiative forcing and climate change.

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

The Himalayan ecosystem is most complex and one of the diversified regions of the world. Due to its varying topography and climate, developmental activities in a certain pocket are taking place continuously. If ongoing developmental activities in its present forms are overlooked, these would be creating numerous environmental problems such as deforestation, landslides, rock fall, soil erosion, air pollution, water pollution and noise pollution, seismic activity, submergence, displacement, health problems, solid waste, public agitation and change in micro-climatic conditions, etc. No doubt, much legislation is formulated to mitigate and manage these environmental issues, among which Environmental Impact Assessment (EIA) as one of the tools is meant to get clearance to the projects. At the same time, this is also fact that the EIA studies are not providing assurance of sustainable development in the Himalayan region. Thus, Strategic Environment Assessment (SEA) is one of the newly introduced important tools that may achieve the objective of sustainable development in the Indian Himalaya. In Himachal Pradesh, it is estimated that more than 21,415.62 MW hydropower potential could be tapped for hydroelectricity from the major five river basins. The total identified hydropower projects in Himachal Pradesh for the benefits by the 12th five year plan were total 15 HEPs having 2457 MW. About 9 mini (>0.10-2 MW), 39 small (>2 to 25 MW) and 78 large (>25 MW) projects were supposed to be completed by the twelfth five year plan. Besides, HIMURJA has identified 526 (mini/ micro/ small) in all the five river basins. Likewise, in Arunachal Pradesh, 26 HEPs of 9578.5 MW were identified for the benefits by the twelfth five year plan, whereas only 3 HEPs (with 1710 MW) have been planned for likely benefits during the 12th plan. To mitigate geo-physical (water, air, soil, etc.), biological, economic, social and cultural problems in the host regions, there is an urgent need to refine the existing policy of development especially in terms of hydropower projects.

Objectives

- To know the status of selected hydroelectric projects (HEPs) in relation to SEA.
- To assess impacts in upslope and downslope regions of HEPs in addition to its immediate environment.
- To assess the future of HEPs in relation to climate change.
- To put forward adaption strategies to combat climate change impacts.
- To suggest measures to promote sustainable HEPs based on SEA.

Achievements

- In Sutlaj basin all 37 hydroelectric projects of different categories spread within the 10 km buffer. Also, the Ranganadi basin is being assessed on more or less similar aspects. Biodiversity assessment around Ranganandi HEP exhibited a total 172 plant species (55 trees, 42 shrubs, 19 climbers, 56 herbs) that are used, directly or indirectly, by the natives. In its downstream locations, an inventory of fishes showed 34 species belonging to 11 families.
- River discharge data of the River Ranganadi at Yazali site indicates that maximum flow in it was 341 cumsec in July 2002 (before start of the project) which reduced to 84.8 cumsec in July 2008 (after the project initiation). The soil samples analysed from the proposed project area in the River Ranganadi were rich in organic matter. N, P and K contents were present under moderate concentrations at all the sampling locations. Soil of the area is typically sandy loam, while its bulk density varied from 1.24 to 1.44 (gm/cc).
- At Sutlej basin the ambient air quality in terms of PM_{10} and trace gases (NO_2, SO_2) was within the permissible limits in upstream (Shongtong HEP) and downstream (Rampur HEP) regions. $PM_{10,}$ on average, was 68±1.7 $\mu g\ m^{-3}$ at Shongtong-Karcham and 48±0.9 $\mu g\ \ m^{-3}$ at Rampur in the study sites. The air quality parameters were within the National Ambient Air Quality Standards (NAAQS). The affected areas of the hydropower projects were taken into account for water quality analysis by assessing water hardness, Methyl Orange (M.O.) alkalinity, chloride, calcium and nitrate, which were within the desirable limits as per Indian

Standard Specifications for drinking water (1991). While turbidity in the river water samples of the study area varied from 150 to 300 NTU (mean 212±12 NTU) during pre-monsoon as compared to desirable limit of 5 NTU (Table 8). As a result, water is not fit for human consumption due to high NTU as well as not fit in all seasons for hydroelectric energy generation due to high silt load.

- At this basin the socio-economic survey conducted in and around selected project areas (such as Shongtong-Karcham HEP, 402 MW; Karcham-Wangtoo HEP,1000 MW; Rampur HEP, 412 MW) at Barang Khas, Shongtong, Tangling, Powari, Purbani Khas, Shuda Rang, Nirath, Nogli and Bayal villages, which showed that during the construction phase of these projects nearby villages lost their agricultural land, houses, orchards, crops and grasslands. The project affected villages within a distance of 2-3 km indicates that influence zones of a majority of the projects are overlapping the ecological and physical boundary of other projects. Upon querying inter-distance of above 8 km for major projects, 5 km for macro projects and 3 km for small projects were supported by 56%, 61% and 61% respondents in the basin.
- Similar study of seven villages around the Ranganadi hydropower project showed that a majority (80%) of the respondents perceived the river very important to them from a viewpoint of a variety of ecosystem services and 100% respondent villagers felt that their age-old livelihoods options due to this project were adversely affected.
- On the occasion of a consultation meeting on March 28, 2014 at GBPIHED, Himachal Unit, Mohal and a training programme on 'Sustainable development of Hydropower Projects' on 26 November 2014 at Reckong Peo, Kinnaur, the participants expressed that large HEPs require geographically more area and more prone to high degree of adverse impacts. All the participants agreed that small HEPs need to be preferred rather than large HEPs.
- Landslide zonal assessment, earthquake, morphometric analysis and land use and land cover (LULC) mapping and change detection in the Satluj basin are being prepared using RS&GIS with a purpose to determine aerial distance from one project to other and for a strategic planning to determine a combination of projects (small, macro and major) with certain numbers within a catchment.

Table 8: River water quality assessment during monsoon season (August, 2014) in the Sutlej basin [a] 'n' number of samples taken for analysis; [b] Source : Manual on water and waste water analysis (1983), NEERI, Indian Standard Specifications for drinking water (IS: 10500), Annexure VII, pp.XV.

Sample sites	pH	Turbidity (NTU)	M.O. Alkalinity as $CaCo_3$ (mg l^{-1})	Total Hardness as $CaCO_3$ (mg l^{-1})	Chloride as Cl (mg l^{-1})	Calcium as Ca (mg l^{-1})	Nitrate as N (mg l^{-1})
Upstream (n^a=16)	8.42±0.1	187.5±23.7	170.5±17.4	176.5±20.1	13.7±1.4	37.6±3.6	0.68±0.7
Midstream (n^a=16)	8.05±0.11	218.8±28.6	172.5±17.7	179.0±20.3	15.5±1.2	35.1±4.0	0.71±0.7
Downstream(n^a=16)	8.18±0.17	231.3±26.6	179.0±18.0	178.9±21.9	14.3±1.0	37.6±3.6	0.82±0.7
Maximum (n^a=48)	8.70	300	198.0	243.0	19.0	45.0	0.95
Minimum (n^a=48)	7.30	150	148.0	128.0	9.0	18.0	0.59
Mean (n^a=48)	8.21±0.6	212.5±12.3	174.0±6.5	178.1±8.8	14.6±0.7	35.8±1.5	0.74±0.9
Acceptable Limit[b]	6.5-8.5	5.0	600.0	300.0	250.0	75.0	45.0

Climate Change Impacts on Ecosystem Services in the Indian Himalayan Region (2012-17, Inhouse)

Mountain regions have emerged among the most sensitive ecosystems under the global climate change (CC) scenario. Among global mountains, the Himalayan region is most prominent on account of its unique topography, micro-climatic conditions and strategic location, and represents one of the 'Global Biodiversity Hotspots'. The richness of forests in the IHR supports a range of ecosystem goods and services (ES) which are highly valuable to the inhabitants both within and outside the region. However, in the recent decades under the changing climate the ES such as provisioning of NTFPs to support the local livelihoods, habitat diversity, C-sequestration potential etc. have altered due to CC. Realizing the above, the present study was undertaken across an altitudinal gradient (300–2100 m asl) on one dominant canopy and sub-canopy species of major forest ecosystems of Central Himalaya (*Shorea robusta, Pinus roxburghii, Quercus leucotrichophora and Quercus floribunda* forests) for selected life cycle phases (phenophases), such as leafing, flowering, fruiting and leaf drop to relate the timing of these events with weather patterns and CC and certain leaf characters (leaf life span, leaf area and leaf mass). It is also essential that we understand how CC will affect nutrient availability in forests and afforested wastelands, particularly N-mineralization, nitrification and nitrifier population. Recreational services of the forest ecosystems and impact of CC on livelihood of rural population was also studied. Data thus collected will be related to CC impacts on forest ecosystem services and expected decline in the magnitude of the ES and human well-being.

Objectives

- To Study early indicators of CC on forest

vegetation through phenological methods in the region.

- Assessment of changes in structure and functioning of forest ecosystems vis-à-vis impact on ES (quantification and valuation) accrued.
- CC impacts on recreational/aesthetic services of the landscape and appraisal of management options like institutional arrangements and policy measures.
- Develop, refine and demonstrate models for rehabilitation of community waste/degraded lands as an adaptation to CC and to improve ES.
- Regional planning for suitable forest types to encounter CC impacts and enhance ES.

Achievements

1. Across all the eight species studied across the four forest types leafing initiated earlier at south (S) aspect as compared to north (N) aspect. Similarly, leaf drop, flowering and fruiting was initiated earlier at S aspect as compared to N aspect in all the species. This difference in delayed phenophases at the N aspect was mainly due to low sunshine and low atmospheric temperature. Sub-canopy species generally initiated all the phenophases little late than the canopy species.
2. Average soil organic carbon (SOC) was found ranging from 0.85±0.03% to 3.01±0.04% across the four forest types. Maximum SOC was recorded for *Q. leucotrichophora* forest (2.24±0.04%) and minimum (1.05±0.05%) for *P. roxburghii* forest (Fig. 19).

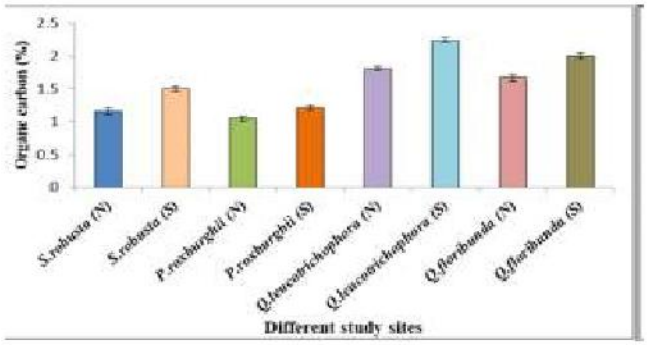


Fig. 19. Soil organic carbon (%) values in different study sites

3. Leaf area at mature stage for tree species was found ranging from 8.43 cm^2/ leaf (South aspect) and 7.02 cm^2/ leaf (North aspect) in *P. roxburghii* to that recorded for *S. robusta* (161.41 cm^2/leaf in S aspect and 144 cm^2/leaf in N aspect. Similarly, leaf weight at mature stage for tree species was found ranging from 0.318 g/leaf (S aspect) and 0.318 g/leaf (N aspect) in *P. roxburghii* to that recorded for *S. robusta* 2.50 g/leaf in S aspect and 2.15 g/leaf in N aspect.
4. To understand the temporal changes in livelihood pattern of local people and impact of climate change in driving such changes, a total of 134 households belonging to 37 villages in Garur Ganga watershed, Bageshwar District (Uttarakhand) were surveyed using a structured questionnaire. 53% households reported a decline in food security. Irrigated fields registered 45% and 49% decline in rice and wheat yields in past one decade, though such decline was less in rainfed areas. The main reasons for poor production comprised lower rainfall (37% respondents), climate change including late arrival of rains and high temperature, etc (30% respondents), and crop damage by wild animals (28% respondents).
5. To ascertain the economic relevance of the recreational services offered by the local environment around Nainital, survey of 125 tourists and 160 businessmen was carried out and tourist inflow trends were also studied. Tourist perception towards threats to natural environment and impacts were also obtained. The preliminary results on WTP (Willingness to Pay) of tourists for conservation of recreational environment vis-à-vis their levels of education were gathered, and people with higher education showed better WTP (Table 9).
6. A restoration site is being developed to assess the role of the multipurpose tree introduction on the soil processes of a pure pine stand. The pattern of natural restoration in soil components and processes (secondary ecosystem services) such as soil nitrogen dynamics is being studied in a pure pine stand and a pine stand which has been enriched by introduction of ten different broad leaved tree species at Nanda Van restoration site, Almora. In the reporting year a total of 415 seedlings of ten broad leaved tree species were planted.

Table 9. Education-wise WTP of Tourists for Conservation

WTP Class	No of Persons (%)			
	Matric	Senior Secondary	Graduation	PG & above
< Rs 500	1 (0.8%)	13(10.4%)	35 (28.0%)	41(32.8%)
Rs 500-1000		1 (0.8%)	10 (8.0%)	2 (1.6%)
Rs 1000-2000			4(3.2%)	5(4.0%)
Rs 2000-3000			1(0.8%)	3(2.4%)
Rs >3000				3 (2.4%)
Av. Stated WTP	Rs 100	Rs 414	Rs 516	Rs 658

n=125

Indicators of Climate Change in the Context of Himalayan Forest Ecosystems Along an Environmental Gradient (2012-2015, DST, New Delhi)

Mountain ecosystems, with their great vertical dimensions representing gradients of temperature, precipitation, and solar radiation form unique candidates to detect and analyze impacts of global change. Among global mountains, the Himalayan region, is most prominent on account of its horizontal and vertical extent and represents one of the 'Global Biodiversity Hotspots'. The richness of endemic species with restricted distribution and life support values (goods and services) of this hotspot are highly vulnerable under the CC scenarios. With this in view the present project was initiated to undertake studies across an altitudinal gradient (500–2200 m altitude) in the Central Himalayan Region covering major forest types from the foothills to temperate conditions. In this transect two-three decade past data sets on many aspects of ecosystem characteristics (e.g., phenology, leaf characteristics, forest composition and recruitment patterns and other structural and functional aspects of forests) is available that may serve a strong bench mark to understand the CC impacts. Therefore, studies were undertaken in the same forest stands/sites, with a view to compare the same with the past available data, and make an attempt to relate the observed structural and functional changes in these forest tree species and ecosystems with CC.

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

- Phenological observations on dominant canopy (*Shorea robusta, Pinus roxburghii, Quercus leucotrichophora* and *Q. floribunda*) and sub-canopy (*Mallotus philippensis, Myrica esculenta, Rhododendron arboreum* and *Machilus duthei*) forest tree species along the altitudinal gradient (500 – 2200 m asl) in Kumaun Himalaya revealed sub-canopy species initiated all the phenophases little late than the canopy species, may be partly due to low amount of sunlight and temperature. In the south facing sites phenological earliness was reported as compared to north facing aspects. Leaf area, leaf mass and leaf number was found greater on south aspect as compared to north aspect.
- A comparative account of various structural aspects of the above forests at two points of time (once in 2014 and three decade ago by earlier workers) revealed that increase in density in *Q. leucotrichophora,* whereas *P. roxburghii* forest shows decline in total tree density whereas reverse was true for importance value index (IVI). Mixed forest had higher number of species in sapling stage but all forests exhibit considerable increase in seedlings but decline in total shrub density in most forests (except *P. roxburghii* forest).
- Using MODIS data, detection of the timing of offset and onset of greenness were analyzed across 18 sites in Sal (*S. robusta*) forest in foothills of Kumaun Himalaya. Statistically significant trend in vegetation growth was observed using t-test method. Healthy vegetation has high NDVI value whereas unhealthy or dry vegetation shows low NDVI value. Sal forest shed their leaves during spring season (from late February to early April), but did not become fully leafless and leaf flushing starts from late March and reaches maximum during April, and extends till mid June.

Gaseous Air Pollution in the Background Site of Sprawling Urban Environment of Himachal Pradesh (2008 - 2017, ISRO, PRL, Ahmedabad)

Tropospheric ozone (O_3) is an important air pollutant threatening human health and vegetation growth. O_3 is also one of the key species affecting the chemical properties of the atmosphere where it is a precursor for the highly reactive hydroxyl radical. Surface O_3 and its precursors play an important role in affecting regional climates and causing adverse effects on human health and vegetation. The relation between O_3 and its main precursors represents one of the major scientific challenges associated with air pollution. Ozone concentrations depend on the absolute and relative concentrations of its precursors and the intensity of solar radiation. An analysis of the influences of meteorological parameters on O_3 and its precursors at a specific site can contribute to a better understanding of the local and regional causes of O_3 pollution. Nitrogen monoxide (NO) is emitted from soils and natural fires and formed *in situ* in the troposphere from lightning, and is emitted from combustion processes such as vehicular emissions and fossil fueled power projects. NO is short lived because it oxidizes to produce nitrogen dioxide gas (NO_2) and

plays a major role in O_3 production. Biomass burning, combustion of fossil fuels, and oxidation of hydrocarbons released from automobiles and industrial solvents are the main sources of atmospheric CO. Its oxidation leads to O_3 formation or destruction, depending upon the NO concentration.

Objectives

- To measure concentration of important 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) and 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 in the background of long range transport sources, and
- To suggest some feasible mitigating measures for policy implications.

Achievements

- Observation of trace gases such as surface ozone and its precursors, nitrogen oxides (NO+ NO_2), sulphur dioxide and carbon monoxide were carried out in different times at two locations, one at valley base- Mohal (1154 m amsl) and other at valley top- Bijli Mahadev (2500 m amsl) (Fig.20a). In an Environmental Observatory at Mohal, different related online analysers and equipments are functional. Among these worth mentioning are UV photometric Ozone Analyzer (Thermo Fischer Model, 49i), NO_x Analyzer (Thermo Fischer, Model 42i), SO_2 Analyser (Thermo Fischer Model 43i) and Carbon Monoxide Analyzer (Thermo Fischer Model, 49i) (Fig. 20b). During the reporting period (2014), higher concentration of surface ozone was observed in the months of June, April and March with 26.23 ± 12 ppb, 24 .43 ± 11 ppb and 22.26 ± 12.82 ppb respectively.
- NO_x precursor, showed maximum in June (3.89 ± 1.21 ppb) followed by January (3.5 ± 1.23 ppb) and December (2.89 ± 1.5 ppb), while CO, another important precursor of O_3, showed maximum in December (0.22 ± 0.05 ppb) followed by January (0.20 ± 0.03ppb) and June (0.18 ± 0.17 ppb). At the same time, SO_2 was maximum in January (1.90 ± 0.26 ppb) followed by November (1.46 ± 0.21 ppb) and December (1.41 ± 0.23 ppb). These precursors are mainly considered to be emitted in the present study sites due to anthropogenic emissions –such as vehicular emission and biomass burning which are considered to be primary pollutants.
- While looking at the rate of change in O_3 concentration, it was lower (-4.1 ppbv h^{-1}) in the evening than morning production rate (4.8 ppbv h^{-1}). The lower rate of ozone loss in the evening suggests that ozone loss process could not be so much stronger at Mohal due to low NO_x emissions. At Mohal, magnitude of morning and evening rate of change is almost similar and closely follows the behaviour as is normally shown by urban sites.
- The daily variation of the mean values of O_3, NO_x, CO and SO_2 concentration at Bijli Mahadev site is shown in Figure 20c. The daily concentrations of O_3 as well as its precursors NO_x, CO and SO_2 were observed maximum from 1 December to 13 December, 2014. The O_3 ranged between 30 to 37 ppb, NO_x between 2 to 3.25 ppb, CO ranged between 0.20 to 0.31 ppb, and SO_2 ranged between 1.5 to 1.7 ppb. Mostly the periods of autumn and early winter are dry in this region, as a result forest fire activities also remain high. During observation period, forest fire incidents in the surroundings of Bijli Mahadev were also noticed.
- During winter months such as November and December, O_3 and its precursors were monitored at Bijli Mahadev site. This is a top site and close to the valley base site Mohal as well as Kullu town with a maximum aerial distance of around 2 km. Here, the influence of anthropogenic sources such as vehicular emissions and others also exist (Fig 20d).

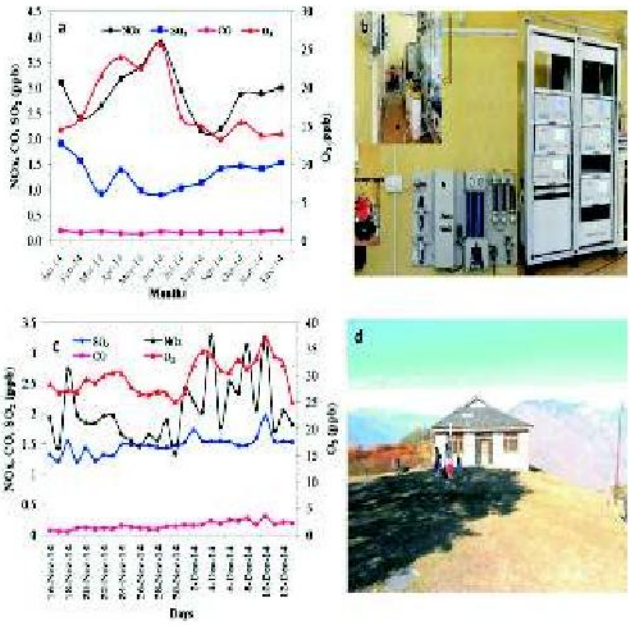


Fig.20. (a) Monthly variation in O_3 with NO_x ,CO and SO_2 concentration, (b) Environmental Observatory at Mohal (1154 m amsl), (c) daily concentration of O_3, NO_x, CO and SO_2, and (d) An overview of Bijli Mahadev site (2500 m amsl)

Aerosols Climatology over the Northwestern Indian Himalayan Region, Himachal Pradesh (2005-2018, ISRO, SPL, Thiruvanthapuram)

Climate change is one of the most important issues over our planet and aerosols play a great role in bringing the changes in it. With the ever increasing man-made activities, there is an increase in the concentration of aerosol in the atmosphere which changes the Earth's radiation budget, hence the climate of the Earth. Among the optical properties of the aerosols, scattering and absorption cause the cooling and heating effect on the earth's surface and atmosphere respectively. Aerosols not only affect the ecosystem, climate but also the human health. The aerosols are responsible for the attenuation of the solar radiation when they pass through the atmosphere and thus produce the solar dimming. The amount of attenuation depends upon the shape, size and other optical properties of aerosols. Columnar aerosol optical depth defines the extinction in the solar radiation reaching the earth's surface. The Ångström parameters such as Ångström exponent 'α' are associated with the fine aerosols whereas turbidity coefficient 'β' is associated with the coarse aerosols. With the increasing concentration of aerosols, there is a decrease in the rainfall. The deposition of the black carbon aerosols on the glaciers in one end increases the light absorption, whereas on the other snow albedo decreases resulting in local temperature increase and the melting of the glaciers. Fossil fuel and biomass burning are the source of fine size black carbon aerosols which become a cause of atmospheric visibility impairment and carcinogens in human beings.

Objectives

- To obtain variations under clear, partially clear and hazy sky day conditions in aerosol optical depths (AODs) at ultra-violet, visible and near infrared spectrums (380-1025 nm) using Multi-wavelength Radiometer (MWR),
- To obtain Black Carbon Aerosol concentrations on land and glaciers,
- To relate AODs with the meteorological parameters with the help of Automatic Weather Stations installed at Mohal, and
- To obtain Radiative Forcing using different models.

Achievements

- Average of the full day AODs at ten wavelengths for the clear sky days of the year 2006 to 2014 was taken into account. It was found that AOD values were noticed maximum for the year 2012 and minimum for the year 2007. This increase noticed at 500 nm was 72.73% and found similar to average values of AOD for forenoon (FN), afternoon (AN) at ten wavelengths for the same period. This increase in AOD values from FN to AN at 500nm was 45.66% and overall increase at ten wavelengths from FN to AN was 43.74%.
- In a majority of the cases (2006 to 2014), the Ångström parameters like Ångström exponent 'α' shows maximum fine size particle concentration in autumn which was minimum in monsoon season. While turbidity coefficient 'β' shows maximum coarse size particle concentration in monsoon and minimum in winter and autumn season.
- In general, during March (0.08) at Kothi has the lowest AOD. However, the highest was observed in November (0.35) and June (0.34). AOD at 500 $_{nm}$ wavelength during observation ranged from 0.08 to 0.35. During March-June 2014, the mean AOD values at 500$_{nm}$ were 0.28±0.14 and during July to December 0.30±0.09 (Fig. 21a).
- AOD over ablation zone at Beas Kund Glacier ranged from 0.16 to 0.20 on 14 June 2014 and 22 June 2014 respectively. During observation, the highest daily mean AOD values were found to be 0.20 which was observed repeatedly highest during observation period (Fig. 21b).

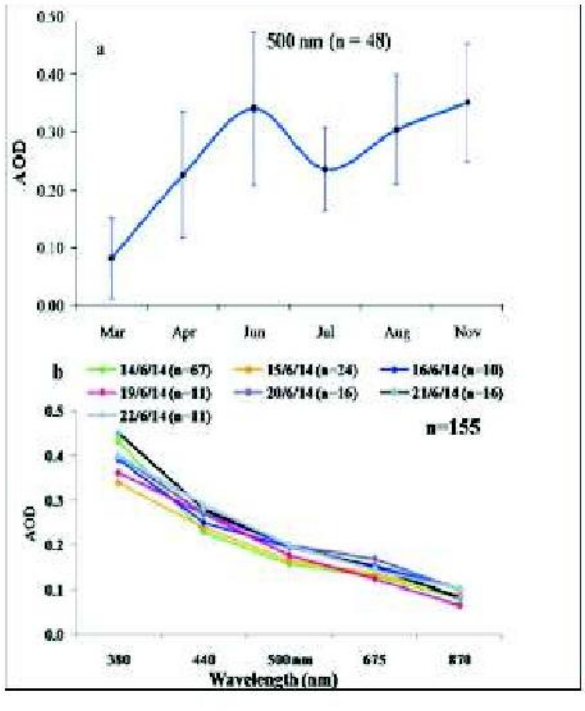


Fig. 21 A-B. Aerosol optical depth (AOD) at 500 nm; (a) Kothi, and (b) AOD values at the Beas Kund Glacier

- At ablation zone, cations were found to be more in the snow samples. Among the identified ions, NH_4^+ (8.9 µeq/L), Na^+ (7.4 µeq/L), Ca^{2+} (7.0 µeq/L), K^+ (6.9 µeq/L), SO_4^{2-} (4.2 µeq/L), F^- (2.1 µeq/L) and NO_3^- (1.6 µeq/L) were worth mentioning. The concentration of ions were observed be Cl^- (14.1 µeq/L) at 70-85 cm snow depth followed by K^+ (12.79 µeq/L) at 0-20 cm snow depth. The concentrations of Na+, K+ and Mg^{2+} and F^- together account for 38% indicating that the contribution of sea-salt to the mass soluble species is insignificant.
- The decrease in snow surface area was analyzed in the glacier close to Rohtang Pass, that is, the Beas Kund. From year 2000 to 2014 during similar months (December), satellite imageries (Landsat 7 ETM^+, Landsat 8 OLI) were analyzed for snow surface area and found that the Beas Kund Glacier has been shrinking at the rate of 20 m yr^{-1}.
- The maximum daily average temperature during observation period at Kothi was observed to be 20.8^{0}C on May 1, 2014 which was followed by 20.6^{0}C on June 5, 2014 and minimum was minus 1.4 on December 12, 2014. The relative humidity was 92% on 12 December, 2014 followed by 90% on August 22, 2014. The lowest ever humidity was 20.6% at Kothi on May 29, 2014 (Fig. 22).
- Rainfall plays a major role in determining the humidity level and washout effect on pollutants in this region. The daily maximum total rainfall at Kothi was measured 90 mm on June 11, 2014. The monthly highest rainfall at Kothi was recorded 258 mm in June 2014. Snowfall in winter was recorded maximum with 106 inch in the month of February 2014. The maximum wind speed was 11 m s^{-1} on 23 May 2014 and minimum was 0.3 m s^{-1} on 6 November 2014.

Fig. 22. Aerosol optical depth (AOD) measurements and local meteorology over the Beas Kund Glacier

Black Carbon and Other Aerosols Loading, and Their Impact on Melting of the Parbati Glacier in the northwestern Himalaya, India (2013-2016, DST, New Delhi)

Understanding black carbon (BC) concentration and other aerosol loading is very important to know the role of atmospheric processes and the effect of local human activities in most of the sensitive parts, such as glaciers of the mountains. The diurnal variation in the atmospheric boundary layer (ABL) height (1 to 2 km) and its structure indicate an influence over the BC and other aerosol concentrations. The present study therefore focuses on the monitoring of BC and other aerosols loading over the Parbati Glacier in Himachal Pradesh. This glacier is located between 31^{0}45'- 31^{0}49' N latitude and 77^{0}45'- 77^{0}51' E longitude in the upper Beas Valley and falls under the Lesser Himalayan sub-humid belt of the Western Himalaya. The Beas valley ranges from 1000-3978 m above mean sea level (amsl) and located between 31^{0}38'N latitude and 77^{0}60'E longitude. The Parbati Glacier is the source of the River Parbati along where two downstream macro projects in a run of the river scheme are under development. Parbati HEP-II (800 MW) and Parbati HEP-III (250 MW) along with their dam sites at Barsheni (2195 m) and Siund (1312 m) are located respectively. With the economic prosperity of the present selected Parbati Glacier, it also supports a rich biodiversity and represents a unique micro-climatic habitat. The BC and other aerosols affect the climate directly as well as indirectly. The direct effects of aerosols are the absorption and scattering of solar radiation which finally leads to a change in radiation budget which create imbalance situation on the glaciers.

Objectives

- To observe the role of BC and other aerosols on the Parbati Glacier environment, and
- To analyze snow and ice chemistry of the Parbati Glacier.

Achievements

- First time, BC is being monitored at the foothills of the Parbati Glacier. Tosh is a site on the foothills of the Parbati Glacier, where diurnal variation of BC showed two peaks; during morning hour (10:00 hrs IST) and other evening hours (18:00 hrs IST). The primary peak is also known as fumigation peak in the morning, while secondary peak is less prominent in the evening. The highest mean value of diurnal BC was observed (2026.28 ng m^{-3}) at 10:00 hrs IST and minimum was (283.48 ng m^{-3}) at 04:00 hrs IST at Tosh site whereas the average concentration was 796.46 ± 91.29 ng m^{-3} (Fig. 23a).

- Looking at the source contribution of BC at Tosh, fossil fuel burning contributed 63% of the total BC. While the remaining 37% BC comes from biomass burning (Fig. 23b).

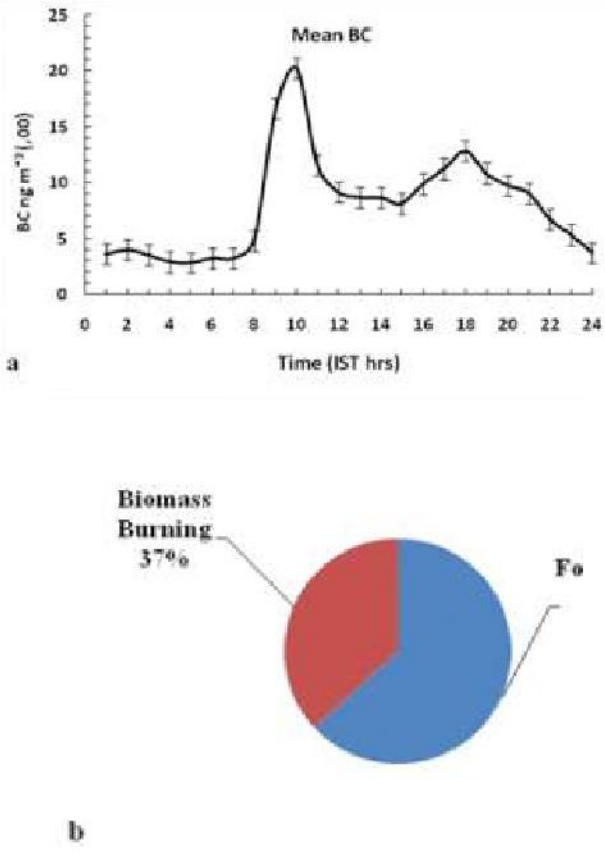
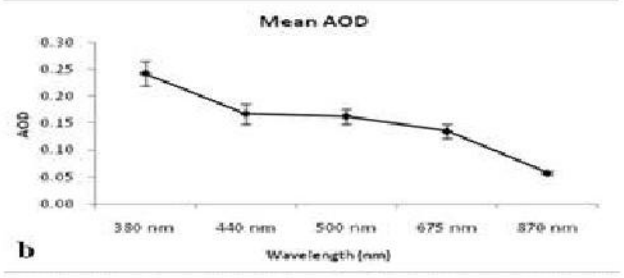


Fig 6 (a) Black carb on concentration at Tosh in the foothills of the Parbati Glacier, and (b) BC sources

- The mean AOD value at 500 nm was observed to be 0.17 ±0.01 (Fig. 24 a&b), whereas this value from minimum to maximum ranged from 0.08 to 0.25 respectively. When AOD is compared with the value over the Beas Kund Glacier (3610 m), it came to be 0.20 at 500 nm.
- The average amount of ionic components stood to be 0.37 ppm for chloride (Cl^-), 0.26 ppm for fluoride (F^-), 0.25 ppm for sulphate (SO_4^{2-}), and 0.19 ppm for nitrate (NO_3^-). On the other hand, the concentrations of the ammonium (NH_4^+) were 0.18 ppm, sodium (Na^+) 0.16 ppm, magnesium (Mg^{2+}) 0.04 ppm, potassium (K^+) 0.03 ppm and lithium (Li^+) 0.02 ppm (Fig. 24 c&d). Thus the dominant anions in snow samples were found in an order of $Cl^->F^->SO_4^{2-}>NO_3^-$, while among cations these were in an order of $NH_4^+>Na^+>Mg^{2+}>K^+>Li^+$.

- Based on the analysis of 50 samples of the snow /ice from the Parbati Glacier, the average amount of TDS and EC in the glacier snow / ice was found to be about 92 ppm, 185 µs cm^{-1} respectively. Their average pH was 8.0 indicating alkaline in nature.
- During analysis of the landsat satellite imageries, it is found that from 1962 to 2014 there was about an average snout retreat of 417 ± 144.56 m^2 which is considered to be melting at a rate of 32.08 m^2 per year.



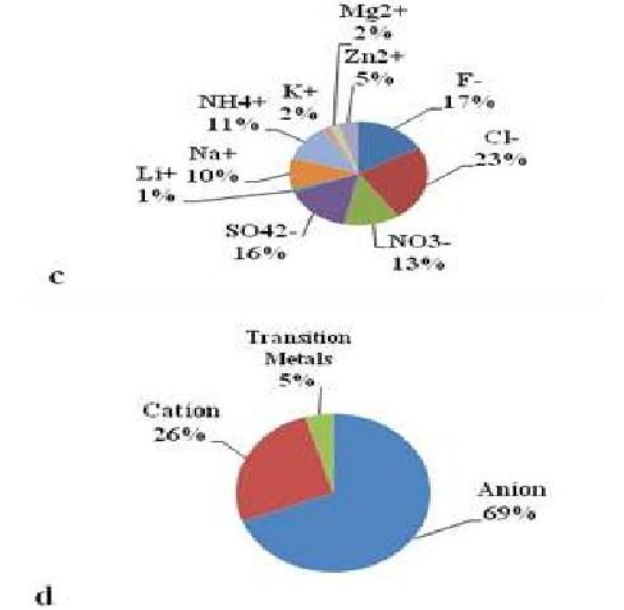


Fig. 24. Aerosol optical depth (AOD) measurements: (a) AOD measurement, (b) AOD values, and (c & d) ionic concentration in snow of the Parbati Glacier

Theme

SOCIO-ECONOMIC DEVELOPMENT (SED)

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

Indian Himalayan Region (IHR) is biologically and culturally, one of the richest regions in the country. IHR offers immense opportunity for the development of various types of tourism, such as, nature based (alpine flowers, bird watching, trout fishing), adventure (trekking, rafting, gliding mountaineering), cultural tourism (festivals, food festivals), pilgrimage (temples, monasteries), leisure (sightseeing, ropeway), agro-tourism (e.g., passage through famous Apatani rice-cum-fish fields in Arunachal Pradesh, fish catching in rice-cum-fish fields), special events (celebration of Dushera in Himachal and Uttarakhand), etc. The tourism, in turn, has potential for economic development of communities and conservation of the rich biodiversity of the region. The project envisages developing an eco-tourism model, incorporating tourism with ecology, economy, culture and community conserved areas and developing eco-tourism as a potential mechanism to promote livelihoods and conserve biodiversity. Status of selected eco-tourism sites in Himalayan States, analyses of economic relevance of eco-tourism and impact of tourism on people and environment are being studied. Technically, the project envisages understanding tourism and eco-tourism including policy issues, documenting successful initiatives, assessing of positive and adverse impacts of tourism (economic, environmental & socio-cultural) and principles and values of sustainable eco-tourism. Initially, the project is being operated in four Indian Himalayan states, namely Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh.

Objectives

- To study the status of eco-tourism in terms of goals and impacts in select pockets across IHR.
- To document, assess and map potential eco-tourism sites in IHR using RS & GIS.
- To develop an ecotourism model integrating tourism with ecology, economy and culture, where the model serves as a potential mechanism to promote livelihood and conserve biodiversity.
- To integrate eco-tourism with community conserved area (CCA)/community forests/village forests to promote livelihood and conservation ensuring CCA as potential gene bank for conservation of biodiversity through functional participation of local communities.
- To enhance community knowledge on ecotourism and conservation using concepts like people's biodiversity register (PBR) and showcase the knowledge to benefit the tourists and help the community capitalize on its indigenous knowledge to encourage conservation of natural resources.
- To inventorize biodiversity of the study site including agro-diversity to quantify impact of eco-tourism on biodiversity and highlight information gaps for improving policies on ecotourism.

Achievements

- During the reporting year, selected ecotourism destinations were evaluated for their status in terms of arrival of tourists over a period, impacts of tourism on local economy and resources, host attitude towards tourism, functioning of homestays focusing on prospects and constraints and many others.

- In Arunachal Pradesh, the ecotourism model developed at Apatani Plateau (Fig. 25) was further strengthened by adding about twenty-five culturally important more items of Apatani tribes such as traditional tools, beads, and ornaments, etc. to the museum, developed in the model. The Community based sales counter developed in this model is providing a market linkage and contributing to women empowerment. Four women groups from Hapoli, Lempia and Kallung villages of Apatani plateau managing tourist affairs. The empowerment has taken place in terms of economic benefit as the women have been able to earn independently, develop corpus fund and take decisions in running the model. 53% inhabitants reported that roads are well maintained because of tourism, 58% felt that tourism in its present form does not provide an incentive for conservation of natural resources and over 48% felt that anti-social activities has increased. 43% of 205 tourists surveyed reported internet as the main source of information about tourist destination. While their preference for stay in hotel and homestays was reflected almost equally, tourists staying in homestays (n=65) opted for it because of their preference for local cuisine and to know the culture. Survey of 11 homestays also revealed that, homestays had substantially promoted economy of the local people, with an average income of Rs 2,00,000 per year per homestay.

Fig. 25. Ecotourism model developed in Apatani plateau

- In Uttarakhand, inflow of domestic tourists has increased many-fold from 2000 to 2012. In 2000, tourists arrival in the state was about 11.13 million, which increased to about 28.4 million in 2012, registering a growth of 253%. Equal growth of international tourists was also registered in the state during the same period; as many as 1.41 lakh international tourists visited Uttarakhand in 2012 against 0.57 lakhs in 2000 registering a growth of about 247%. To understand inflow trends the reconnaissance surveys were conducted at Jageshwar and Kausani, which revealed that former station has become popular amonst foreign tourists in recent times as some prefer to stay up to 3-4 months resulting a gradual change in the income of local people along with improvement in quality of residential buildings/ houses thus increases the standard of living. In the reporting year, about 249 tourists were surveyed in Kausani (Fig. 26) for their perceptions regarding attractions, motivations, impacts, problems and suggestions, etc., and their expenditure patterns were analysed (Fig. 27). Data on river rafting for the year 2012-13 revealed that about 27,176 domestic tourists and 2,612 international tourists participated in Kaudiyala-Rishikesh sector.

Fig. 26. Monthly pattern of tourist inflow at Jageshwar

Fig. 27. Patterns of touris inflow in Kausani

- In Sikkim, tourist flow to Fambhonglho wildlife Sanctuary, Tsomgu, Baba Mandir, and Nathula was analysed; at Tsomgo (East Sikkim) during 2006 to 2014 the peak period of visit was May (Fig 28), while for Fambhonglho wildlife Sanctuary comparatively low tourist growth (9%) registered in past 18 years, which is because of lack of proper infrastructure and poor animal sightings. Contrarily the pilgrimage sites, such as Siddhesvara Dham, Samdruptse, Sai Mandir and Buddha Park in south district of Sikkim registered an annual growth rate of 32.79% during 2013 to 2014 with as many as 2,42,154 tourists arrival at these site during 2014. Field surveys conducted at tourist destinations in and around Gangtok viz. Hanuman tok, Ganesh Tok, Banjhakri falls, Rumtek and Old Rumtek monastery in East District of Sikkim revealed that about 33% tourist travel to destination for nature observation like waterfalls, greenery and nature's beauty followed by religious motives (22%). Frequency of tourists visit in Sikkim at first time is 35%, which is higher than the other categories, 24% tourist visited to destination once and 41% tourists visited to Sikkim by twice to fifth times.

- In Himachal Pradesh, listing of the major stakeholders of ecotourism in Great Himalayan National Park (GHNP) was carried out that included among others, Tourism and Community Advancement (BTCA) society, nature guides and porters, registered home stays, trout fish farmers, women groups (56 in numbers comprising 535 members), traditional beekeepers, potters, etc. 40 tourists interviewed on the quality of facilities with respect to stay and connectivity reported being highly satisfied, while 30 guides/porters assessed for their satisfaction level on different aspects of ecotourism in GHNP also reported satisfied with their work and earning.

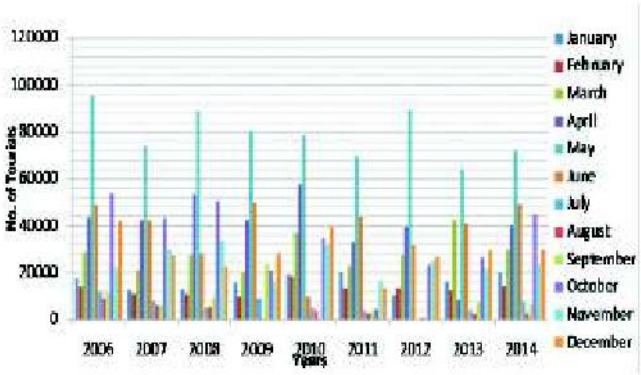


Fig. 28. Monthly tourist vist to Tsomgo, East Sikkim from 2006-2014

Summary of completed project

Wildlife Management/Biodiversity Conservation Plan for Trans-Arunachal Highways (2012 - 2015, Govt. of Arunachal Pradesh)

In Indian Himalayan Region (IHR), road network is considered to be the 'lifeline' since it provides the only mode of transport and communication. In the IHR around 70,000 km long road network is under operation and many more are under construction. The construction and improvement of roads/highway projects sometimes leads, directly or indirectly, to significant loss or degradation of natural habitats and increased wildlife mortality. As a result, road development projects frequently pose conflicts with biodiversity conservation objectives. Ecological impacts of road development projects on biological diversity are poorly studied in the IHR. Arunachal Pradesh is the largest mountain state in North-East India, covering a geographical area of 83,743 km^2 that constitutes 2.54% of the total area of the country, 15.76% of the Indian Himalayan Region and 43.62% of the Himalayan biodiversity; the state contains 11 sanctuaries, 2 national parks and 1 biosphere reserve. The recorded forest cover of the state is 67,410 km^2, which constitutes 80.50% of the geographical area of the state. There are 26 major tribe and over 110 minor tribal communities live in the state that have close association with forests. The state has only 2,027 km length of National highways, which is relatively lower than many other states of the country. Therefore the proposed Trans-Arunachal Highways (TAH) is an important initiative in the line of development of the Arunachal Pradesh. The highway is envisaged to touch eleven district headquarters out of seventeen districts (Fig.29). Considering that the development of TAH may affect the ecology and rich biodiversity of the State, the North East of GBPIHED was assigned to prepare a biodiversity and wildlife management plan for five road segments of proposed project by Department of Environment and Forest, Government of Arunachal Pradesh. The road segments comprised Nechipu to Bana (62.58 km, West Kameng district), Seppa to Passa (70.00 km, East Kameng district), Potin to Bopi (157.12 km, Lower Subansiri district), Godak to Tai (141.39 km, Upper Subansiri district) and Tai to Bame (38.43 km, West Siang district). The task included assessment of the present baseline status of biodiversity of the target area; identification of hotspots and wildlife corridors of important mammals; assessment of direct, indirect and induced impacts on flora and fauna; and formulation of a comprehensive Biodiversity Conservation and Wildlife Management Plan.

Major achievements

The proposed TAH is passing along an altitudinal gradient of 200-2500 m asl that comprised rich biodiversity and cultural areas. The vegetation comprised tropical evergreen, tropical deciduous, subtropical evergreen, subtropical deciduous, and temperate evergreen forests with rich species composition and diversity. A total 859 species of higher plants, higher and lower cryptogames were

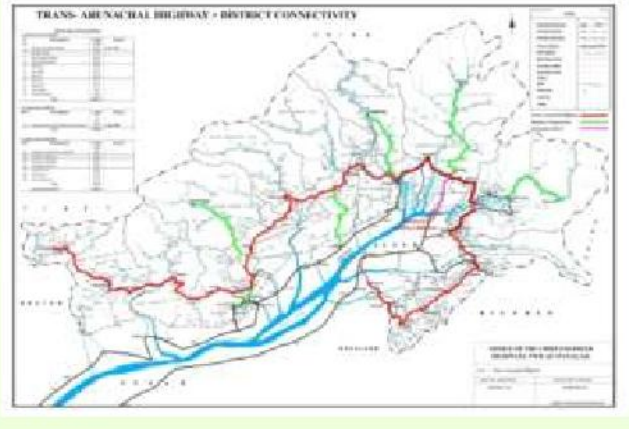


Fig. 29. Layout map of Trans-Arunachal Highways in Arunachal Pradesh

recorded from proposed road segments, which comprised 251, 193, 271 and 144 species of trees, shrubs, herbs and climbers, respectively. Of these, around 724 (84%) species have ethnobotanical importance as they are used as food, medicine, cultural and timber plants by the local tribal communities. A total of 287(33%) species were reported as rare, endangered and threatened (ret) while 23 species were endemic to North East India, Indo-China and Arunachal Himalayan region. Of these RET species, 72 species (25%) were evaluated by IUCN under different threat categories.

The proposed five road segments of TAH are rich in faunal diversity such as leopards (*Panthera pardus*), clouded leopards (*Neofelis nebulosa*), sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjak*), dholes (*Cuon alpinus*), wild boars (*Sus scrofa*), jackals (*Canis aureus*), and small cats, common squirrels, rats, avifauna and various reptilian species. A total 52 animal species of prime ethnozoological significance were recorded in the project area, which belong to different higher animal group ranging from fish to mammals and birds. Almost 80% of the animal species reported were mammals while birds represent 12% and fish and others represent only 8% out of total reported animal species. Some of the faunal species were listed in the threatened and endangered categories of IUCN.

After thorough field studies, eleven sectors were identified as biodiversity rich zones and prioritized areas for wildlife management in Potin to Bame road segment. Four biodiversity rich sectors were identified between Nechipu to Bana and Seppa to Passa road segments for taking mitigative measures, if damage is perceived, for conservation of the rich biodiversity.

The likely impact on biodiversity and wildlife as a consequence of TAH is the fragmentation of wildlife habitats and also disruption of wildlife corridors. Removal of road side trees for widening may deprive the birds, animals, reptiles, orchids, mosses, lizards and insects of their habitat in proposed TAH. Due to fragmentation and reduction of natural habitat, animals may enter crop fields and habitation, thereby increasing man-animal conflict, which is detrimental to both human and wildlife. 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. Labour camps inside the forest areas, may not only disturb their habitat, but may also increase fuel wood collection, forest fire hazard, poaching, thereby killing the ground vegetation and small animals, birds and others. Apart from habitat fragmentation, noise caused due to running of big construction equipment's, hill cutting, blasting etc. during construction phase and subsequently traffic, noise of vehicles and motor horn can certainly effect the wildlife movement and habitation along the areas of proposed road.

Keeping in view the above likely impacts on biodiversity of proposed Trans Arunachal Highway development project, various biodiversity conservation and wildlife protection measures such as conservation and relocation of rare, endangered, threatened and endemic (RETE) species, establishment of botanical garden for *ex-situ* conservation, protection of identified biodiversity rich areas and wildlife corridors, noise mitigation and management measures, afforestation and rehabilitation programme in degraded and open forests, road side plantation, removal of alien and invasive weeds, installation of biodiversity conservation sign boards in prioritized biodiversity rich zones, conservation of biodiversity through Community Based Natural Resource Management (CBNRM) approach, cultivation of medicinal and aromatic plants (MAP), implementation of effective hill slope stabilization bio-engineering technology, constitution of Biodiversity Management Committees (BMCs), organization of biodiversity education and awareness programmes, institutional support for implementation conservation activities etc. have been suggested. In addition to these activities, State Biodiversity Board, State Environment and Forest Department and BMCs may regularly monitor and evaluate the progress of Wildlife Management and Biodiversity Conservation activities.

Theme

BIOTECHNOLOGICAL APPLICATIONS (BTA)

The thematic area 'Biotechnological Applications' is complementary to the first theme of the group, i.e., Biodiversity Conservation and Management. The background of the theme is based on identification, documentation and applications of the bioresources of Indian Himalayan Region (IHR). Studies related to three major groups of bioresources, viz. plants, animals and microorganisms are the main aspects of the theme. A thorough understanding of the mechanism of plant adaptation to stress, be it physiological, biochemical or molecular aspects, is extremely relevant for increasing productivity of plants, the primary producers. Plant propagation packages, addressing the need of local people, have been developed using conventional and biotechnological tools. Documentation of animal and microbial diversity is equally important aspect of the theme. A major study on diversity and reproductive success on fish (Ichthyology) has been done in NE Unit, Arunachal Pradesh. Exploration on microbial diversity with special reference to rhizosphere microorganisms has been carried out which has led to the formulation of carrier based bioinoculants for mountain ecosystem. The microorganisms that thrive under extreme environments, from polar deserts to geothermal springs, are referred 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 focuses on to (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 (2013-2017, In-house)

Biodiversity is most valuable for the human beings directly, indirectly, aesthetically and ethically. The unique topography, diverse habitats and large altitudinal range of IHR support rich biodiversity including ecologically and economically important plants. While the country ranks 8th in its plant biodiversity, IHRwith its unique topography, diverse habitats and varied altitudinal range (200-8000 m asl) supports representative, natural, unique and socio-economically important floristic diversity. It harbors about 18440 plant species, of which 25.3% are endemic to the Himalaya. More than 1748 species of medicinal plants, 675 wild edibles, 960 orchids and 155 sacred plants have been reported from the IHR. Due to the dependence on these plants, not only for their need but also for income generation and trade, the population of many of the useful and economically/ecologically important species has depleted, and as a consequence several species are currently listed under threatened, endangered or critically endangered status. Considering the high rate of disappearance/depletion of plant species in their natural habitats, it would be pertinent to adopt conservation measures, both *in situ* as well as *ex situ*.

National Biodiversity Strategy and Action Plan (NBSAP) 2002 and Strategic Goals of the Aichi Biodiversity Targets also envisage improvement of status of biodiversity by safeguarding ecosystems, species and genetic diversity, enhancing the benefits to all from biodiversity and ecosystem services, and enhancing implementation through participatory

planning, knowledge management and capacity building. Keeping in view the local, regional, national and global importance of ecologically and economically important biodiversity elements, the present study will be conducted on above lines in Himachal Pradesh, Uttarakhand and Sikkim of the Indian Himalaya with a particular focus on the selected ecologically and economically important biodiversity elements.

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

HQs

- *In vitro* regeneration protocol of *Nardostachys jatamansi* has been developed in MS medium supplemented with different auxin and cytokinin concentration. Callus was induced from the leaf explants of aseptic culture and 88% calli showed regeneration. MS medium supplemented with TDZ and IAA showed 5 shoots/calli (Fig. 30). These shoots when transferred to MS medium containing NAA showed 75% root formation. Rooted plants were transferred to soil and vermiculite for monitoring survival percentage and growth response.

- *In vitro* production of secondary metabolites in *Nardostachys jatamansi* callus suspension culture was attempted. Maximum growth of callus (7.8 g) was obtained in the combination of BA, NAA and kinetin after 30 days of subculture. Analysis of total phenolics, flavonoids and tannins content showed higher values in callus culture treated with 8 µM methyl jasmonate as compared to leaf and rhizome collected from wild. Similarly antioxidant activity in the same combination was higher in *in vitro* callus than the sample collected from wild.

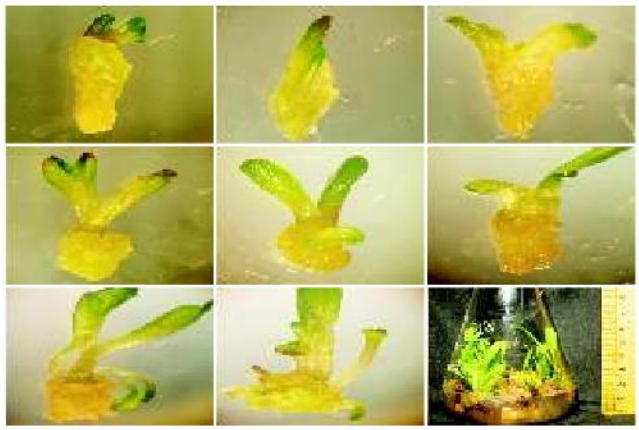


Fig. 30. Organogenesis in *N. jatamansi* from leaf derived callus

- Use of biotechnological approaches in the different *Podophyllum* species (*P. peltatum, P. hexandrum* and *P. sikkimensis)* for understanding the biosynthetic pathway of podophyllotoxin was attemted. Higher level of expression of two key genes (pinoresinol lariciresional reductase- PLR and secoisolariciresinol dehydrogenase- SDH) was observed in the rhizome of *P. peltatum* and *P. hexandrum* as compared with the leaves. Two–three fold higher expressions was observed in the rhizomes of *P. hexandrum* compared to *P. peltatum* while significantly low expression was observed in *P. sikkimensis* (Fig 31). High podophyllotoxin content was observed (1.58% DW) in the rhizomes of *P. hexandrum* and low (0.73% in rhizomes and 0.01% in leaves) in *P. sikkimensis* (Fig 32).
- In-vitro culture of *Ginkgo biloba* (old and new) trees was carried out for metabolic engineering of ginkgolide pathway to enhance the ginkgolide content in cell/tissue lines. Enhanced expression was observed in cell lines developed from the leaves of *G.biloba*.

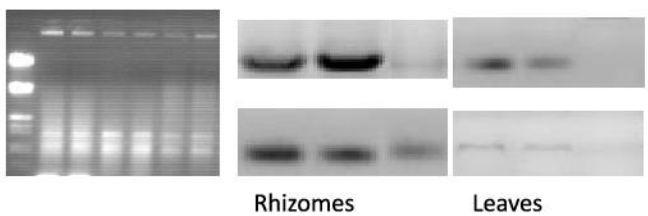


Fig 31. Differentiale expression of two key genes of podophyllotoxin pathway in rhizomes and leaves.

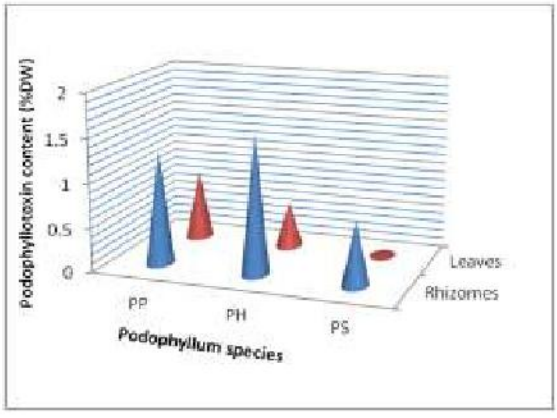


Fig 32. Podophyllotoxin content in rhizomes and leaves

Note: PLR gene-pinoresinol lariciresional reductase SDH gene-secoisolariciresinol dehydrogenase

(PP- *Podophyllum peltatum*; PH- *P. hexandrum;* PS- *P. Sikkimensis)*

- Seeds and plants of various high values species were collected and maintained in the Suryakunj-Nature Interpretation and Learning Center. 32000 saplings of multipurpose trees were distributed to diverse group of stakeholders for restoration of waste land. Similarly, around 10000 high value medicinal plants were distributed to different stakeholders in order to promote cultivation at farmers field. In addition, tissue culture raised plants of *Valeriana jatamansi* were planted in the demonstration center of Sri Narayan Ashram (3000 m asl). The survival rate and growth performance of these plantlets is being monitored.

Sikkim Unit

- Seeds collected from three different populations were preliminary tested for physiological dormancy, which lasted 3-5 months after seed maturation. Following, thiourea and GA_3 treatments promising seed germination, i.e. 50% and 40%, respectively over control (7%) was observed.
- Nursery raised seedlings of *Swertia chirayita* and *Pandanus nepalensis* were transplanted to different habitats in semi-natural sites in arboretum and maintained for their survival; on-going.
- Development of propagation protocol using in vitro methods was initiated. Fresh seeds of *Aconitum ferox* were collected in the month of November 2014 from Yumthang, Lachung, North Sikkim were germinated in Murashige and Skoog medium (MS) containing 0.8% (w/v) agar and sucrose (3% w/v) without any plant growth regulators.
- Nodal segment taken from *in vitro* germinated seedlings were inoculated in different strength of MS medium i.e. Full and half, and Anderson Medium (AM) supplemented with different cytokinins, 6-benzyladenine (BA); 2-isopentyladenine (2iP) or kinetin (KIN) at different concentrations (5, 15, 25, 35, 45 µM) with various concentrations of 2,4-D along with additives (100 mg/l PVP, 100 mg/l ascorbic acid and 10 mg/l citric acid). Callus initiation occurs from nodal segments on MS media supplemented with 25 µM BA and 5.6 µM NAA, single shoot was obtained from the nodal bud.
- Over 250 seedlings of *R. maddeni* were distributed to different stakeholders i.e., State Forest Department, local inhabitants and NGOs. 100 seedlings of Rhododendron spp. were planted at office premises during World Environment Day.
- Phytochemical studies in relation to total phenolic content, flavonoid content and antioxidant activity in the different parts (viz. leaves, stem and tuber) of *Aconitum ferox* revealed that the total phenolic and flavonoid contents of the tuber extracts showed the highest amount of total phenolic compounds (117.25 mg GAE/g extract), followed by stem (50.88 mg GAE/g extract) and leaves (44.62 mg GAE/ g extract) (Fig. 33). However, the total flavonoid content was found higher in the stem (75.18 mg QE/g extract), followed by the leaves (46.09 mg QE/g extract) and tuber (6.80 mg QE/g extract). Antioxidant activity using DPPH test

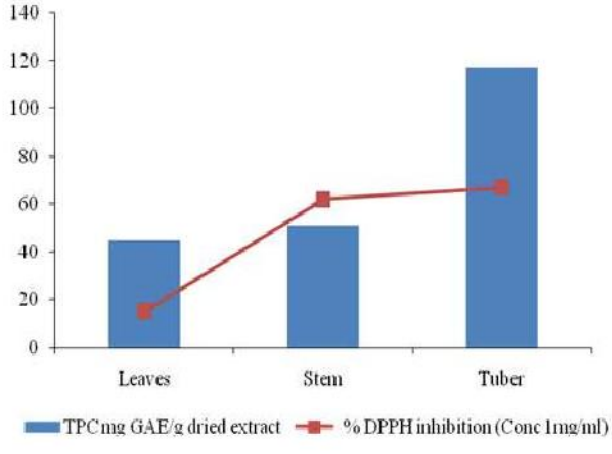


Fig. 33. Total phenolics contents (TPC) and antioxidant capacity of the methanolic extracts of different parts of *Aconitum ferox.*

showed moderate inhibition in the tuber (66.69%) and stem (61.80%) at 1 mg/ml concentration. Leaf extract showed only 15 % DPPH inhibition at 1 mg/ml concentration.

The effect of water stress on relative water content and leaf water potential in three-month old seedlings of *Spondias axillaris* revealed no change in leaf water potential in control plants during the experimental period. Leaf water potential in stressed plants started decreasing from 8 d as compared to control plants. The leaf water potential in stressed plants decreased considerably from -0.79 MPa to -2.30 MPa during the stress period; more than three times decrease in leaf water potential (Fig. 34).

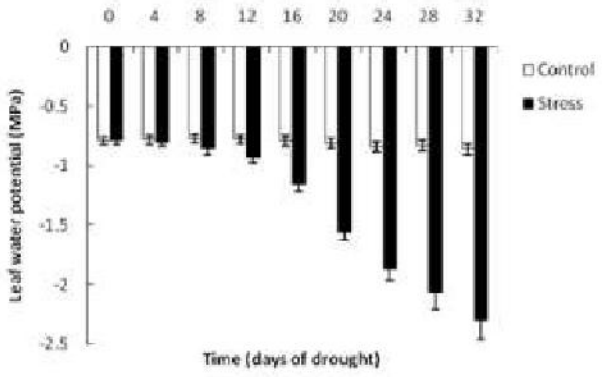


Fig. 34. Changes in leaf water potential in control and stressed plants during the drought treatment.

- A progressive decrease in soil moisture content was observed with the imposition of drought stress. The decrease in soil moisture content was observed quiet early. A significant decrease in soil moisture content was observed in water deprived pots as compared to control (watered) pots. Soil moisture content which was about 70.62% prior to imposition of drought stress decreased to 5.78%; a decrease of approximately more than 90% (Fig. 35).

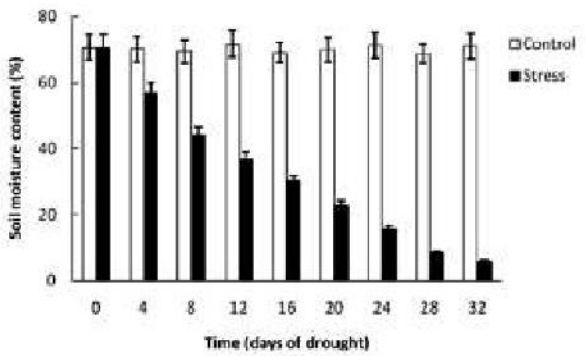


Fig. 35. Changes in soil moisture content in control and stressed pots during the drought treatment

HP Unit

- Seeds germination of *Buxus wallichiana, Corylus jacquemontii, Ferula Jaeschkeana* collected from diverse localities showed variation in germination among treatment types and concentration used. For example, *Buxus wallichiana* seeds showed cent percent germination in 15µM GA_3 as compared to 46.67% in control (Fig. 36). Seed germination experiments for *Ferula jaeschkeana* and *Corylus jacquemontii* are under progress.

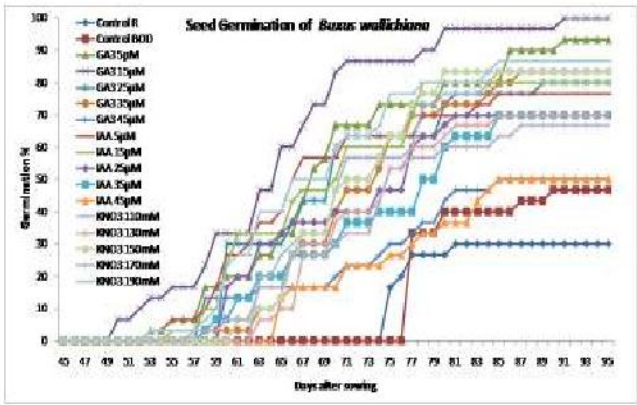


Fig. 36. Seed germination (%) following pretreatment with different growth regulators

- Stem cuttings of *Olea ferruginea Royle* treated with IAA for 5 min followed by treatment of IBA powder for 40 min, planted on peat moss, perlite and vermiculite in ratio of 1:1:2 and control (soil: farm yard manure) in nursery at Mohal, Kullu showed shooting and rooting (100% and 20%, respectively) after 60 and 540 days after plantation over control.
- Total phenolics and flavonoid contents in methanol extracts of leaf, stem and rhizome *of Trillium govanianum* Wall. ex Royle collected from Kullu (2200m) and Thirthan Valleys (2300m and 2500m) of Himachal Pradesh were quantified and their antioxidant activities were evaluated using 1,1-diphenyl-2 pycrylhydrazyl (DPPH), 2,2'–azinobis,3 ethylbenzothiazoline-6-sulphonic acid (ABTS) and ferric reducing antioxidant power (FRAP) assays. Results showed that rhizome of *Trillium govanianum* is rich source of natural antioxidants and possess significant antioxidant properties (Table 10).

Table 10. Total phenolics and flavonoids contents in methanol extracts of rhizome, stem and leaf of Trillium govanianum plants and their antioxidant activities

Plant extracts		*T. govanianum*		
		Rhizome	Stem	Leaf
Total phenolics	mg GAE/100g fw	34.93±0.60	7.68±0.27	81.29±0.47
Total flavonoids	mg QE/100g fw	30.41±0.58	19.72±0.71	135.31±2.57
In-vitro assays				
DPPH	%	92.48±1.46	21.94±0.98	55.92±0.52
ABTS	%	96.58±0.17	35.96±2.40	74.49±0.85
FRAP	µg (FeII)/g fw	2.63±0.08	1.76±0.05	2.46±0.11

Values are mean ± SE of three pooled sample populations. Each sample was analyzed in triplicates.

Extremophiles from Himalaya: Ecological resilience and biotechnological applications (2012-17, In house)

The microorganisms that thrive under extreme environments, from polar deserts to geothermal springs, are known as extremophiles. Such microbes contain enzymes (extremozymes) which function in extreme environments and have several biotechnological applications. The Himalayan region presents great variation, particularly in respect of topography as well as geographic and climatic conditions; this variation, in turn, supports a wide variety of habitats. Hot springs are manifestation of geothermal activity, provide niche habitat for a diversity of microorganisms, thermophiles in particular. The low temperature environments, such as the glaciers and cold deserts, provide excellent opportunity for studying the psychrophiles. The Microbiology Laboratory of the Institute has taken initiatives on various microbiological research aspects of IHR, covering a wide altitudinal range in 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 microorganisms. 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.

Plant-microbe interaction based studies with respect to heavy metal contamination and colonization of mycorrhizae and other endophytes in apple orchards, role of PGPRs in bioremediation of heavy metals and tissue culture protocols and determination of plant based antimicrobials with particular reference to medicinal plants are gaining attention across the HQs and the Units as well.

Objectives

- Phenotypic and genotypic characterization of extremophiles, inhabiting the extreme climatic regions in IHR (HQs), heavy metal contaminated sites (Kullu unit) and rhizosphere microorganisms (Sikkim).
- Determination of microbial activities, with special reference to production of secondary metabolites, such as enzymes, pigments, antimicrobials, with reference to 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 and NE), and bioremediation 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

- A psychrotolerant bacterial strain of *Serratia marcescens*, originally isolated from a glacial site in IHR, has been investigated for laccase production under different culture conditions. The bacterial strain was found to grow between 4 to 45 °C (opt. 25 °C) and 3 to 14 pH (opt. 5 pH) on prescribed growth medium, coinciding with production of laccase in laccase producing medium. However, the production of laccase was more consistent toward alkaline pH. Biochemical studies on production of cold active lipases and pigments from psychrotolerant fungi are in progress.
- Soil and root samples collected from apple orchards located at three altitudes were analysed for presence of heavy metals (Cr, Cu, Cd, Pb and Zn; dormant season) using Atomic Absorption Spectrophotometer and colonization of arbuscular

mycorrhizae (AM) and fungal endophytes following microscopy. The concentration of all the tested heavy metals was found maximum at 1800m followed by 1200m and 2400m altitude, respectively. While the Cd concentration was found to be above the safe limit (6mg kg^{-1} dw) at 1800m, it was not detected in soils from 2400m altitude. Higher colonization of AM and fungal endophytes was recorded as 94.0% and 75.3%, respectively, at 2400m amsl.

- In Petri dish based assays, the PGPRs namely *Pseudomonas putida* and *Bacillus subtilis* were demonstrated for their tolerance to cadmium (Cd) up to 18 µg ml^{-1} and 20 µg Cd ml^{-1}, respectively (Fig. 37).

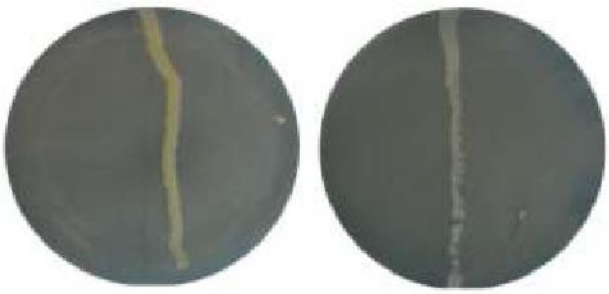


Fig. 37. Growth of *P. putida* and *B. subtilis* on 10 µg Cd ml^{-1}

- *Bergenia ciliata* growing in Sikkim has been investigated for the phytochemicals (total phenolic and flavonoid content) and antioxidant activity. Using leaf disc explants the plant species is being tissue cultured for developing the propagation protocol of the species involving microbial inoculations for hardening of the species during lab to field transfer (Fig. 38).

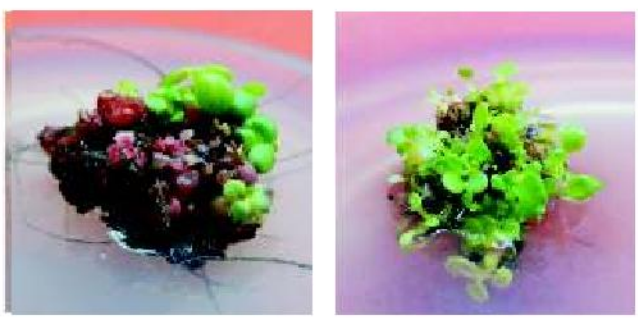


Fig. 38. *In vitro* cultures of *Bergenia ciliata* showing shoot growth from leaf-disc explants

- Investigations on bioactive constituents of three medicinal plants i.e. *Spilanthes paniculata* (leaves), *Solanum spirale* (leaves), *Drymaria cordata* (whole plant except root) are in progress with emphasis on the importance of extraction procedure and solvent in NE unit. Besides, field surveys with a view to document the ethno-medicinal information on medicinal plants of Arunachal Pradesh is also being conducted.

Preventing extinction and improving conservation status of threatened plants through application of biotechnological tools (2012-17, DBT 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 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

- To assess, map and monitor the populations of selected threatened plants of the Indian Himalayan Region
- To develop Ecological Niche Models for predicting the potential areas of distribution of the selected threatened plants

- To investigate the phytochemical properties of the selected threatened plants
- To develop efficient conventional (seed and vegetative) and micro-propagation protocols for mass multiplication of a selected threatened plants
- To evaluate performance of seedlings and plantlets raised through tissue culture and vegetative means and establish and maintain in *ex situ* and *in situ* conditions
- To establish a field gene bank incorporating all possible populations of the threatened plants

Achievements

Head Quarters

- Quantitative assessment of target species was carried out along an altitudinal gradient in Bageshwar and Pithoragarh districts of Uttarakhand. The density (Ind/m^2) of *Dactylorhiza hatageria*, *Paris polyphylla* and *Podophyllum hexandrum* was found to be ranging from 0.10-0.40 ind/m^2, 0.20-0.50 ind/m^2 and 0.10-0.38 ind/m^2 respectively. A total of 69 distributional records along with Bioclimatic variables were utilized for the prediction of potential areas of occurrence/distribution of all 4 target species with the help of ENM packages. The model test yielded satisfactory results for *A. glauca* (AUC_{train}=0.9985 and AUC_{test}=0.998), *D. hatageria* (AUC_{train}=0.9987 and AUC_{test}=0.9917), *P. polyphylla* (AUC_{train}=0.9976 and AUC_{test}=0.9966) and *P. hexandrum* (AUC_{train}=0.9966 and AUC_{test}=0.9952).
- On field morphological parameters of target species (*A. glauca* and *P. hexandrum*) were recorded. A positive correlation was observed in *P. hexandrum* between plant height and increasing altitude and the same trend was observed for stem diameter. Analysis of root and rhizome of *P. hexandrum* collected from 9 populations (2653-3640m) revealed that the podophyllotoxin content ranged from 0.238-0.489% (on dry wt. basis) in root samples and from 0.221%-0.961% in rhizomes. Maximum podophyllotoxin was found in roots (0.489%) and rhizomes (0.961%) collected from Martoli Bugyal (3640m) and minimum in root (0.238%) and rhizome (0.221%) collected from Dunyadong population (2653m).
- GC-MS analysis of essential oil of underground part of *Angelica glauca* collected from Sunderdhunga (3638m) and Dhoratoli (3404m) populations showed the presence of a total of 36 constituents among which Ligustilide Z (66.52%) and 3-Butylidenephthalide (14%) are major. The methanolic extract of roots collected from 4 populations [Lata-Kharak; 2747m, Dhoratoli; 3404m, Sunderdhunga; 3638m, Martoli; 4605m] contained 46 constituents with 3N butylpthalide (59.52%) and p-cumic aldehyde (5%) as major constituents. Based on the phytochemical content (tannins, phenols, flavonoids) in the above mentioned 4 populations, Dhoratoli population was found to contain high level of these compounds.
- To influence germination, various treatments (PGRs, organic solvents and hot water treatment) were provided to seeds of *P. hexandrum* collected from different alpine and sub-alpine areas; maximum germination of 50.08% and 78.19% was observed in seeds treated with 500µM GA_3 and 1000 µM GA_3, respectively. These seedlings are being grown and hardened for field plantation.
- Excised embryos of *P. hexandrum* were cultured on various combinations of PGRs. Shoot and root formation occurred on MS medium supplemented with 0.5 µM GA_3 + 0.5 µM BAP. Subsequently, these cultures are being sub-cultured and are maintained/multiplied for further studies.

Himachal Unit

- Total 100 populations of *Arnebia euchroma* (5), *Dactylorhiza hatagirea* (19), *Podophyllum hexandrum* (24), *Angelica glauca* (7), *Aconitum heterophyllum* (13), *Picrorhiza kurrooa* (12) and *Rheum australe* (20) were studied between 2341-4587m amsl in the Lahaul & Spiti, Chamba and Kullu districts of Himachal Pradesh. Soil of all the sites/populations was analyzed. The moisture content ranged from 0.85-54.97%, pH 4.55-8.36, total nitrogen 0.04-1.05%, organic carbon 0.117-8.08% and organic matter 0.21-13.93%.
- In *Picrorhiza kurrooa* populations, the total trees density ranged from 300-320 Ind ha^{-1}; total shrubs density 190-3590 Ind ha^{-1}; total herbs density 26.10-65.60 Ind m^{-2}; relative density 0.38-42.32 (%); Concentration of dominance for trees 0.77-1.0, shrubs 0.21-1.0, and herbs 0.06-0.34 and species diversity (H') for trees 0.0-0.46, shrubs 0.0-1.77, and herbs 1.35-3.22. In *P. hexandrum* populations, the total trees density ranged from 10-800 Ind ha^{-1}; total shrubs density 90-1110 Ind ha^{-1}; total herbs density 14.90-172.40 Ind m^{-2}; relative density 0.03-16.11 (%); concentration of dominance for trees 0.17-1.00, shrubs 0.21-1.00 and herbs 0.04-0.66; and species diversity (H') for trees 0.00-1.99; shrubs 0.0-1.77 and herbs 0.86-3.61. In *R. australe*

populations, the total trees density ranged from 170-300 Ind ha^{-1}; total shrubs density 15-1110 Ind ha^{-1}; total herbs density 6.7-84.35 Ind m^{-2}; relative density 0.12-22.22 (%); concentration of dominance for trees 0.31-1.0, shrubs 0.21-1.0 and herbs 0.06-0.34; and species diversity (H') for trees 0.0-1.18, shrubs 0.0-1.77 and herbs 1.66-3.18.

- Sixty four (64) distributional records, bioclimatic and DEM variables were utilized for the prediction of potential areas of *Aconitum heterophyllum*, *Dactylorhiza hatagirea, Picrorhiza kurrooa* and *Rheum australe* with the help of Ecological Niche Modelling packages. The model test yielded satisfactory results for *Aconitum heterophyllum* (AUC_{train} = 0.988 and AUC_{test}= 0.983±0.031) *Dactylorhiza hatagirea* (AUC_{train} = 0.972 and AUC_{test}= 0.950± 0.061), *Picrorhiza kurrooa* (AUC_{train} = 0.988 and AUC_{test}= 0.970) ±0.044 *and Rheum australe* (AUC_{train} = 0.984 and AUC_{test}= 0.968 ± 0.109)
- Seeds of *P. hexandrum* and *A. heterophyllum* were collected from Lahaul & Spiti and Kullu districts of Himachal Pradesh. Treatment of *Rheum australe* seeds with GA_3 (5 µM or 25 µM), IAA (5 µM or 25 µM or 35 µM), or KNO_3 (130mM or 150mM) resulted in 100% germination as compared to 97.78% in control condition in laboratory. In polyhouse condition, the germination percentage was however lower e.g. 15µM IAA (42.8%), 130mm KNO_3 (35%), 15 µM GA_3 (33.33%) and 150mm KNO_3 (30.91%) as compared to 19.6% in control.

Sikkim Unit

- Seeds of *Rhododendron leptocarpum* were collected for propagation experiments. Seeds germinated within 20-25 days of inoculation on hormone-free MS medium and the nodal segments obtained from six weeks old *in vitro* aseptic seedlings were used as the explants for shoot multiplication. The response of nodal segments cultured on various media types, i.e., MS, ½, MS and AM, each supplemented with 5-35 µM 2-Isopentyl adenine (2iP) were compared in terms of multiple shoot proliferation. Of the three different media tested, the frequency of multiple shoot was highest (78%) on AM medium and the lowest (68 %) on MS medium. Thus, AM medium was the best basal medium among the three media attempted.
- *In vitro* grown individual shoots were separated from the shoots of primary culture and placed in MS-liquid medium containing different concentrations of auxins (NAA, IAA and IBA) for rooting. More than one hundred *in vitro* multiple shoots of *R. leptocarpum* are currently being maintained in Tissue Culture laboratory.
- Field surveys of Peshok (Darjeeling) were conducted for the collection of propagules from all the available populations of *Phoenix rupicola*. Seed germination protocol for the *Phoenix rupicola* was developed in polyhouse and closed poly tunnel condition with various presoaking treatments of plant growth substances and systemic fungicide (Bavistin). Over 2100 seedlings and saplings have been propagated under different sowing treatments and field conditions (Fig.39).
- Zygotic embryo culture of *P. rupicola* was initiated using WP and MS media. The basal media was tested with 2-4 dichlorophenoxyacetic acid (2, 4-D) and kinetin either alone or in combination with 2iP and antioxidants. The media was solidified with phytagel. Of the various PGR treatments tested, callus proliferation occurred from zygotic embryo cultures on MS+15 µM 2-iP and 6.78 µM 2, 4-D after 120 days. On subsequent subculture onto MS

Fig. 39. Conventional propagation of *Phoenix rupicola*

+15 µM 2-iP and 15 µM kinetin, embryos proliferated; upon transfer of these embryos on to MS basal medium, they germinated into full plantlets.

Characterization of pyschrotolerant fungi with particular reference to lignin degradation under mountain ecosystem (2010-15, ICMR)

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

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

Achievements

- Psychrotolerant fungi namely *Cladosporium tenuissimum* and *Phialophora melinii* have been studied for laccase production. Laccase activity of *C. tenuissimum* was recorded almost twice at 14 °C in comparison to the activity at 24 °C. Optimum pH for fungal growth as well as laccase production was 5.5. The molecular weight of laccase determined by native PAGE was approx 48 kDa. Km and Vmax values of the enzyme were determined 0.21 mM and 0.38 mM min^{-1}, respectively. In quantitative estimations, *P. melinii* produced 21.0 ± 4.0 U/L laccase at optimum growth temperature and pH. Native PAGE study revealed 35 kDa molecular mass of the fungal laccase. Addition of carbon and nitrogen sources and organic solvents (supplements) affected enzyme activity variably. Age of the fungal culture (incubation days) was observed as an important factor for laccase production.

Eco-physiological and microbiological studies in relation to climate change along an environmental gradient in Himalayan system (2012-15, DST new Delhi)

Under the global climate change scenario, mountain regions have emerged as among the most sensitive ecosystems. These ecosystems with their vertical dimensions representing gradients of temperature, precipitation, and solar radiation from unique candidates to detect and analyze impacts of global change. In this background, the present proposal has been framed aiming to undertake systematic study across an altitudinal gradient in Uttarakhand under IHR with respect to the plant species and the soil microbial communities that experience varying level of shifts across these gradients, and thereby act as potential indicators of change. For ecophysiological and biochemical studies field experiments for two consecutive growing seasons including winter (*Triticum aestivum*) and summer (*Fagopyrum* spp.) at three study sites between 600-2200 m asl (Majhera, Nainital - 900 m, Sukhiatal, Almora - 1500 m and Shitlakhet, Almora, 2000 m asl) representing different climatic conditions have been planned, while the microbiological studies have been planned at sites (S1-Kosi-Katarmal, Dist Almora,1345m amsl; S2-Kalimati, Dist Chamoli, 1900m amsl; and S3- Lata, Dist Chamoli, 2400m amsl), representing three sets of climatic conditions with respect to cultivation of local wheat.

Objectives

1. To determine the effect of climate change on growth along with morphological, physiological & biochemical aspects in selected Himalayan food-grain crops (Target species: *Triticum aestivum*, *Fagopyrum esculentum*, *F. tataricum* & *F. cymosum*)
2. To assess the soil microbial diversity vis-a-vis rhizosphere as influenced by climate variables (in wheat).

Achievements

- In ecophysiological studies, in general, grain weight (100 seed) was found to be higher at lower altitude (900 m) in almost all the varieties, and was particularly prominent in the local variety. As far as yield is concerned maximum yield (44.5 quintals/ha) was obtained in hybrid VL-892 under irrigated conditions at 900 m asl while lowest (23.4 quintals/ha) was in local (traditional) variety growing at 2000 m under non-irrigated conditions.

- Among microbial parameters, the rhizosphere soil possessed high microbial as well as enzymatic activity in comparison to non-rhizosphere soil within a site. Results on the soil nutrients status showed that S2 possessed best soil quality in comparison to the other two sites followed by S3 and S1, respectively. The soil at S2 also coincided with the highest soil enzyme activity. However, the soil dehydrogenase activity was found to increase along with the increase in altitude.
- Microbial diversity at the three sites was observed to vary with respect to the microbial counts, antagonistic activity and pigmentation in soil dilution plates.

Studies on propagation and genetic diversity in *Zanthoxylum armatum* in Uttarakhand (2013-15, UCOST Dehradun)

The use of medicinal and aromatic plants is well known and has been used since the Vedic times for the cure of various ailments. The Indian Himalaya region (IHR) is a home to various medicinal and aromatic plants. Most of these species have slow growth rates, low population densities and narrow geographical ranges. Among various medicinal plants of IHR, *Zanthoxylum armatum* (Local name-"Timur"; family-Rutaceae) has gained tremendous importance in the recent years as it is one of the most preferred species by the local people and industries. Besides being used as a spice, in the Indian system of medicine it is used as a carminative, stomachic, toothache, fever, dyspepsia and expelling roundworms. Essential oils of *Z. armatum* exhibit antibacterial, antifungal and anthelmintics activities. It is reported to contain mostly linalool (more than 50%), limonene, methyl cinnamate, amide and cineol. Many pharmaceutical companies use *Z. armatum* for making different types of toothpaste and medicine. Natural regeneration of *Z. armatum* is reported to be poor and the same for germination under laboratory/nursery conditions and vegetative propagation through stem cuttings. The ever-increasing demand of this species by the both pharmaceutical industries, and traditional system have resulted in overexploitation; hence immediate attention is needed for sustainable management of the plant and its future availability for medicinal and other purposes. Very limited information is available about *in vitro* propagation of this species and tissue cultur raised plants have never been transferred in the field. Moreover, reports on genetic diversity and phytochemical (linalool) content amongst populations do not exist.

Objectives

- Quantification of active ingredient (linalool) content among different populations.
- Development of conventional and *in vitro* propagation protocols of elite individuals.
- Analysis of genetic diversity among and within populations of *Zanthoxylum armatum* growing in different locations in Uttarakhand.

Achievements

- Seed germination protocol and conventional propagation through air layering method has been developed (Fig. 40)
- *In vitro* propagation protocol was developed and regenerates were analysed for genetc fiedility using RAPD and ISSR marker. Results reveals hundred percent similarity between in vitro regenerates and mother plants; thus indicates that the protocol can be utilized for mass multiplication of the species for quality plant production (Fig. 41).
- Among the 19 different populations of *Z. armatum* seed analysed using GCMS, linalool content was highest in Munsiyari population as compared to others.

Fig. 40. Propagation through air layering, seed germination and tissue culture in *Z. armatum*

Summary of Completed Project / Activity (Externally funded)

Determination of antimicrobial properties of medicinal value of *Ginkgo biloba* L., growing in Indian Himalayan region (2013-15, CSIR New Delhi)

Ginkgo biloba L. (English name: Maiden hair tree), often referred as "living fossil", is the only living member of family Ginkgoaceae. While its native habitat is China, Japan, and Korea, some established trees have been reported from the hilly areas of IHR, maximum number being from Uttarakhand. *G. biloba leaves* contain pharmaceutically important flavonoid glycosides and ginkgolides which improve blood flow, act as antioxidant and mainly used as memory enhancer and anti-vertigo agent. While *G. biloba* has been well recognized for medicinally important active ingredients, the species has received limited attention for its antimicrobial properties. The project thus focuses on (i) collection of *G. biloba* plant samples from different locations in IHR, (ii) screening of antimicrobial activity of *G. biloba* plant parts (mainly leaves) against microbes (bacteria, actinomycetes and fungi), (iii) chemical determination of the antimicrobial metabolites, and (iv) separation and purification of antimicrobial metabolites from leaf extracts of *G. biloba. Five trees,* located in Almora and Nainital districts of Uttarakhand, *were selected for the collection of leaf material.* Extraction of active ingredients from powdered leaf samples was done in 5 sets- 3 pure solvent (methanol, ethyl acetate, n-butanol), fourth as combination of acetone/water (3:2) and fifth as aqueous. The antimicrobial activity assays were performed following agar disc diffusion method using 5 Gram +ve and 5 Gram -ve bacteria, 5 actinomycetes and 4 fungi as test organisms. Minimum inhibitory concentration (MIC) was determined following Clinical and Laboratory Standard Institute methodology. Total phenolic and flavonoid contents and antioxidant activity was estimated using spectrophotometer and HPLC. Factorial analysis was performed to correlate the influence of location, season and solvent on production of phytochemicals and antioxidants. Leaf extracts exhibited antimicrobial activity against all the 3 groups of microorganisms, bacteria being most sensitive (Fig. 41), followed by actinomycetes and fungi. While methanolic extract gave best results amongst the organic solvents used, aqueous leaf extract did not show any activity. The reference substances, ginkgolides, bilobalide and flavonoid glycoside also exhibited antimicrobial activity. Values obtained for MIC were found to be in line with the antimicrobial activity.

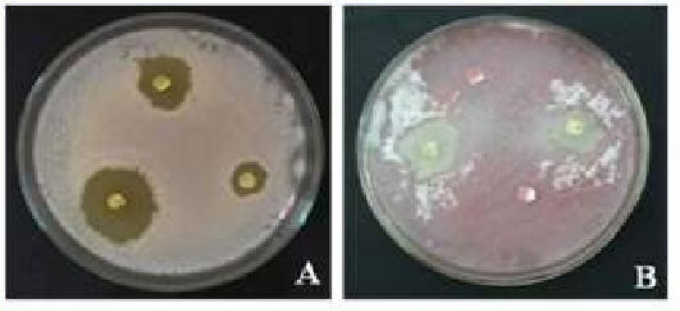


Fig. 41. Antimicrobial activity of *Ginkgo* leaf extracts against A. bacteria, and B. Fungi

Significant variations in phytochemicals and antioxidants in three *in vitro* assays (ABTS, FRAP, and DPPH), with respect to the locations, seasons and the solvents were recorded. Maximum amount of total phenolic and flavonoid contents as well as the antioxidants was obtained in autumn. Among solvents, acetone/water extracts gave best results for phenolic and flavonoid contents, methanolic extracts for ABTS and FRAP and aqueous extracts for DPPH assay. Phenolic content, the predominant indicator of phytochemicals, showed significant correlation with antioxidant activity. RP- HPLC analysis of flavonoid glycisodes also showed a significant difference among locations. These findings were further supported by HPLC analysis that was done using 3 flavonoid glycisodes, namely quercetin, kampferol and isorhmnetin in methanolic extracts for rainy season.

Summary of Completed Project / Activity (Externally funded)

Twisted chir pine in Uttarakhand: Molecular marker for early detection of 'twisted' trait at the nursery stage (2012-14, 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. Based on the literature of Civil & Soyam, Department of Forest, Almora, 81.43% chir forest has been reported in Almora district. There are two types of twist in chir trees: 1- twist in anticlock direction which is initiated at the early stage of trees at the angle of 7^{0}C and is not useful for commercial purposes, and 2- Clockwise twist is initiated at certain age and height of trees. Twenty trees of each trait (straight and twisted) from five sites of dense pine jungles were randomly selected for the study. Leaf samples of selected trees were taken for study. Pure isolated DNA was amplified using RAPD, ISSR and AFLP primers. One RAPD and 5 AFLP primer combinations were observed which were able to segregate the straight and twisted trait (Fig. 42) and more than 55% diversity was observed in the studied population. In dendrogram two distinct groups were observed, interestingly the trees which were at the initial stage of twisting were found in the straight category (Fig. 43). Simultaneously in eco-phytological parameters it was observed that altitude showed positive and significant correlation with the tree height and angle of twist whereas it was found to be negatively correlated with drum width, number of branches and number of twists. The results of this study will be helpful in developing strategies to segregate twisted and straight trait in Chir pine at an early stage not only for the plantation programmes but also for management purposes.

Fig 42. Twisted and straight pine trees and RAPD segregating profile of twisted and straight pine

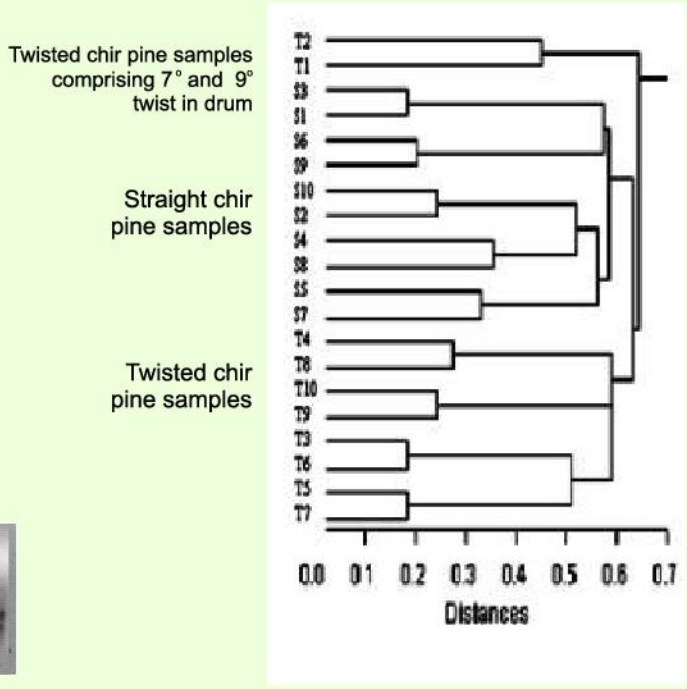


Fig 43. Dendrogram depicting segregating groups of twisted (T) and straight bole (S) chir pine trees twisted

Theme

KNOWLEDGE PRODUCTS AND CAPACITY BUILDING (KCB)

Traditionally knowledge is often acquired from particular site in the landscape of spiritual significance such as sacred lakes, rivers, forests or mountains. The traditional wisdom is based on the intrinsic realization that man and nature form part of an individual, and therefore view of traditional societies is widely reflected in their attitude towards plants, animals, rivers, and the earth. Landscapes provide the physical space for interaction with natural and biological resources and for sharing of knowledge and resources between individuals and communities. Unlike modern human societies who impact upon ecosystem from outside, traditional societies influence the functioning of ecosystem from within they being well integrated within the ecosystem boundary and deriving a variety of benefits and services. However, the way in which knowledge, cultural expressions, cultural values, customary laws, biological resources and landscapes are inextricably linked together which form and maintain the integrity of knowledge systems. All these elements play a critical role in maintaining traditional knowledge, innovations and practices. The knowledge products and capacity building (KCB) theme is using this concept to provide both a common framework for the research and as the basis for policy engagement. The focus of knowledge products and capacity building (KCB) programme is on enhancement of institutional outreach based on its research outcomes. With greater realization of the value of knowledge product, 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 to sustainable development. However, 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. The main objectives of the theme are: (i) Undertake in-depth studies on documentation and validation of knowledge (traditional/indigenous/rural) system of traditional communities including cultural, biological, material, spatial, landscape as well as intellectual components and their on-going interactions as the basis for protecting, safeguarding and improving knowledge base; (ii) Utilize natural resources for income generation using local knowledge and capacity building through S & T interventions and translate existing knowledge related to bio-and natural resources into products; (iii) Enhance capacities and skill of rural and marginal societies in harnessing the potential of knowledge systems for socio-economic development; and (iv) Provide opportunity for stakeholders to interact with each other and with institutions working on knowledge products system together to address research, action, and policy needs and help to develop appropriate knowledge sharing and dissemination to the user community at large.

Capacity Building of Mountain Communities for Use and Management of Natural Resources through Rural Technology Complex (2012-2017, In house)

The Indian Himalayan Mountains are among the most fragile and complex ecosystem in the world. In these mountain ranges majority of population is engaged in agricultural and allied activities, from which they are neither able to generate economic surplus nor to find off-farm employment opportunities.

About 70% of the total workers and more than 85% of women workers are heavily involved in land based or agriculture activities. The mountain people face a range of socio-economic and environmental problems. They live in geographical isolation under ecologically sensitive and economically constrained conditions. Poor access to appropriate technologies due to difficult topography and tough mountain conditions is one of the major causes of poverty, drudgery and natural resource degradation. Therefore, attaining livelihood security and sustainable food production through efficient management of locally available natural resources and environmental protection have always been challenging in the mountains context. Because of limited opportunities of economic development in the mountains, people are completed, particularly rural youth, to migrate and explore other options of livelihood and employment in other parts of the country. Thus, to minimize the existing rate of migration on one hand and to utilize diverse bioresources sustainably on the other, sustainable livelihood development approach focusing more on diversifying land based livelihoods generating alternative source of incomes through application of simple S & T interventions are recorded. The present activities are expected to develop a resource conservation and sustainable utilization model of natural resource management. In addition, capacity building and generation of year round employment opportunities should positively impact the stakeholders. Attainment of livelihood security coupled with food, nutrition, energy and environmental security will ensure better quality of life on a sustained basis. This will be achieved by scientific interventions, skill development of the human resource and strengthening of local institutions, etc.

Objectives

- To provide various hill specific, low cost technological interventions based on locally available resources along 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 achieved overall improvement in the quality of life of rural folk.

Achievements

- A total of 40 technologies were in-housed, tested/modified revalidated and maintained at the RTC (HQs), Triyuginarayan (Garhwal Unit) and Pangthang (Sikkim Unit) with a view to demonstrate, replicate and/ or disseminate to user groups particularly rural people and women folk in the mountains.
- During the reported period a total of 18 training and awareness programmes were conducted for different user groups (farmers/officials selected by Govt. organizations, Non-government organizations, Institute programme, students, etc.) of which 15% training/awareness programmes were Institute programmes, 60% Govt. organization, 7% Army personnel, 11% NGOs, and 7% students. A total of 654 persons (Female, 344 and Male, 305) covering 10 districts and 147 villages of Uttarakhand state were benefited (Table 11).
- Adopted 4 disaster affected villages in Kedar valley (Kaviltha, Khonu, Sirsi, Badasu, Toshi and Triyuginarayan) for strengthening and diversifying land based livelihoods options for the disaster affected people through improving ago-horticultural productivity, fodder biomass production, off-seasonal vegetable cultivation and medicinal plants cultivation, etc.
- The assessment of survival, growth and biomass of two important medicinal plants such as *Valeriana wallichii* and *Inula racemosa* has been carried out at low (560 m) and high altitude (2200 m) under different micro-climate conditions (polyhouse, shadenet and open conditions) so as to develop suitable package of practice for promoting large scale cultivation in farmers fields.

Table 11. Training and Capacity Building Programme/ Workshop organized between (April, 2014- March, 2015) for different stakeholders

Stakeholders	Total	Male	Female
Farmers selected by NGOs	62	15	47
Farmers/officials selected by Govt. organizations	298	116	182
Institute programs/or external funded projects	220	107	113
Students	44	37	07
Army Personnel	30	30	-
Total	654	305	344
Village covered	147		
District covered	10		

Threat Assessment and Conservation of Himalayan silver birch (*Betula utilis* D. Don): A Keystone Species in Timberline Zone of Central Himalaya, Uttarakhand (DST-YS, 2012-2015)

Himalaya is known for its rich biodiversity due to unique geographical setup, topography and undulant landscape the climatic conditions varied along altitudinal gradients, which attributes diversified ecological habitat ranging from tropical forest, grassland to alpine meadows with vast and diverse natural resources. The timberline forms one of the most prominent ecological boundaries in the Himalaya that marks the upper limit of the forest vegetation between 3300-3600 m in the Western Himalaya and represents an ecotone between the sub-alpine and alpine zone (Plate 1). Being an important ecological boundary, this ecotone harbors great diversity of flora and fauna and provide shelter to several endangered species and is commonly referred as timberline. Therefore, effects of anthropogenic disturbances and climatic fluctuation are known to be more prominent in this zone, which makes timberline an important area for the long-term research and monitoring. These areas have been utilized by traditional hill societies for thousands of years, providing important ecosystem services such as livestock grazing, collection of Medicinal and Aromatic plants (MAPs) and water resources.The tree line zones are mainly dominated by Himalayan birch and generally cover the ecotone or buffer zone between the coniferous forest zone and the sub-alpine and alpine areas. The Himalayan silver birch *(Betula utilis)* is a multipurpose tree species belonging to the family betulaceae. It is considered a keystone species of timberline zone sensitive to climate change. Therefore, it is very important to monitor these sensitive areas and keystone species for future changes. The *Betula utilis* is distributed across the Himalayan region between the altitudinal ranges of 3000-4200 m asl. It is generally grows with the association of *Cedrus deodara, Taxus baccata, Pinus wallichiana, Asculus indica, Abies pindrow, Acer acuminatum, Sorbus aucuparia, Prunus cornuta and Salix spp*.

Objectives

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

Achievements

- The total tree density in pure *Betula* forest was found higher (1388 ind ha^{-1}) at Valley of Flower as compared to mixed *Betula* forest (1116 ind ha^{-1}) whereas in Tolma region the reverse trend was observed where mixed *B. utilis* forest showed maximum tree density (1632 ind ha^{-1}) as compared to the pure *Betula* forest (1536 ind ha^{-1}). However, overall tree density in pure & mixed forest was recorded higher at Tolma site as compared to Valley of Flower forest.
- The maximum anthropogenic pressure recorded for *Betula utilis* by *Cordyceps* collector at timberline area of Dronagiri villages (205 kg/family/season) followed by Niti (187.2 kg/family/season), Malari (158.4 kg/family/season) and Gamsali villages (153 kg/family/season), respectively.
- The land use land cover change (LUCC) data of the National Park (NP), old Nanda Devi Biosphere Reserve (NDBR) and new NDBR highlighted that forest cover has decreased slightly from 1990 to 2013. This may be due to over exploitation of the bioresources by the people inhabited in and around the reserve (Fig. 45). However, the area under grassland has increased in NP, old and new NDBR region and this may be due to difference in radiometric resolution of TM sensor (8 bit) and ETM+ (Landsat 8) data with 16 bit resolution. On the other hand, the agriculture and settlement area has increased in old and new NDBR region from 4.90 sq km to 7.21 sq km and 0.81 sq km to 1.40 sq km, respectively.

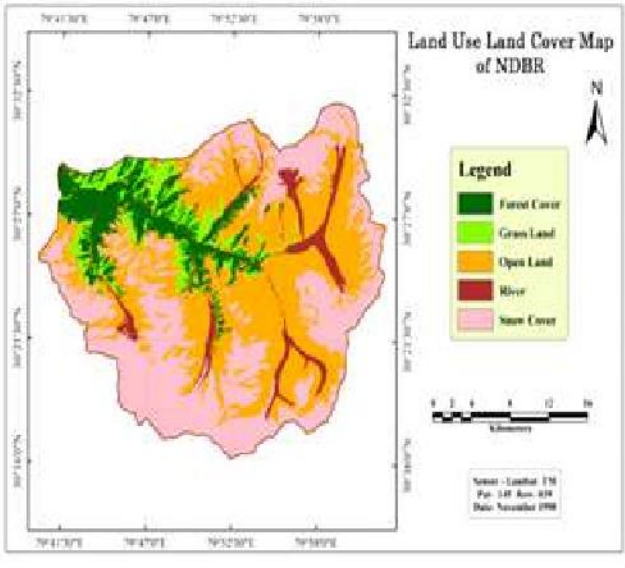


Fig. 45. Land use land cover (LULC) changes in Nanda Devi Biosphere Reserve (NDBR).

Assessment of spatio-temporal changes in *Polygonum polystachyum* and its impact on biodiversity of Alpine Ecosystem, Central Himalaya (2014-2017, DST-YS, New Delhi)

In recent years a number of studies have been undertaken on invasive species in natural environments while efforts on understanding the factors causing the success of aggressive native colonizers or fast expanding species with vast geographical ranges and impacts of such colonisations on ecosystem functions and services are limited. There is lack of ecological studies on the proliferation or colonization of native herbaceous species and their impact on other native species, particularly in the Himalayan region. The threat to the biodiversity is now increasing due to colonization of *Polygonum polystachyum* and expansion *of* other opportunistic plants (*Impatiens sulcata*, *Osmunda clatoniana* etc). *Polygonum polystachyum* commonly known as Himalayan Knotweed is an aggressive herbaceous invading and colonizing native species with vast geographical ranges and impacts suppressing other plants species particularly of high value threatened medicinal plants in the timberline and alpine ecosystem of the Western Himalaya. This species has proliferated in large area of the world famous Valley of Flowers National Park (VoFNP) and subalpine and alpine ecosystem of Nanda Devi Biosphere Reserve (NDBR) and has become colossal threat to the existing biodiversity of the region.

Objectives

- To assess the impacts of *P. polystachyum* colonization on biodiversity of medicinal and unique flowering plants in Valley of Flower National Park and Nanda Devi Biosphere Reserve.
- To document ethno-botanical knowledge system of important medicinal plants associated with the *P. polystachyum* community.
- To assess the impact of *P. polystachyum* incursionon carbon sink and sequestration potential of soils.

Achievements

- In-depth survey of colonizing and invading *P. polystachyum* (commonly known as Himalayan knotwood) across an altitudinal gradient and different habitat in VoFNP and Lata-Khark area of NDBR and adjoining area have been carried out with regard to its impact on other species. Population density of *P. polystachyum* and associated medicinal plants was monitored in the Valley of Flower National Park (VoFNP) and other subalpine and alpine ecosystem of Nanda Devi Biosphere Reserve (NDBR) and compared with the previous study in the region for better management plan.
- The diversity of herbaceous species in *P. polystachyum* areas ranged between 1.12 to 1.57 in the VoFNP and 1.08 to 1.73 at Lata-khark area along an altitudinal gradient (2800-3800 m asl). The highest density (71.87 Ind/m^2) of Polygonum was recorded at 3600 m asl in the VoFNP area followed by (64.87 Ind/m^2) in Lata-kharak area at 3800 m asl.
- *P. polystachyum* was found in limited habitats with very low density before two decades in the agroecosystem as revealed by local people however presently it is densely colonized (16.76 Ind/m^2) to the edge of agriculture farms and abandoned land adjoining to village surrounding (30.76 Ind/m^2). Even it was observed that this species is expanding rapidly (6.72 Ind/m^2) through their deep root in the agriculture field and has negative impact on the productivity of some valuable crops such as *Phaseolus vulgaris* (Kidney bean), *Amaranthus* spp. (Amaranthus) and *Solanum tuberosum* (Potato) grown in the villages situated between 2800 m to 3200 m asl (Fig. 46 & 47).

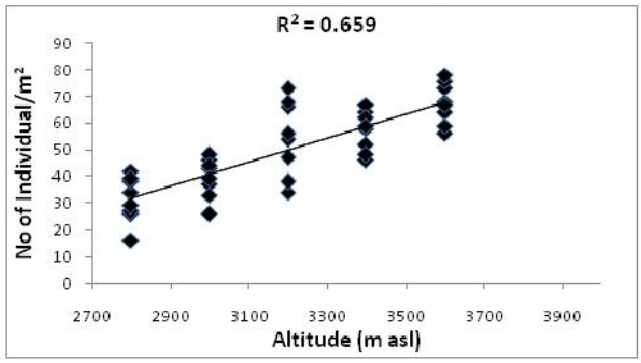


Fig. 46. Density of *Polygonum polystachyum* across an elevational gradient at Valley of Flower National Park

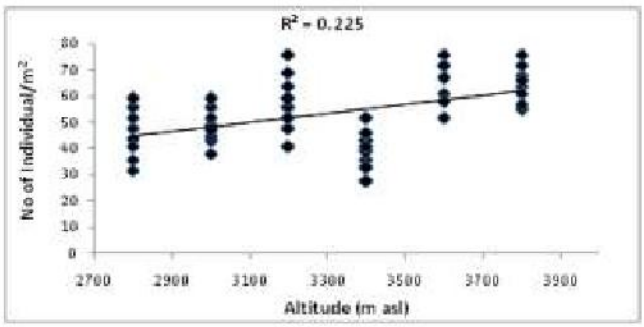


Fig. 47. Density of *Polygonum polystachyum* across an elevational gradient at Lata-kharak, NDBR

Assessment and quantification of defoliation by insect herbivory and its impact on regeneration and population dynamics of *Betula utilis* D. Don: A key stone species of timber line zone in Central Himalaya (2013-2016, DST-YS, New Delhi)

For more than a century, forest insect outbreaks, resulting in a large scale defoliation of trees, have captivated the attention of biologists and forest managers alike. The high altitude vegetation seems to have become already well differentiated and ecologically stable, whereas insect life in this region is still in the process of acquiring its high altitude characters. *Betula utilis* D. Don (birch), locally known as 'Bhojpatra', forms treeline vegetation all along the central Himalayas, and its forest is the dominant natural ecosystem in timberline zone of central Himalaya. Its significance as a source for building material, fuel, fodder and for shelter and tourism is fundamental. The seriousness and seeming novelty of this outbreak and its coincidence with a sequence of winters make it interesting in several respects including its possible dependence on climate variability and future climate dependent incidence. Defoliation of central Himalayan birch forests in timberline zone by insects herbivory is obviously the most important disturbance factor in these ecologically sensitive ecosystems. Recently it was reported that *Betula utilis* growing in association with *Abies pindrow, Rhododendron campanulatum,* and *Taxus baccata* between 3,300 to 3,600 m asl were damaged severely by defoliator moths (insects) and this probably due to a decrease in snowfall in the past eight to 10 years and a gradual increase in temperature . But yet this kind of herbivory (moth) has not yet been identified which is a serious concern for population depletion and natural regeneration of this key stone species in timber line zone of the central Himalayan region.

Objectives:

- To identify herbivory (insects/moths) damaging *Betula utilis* population in different season in selected provenance of timberline zone of the central Himalaya.
- To study the detail life cycle of the herbivory (insects/moths).
- To assess and measure defoliation rate in *Betula utilis* caused by herbivory in selected provenance.
- To assess the impact of herbivory on population dynamics, regeneration potential and phenophases of *Betula utilis.*

Achievements:

- The trend of insect outbreak on *Betula utilis* was observed in different season throughout the year which revealed that the outbreak of insect reached at its peak level in the month of June and remained up to the month of July in both the study site however, the magnitude of insect outbreak was higher in Tolma region as compared to Valley of flower. The intensity of insect outbreak was higher in Betula pure forest as compared to mix forest in both sub-sites. In Tolma region however, Betula pure forest was more susceptible to insect herbvory compared to pure forest of Valley of Flower.
- Defoliation by insect herbivory was quantified maximum (39.26%) in tree strata of *Betula* pure forest in Tolma region whereas, the tree strata of pure forest in Valley of Flower was less affected in which defoliation rate was observed (21.36%). Damage by leafminer was predominant in both pure and mix forest in both sub-sites but the frequency of birch borer and gall inducer were observed only in mix forest of the two sub-sites.
- The Damage of foliage in *Betula* pure forest by insect herbivory was 2 times greater in Tolma region as compared to mix *Betula* forest however, in valley of flower the defoliation in pure *Betula* forest was 1.5 time higher if compare to mix forest.

Model Nursery development of *Valeriana wallichii* and *Inula racemosa* under National mission on medicinal plants (2012-2015, HRDI, Gopeshwar)

Out of about 2500 plants of known medicinal value growing wild in the Indian subcontinent, 300 species are used by 8,000 licensed drug manufacturing unit in India. Rich diversity on medicinal plants occur in the Himalaya growing naturally under diverse environmental conditions i.e., from dry deciduous forest of the north-west to rain forests of the north-east and extending upto the alpine meadows. Though the region occupies only 15% of the geographical area of the country, about 30% of the endemic species of Indian sub-continent is found in this region. According to a survey report by WHO, about 25% of the prescribed human medicines are derived from plants and over 80% of the population in the developing countries still depends on the traditional or folk system of medicine. Almost all medicinal plants are collected, either legally or illegally, from the nature all over the country for the different purposes. Large scale over exploitation has resulted in the reduction of the population of many of these species in their natural habitat.Therefore, domestication and cultivation of medicinal and aromatic plants (MAPs) is one of the viable options to meet the growing demands from the industries and

reduce the extraction pressures in the natural habitats of MAPs. The available data suggests that cultivation of MAPs can be economically more profitable for farmers compared to traditional crops being grown currently in such environments. Cultivation of medicinal plants at present has limitations due to a number of factors. The most important among them is the availability of material at low prices due to large-scale collections from the wild with only collectors' labour as monetary input. Presently institute is involved in raising large number of planting materials of two important medicinal plants such as *Valeriana wallichii* and *Inula racemosa* at village common land at Triyuginarayan at an altitude of 2000 m asl. In addition, institute is also promoting of nursery of kut and kutki for their large scale cultivation in the surrounding villages.

Objectives

- To establish and develop a model nursery of selected MAPs viz., *Valeriana wallichii* and *Inula racemosa*.
- To assess the performance of the selected MAPs under various cost effective technologies viz., shade-house, poly-house and poly-tunnel and construction of water harvesting tank to facilitate irrigation.
- To develop large number of seedlings of the selected MAPs through various propagation techniques for distribution to the farmers of the nearby villages.
- To provide suitable cultivation practices and knowledge to the farmers regarding large scale cultivation of selected plant species viz., *Valeriana wallichii* and *Inula racemosa* through demonstration and training programme.

Achievements

- Developed and demonstrated huge nursery of medicinal plants having economic potential (*Valeriana wallichii* - 1.5 lakh seedlings, *Inula racemosa* - 0.25 lakh, *Picrorhiza kurooa* - 0.20 lakh and *Saussurea costus* - 0.15 lakh) under different micro-climatic conditions for large scale cultivation in the farmers field for income generation.
- Demonstrated an innovative model for the first time on integration of medicinal plant cultivation with horticultural system as a potential option to increase per unit area production and income particularly for high altitudinal region/villages located between 1600-3000 masl where climatic conditions are favourable for such kind of interventions.
- Experiments were conducted in the field to raise the planting materials of *Valeriana wallichii* and *Inula racemosa* vegetatively and through seeds under different micro-climatic conditions.

Gaps between environmental policies and human actions: a study of the impact of natural disaster in Garhwal Himalaya on the women of Rudraprayag district and their coping strategies (2014-2016, ICSSR, New Delhi)

The Central Himalaya region (Uttarakhand) is an abode of famous Hindu shrines as four Dhams (Badrinath, Kedarnath, Gangotri and Yamnotri) along with the holy Sikh shrine Hemkund Sahib are the major destination of pilgrimage/tourist across the globe and every year millions of pilgrims visit these sites for salvation and purification of sin. Among these pilgrimage destinations, Kedarnath dham dedicated to Lord Shiva and is regarded as one of the holiest shrine of the Hindus and visited by millions of pilgrim throughout the India every year. It is located in the snow cover area of Himalayan region at the height of approx 3,583 meter above sea level in the Mandakini valley of Rudraprayag District, Uttarakhand. Ironically, on June 16th and 17th of 2013 heavy rains together with moraine dammed lake burst caused flooding of Saraswati and Mandakini Rivers damaged the banks of River Mandakini for 18 km between Kedarnath and Sonprayag and completely washed away Rambara (2740 m asl), Kedarnath (3546 m asl) and Gaurikund (1990 m asl) towns in Rudraprayag district of Uttarakhand. Due to unprecedented rains of more than 4 days (400 mm) resulted into the flash floods followed by landslides at thousands of places killing more than 6000 pilgrims as well as local people. Though it was natural calamity but unplanned developmental activities by people and government authorities in Kedarnath and downstream was considered major responsible factor for causing huge human and livestock death and loss of infrastructure, property and resources. In view of this, a project was developed for analyzing the gaps between environmental policies and human actions: a study of the impact of natural disaster in Garhwal Himalaya particularly on the women of Rudraprayag district and their coping strategies.

Objectives

- To examine the role of man made factors in increasing the magnitude of the environmental crisis which washed away a large number of the people in Kedarnath Dham.
- To collect information on the awareness of local people about environmental policies.
- To highlight the gaps between the environmental policies and the human action which increased the magnitude of the losses.

- To investigate whether the authorities are competent to handle these issues and maintaining law and order effectively.
- To examine how the women are bearing the impact of June 2013 natural disaster and to understand their coping strategies in the absence of the male members.
- To find out the alternative and appropriate techniques which can be devised for empowering the women under present circumstances.

Achievements

- Detail survey was carried out to analyze the status of natural resource, agriculture production system, animal husbandry system, and livelihood status in Kedar Valley before and after disaster.
- In the Kedar valley, agriculture is major source of income of the local people after pilgrimage and tourism and it covers 15 to18 percent of the annual income of the district. Potato, Soyabean, Amaranths, Millets, Malta and Pulses are the main crops which are grown traditionally in this region. Unfortunately a total of 206.612 ha agriculture land was washed away or damaged with debris during the June 2013 - disaster. The loss of fertile land and the crops affected the people's livelihood adversely.
- Environmental and other related policies (i.e. forest policy, wild life protection, environmental education, awareness and training, disaster management act) were analysed in detail so as to understand gaps between all these policies and human actions which increased the magnitude of losses.
- Women's role and contribution in livelihood and environment management was analysed for developing coping strategies and understating the gaps between environmental policies and human actions in the Kedar valley. Among the respondents, in all the village clusters, above 73.91% respondent expressed that women may contribute a lot in improvement of the socio-economic conditions of the affected families.

R&D HIGHLIGHT OF THE REGIONAL UNITS

GARHWAL UNITS

- Assessment of food, biochemical and nutritional potential and economic valuation (Rs./Kg), value addition, conservation and commercial utilization (product development) of more than 30 potential wild bioresources/NTFPs has been worked out.
- Investigated the seasonal water scarcity and recorded the continuous water discharge data through integrated approach of isotope technique, remote sensing and GIS application, in small micro-watershed in Pauri district.
- The action and participatory research work carried out between 2014-15 in the Unit on various sectors (medicinal plant, agriculture, water and forest resources) is given due consideration by various line agencies at district and state levels and most of our findings have been incorporated in the Action plan of MNREGA, GRAMYA, horticulture mission, district planning etc.
- Assessment of farmer's perception, response, adaptation and coping strategies due to climate change impact/variability in agriculture and forests sector and their overall impact on livelihood of the people inhabited in lower and upper Nayar valley and Alaknanda catchment were carried out.
- Developed and demonstrated innovative model for the first time on integration of medicinal plants cultivation (*Picrorhiza kurrooa*, *Saussurea costus*, *Valeriana wallichii* and *Inula racemosa*) with horticultural system (apple, plum *Juglans regia* etc.) as a potential option to increase per unit area production and income particularly for high altitudinal region/villages located between 1600-3800 m asl where climatic conditions are favourable for such kind of interventions.
- Developed large nursery of medicinal plants having economic potential (*Valeriana wallichii* - 1.5 lakh seedlings), *Inula racemosa* (0.25 lakh), *Picrorhiza kurrooa* (0.20 lakh) and *Saussureacostus* (0.15 lakh) under different micro-climatic conditions (polyhouse, shade net and open condition) for large scale cultivation in the farmers fields for income generation.
- A total of six training programmes, each of two-day on "Capacity Building and Skill Development of Stakeholders with regard to Management of Bioresources through Eco-friendly Technologies, Ecotourism, Livelihood Enhancement and Entrepreneurship Development" were organised between April 2014 to March 2015 and a total of 350 participants were imparted live demonstration and training on the above mentioned areas.
- Adopted four (4) disaster affected village clusters (each cluster with 7 villages) in Kedar valley for empowering human resource particularly women and unemployed youth and farmers for capacity building / skill development in the field of livelihood enhancement, income generation and natural resource management through on-site training, exposure visit and live demonstration.
- Long term assessment of growth and carbon stock of 20 years mixed species plantation was established (following the approaches of SWEET technology) on highly degraded land (8 ha) and abandoned agricultural land (6 ha). The both sites had almost similar total (vegetation + litter + soil) C accumulation rates (2.3–2.5 mg C/ ha/ year). To our knowledge, this is first attempt of evaluating the performance of plantations on degraded land based on repeated measurements of the same sites over 20 year period in the Himalaya.

- The density diameter curve of the tree population of *Betula utilis* in mixed and pure forests at both the sites of NDBR resembled a reverse J shape. Thus, in general, it indicates that both the forests are regenerating well, although *B. utilis* found fair regeneration in both forests followed by *R. campanulatum, A. pindrow* and *C. deodara.*
- The land use land cover change (LUCC) data of the Nanda Devi Biosphere Reserve (NDBR) highlighted that forest cover has decreased and the area under grassland, agriculture and settlement has also increased slightly between 1990 to 2013 (Figure 1). The area under snow cover in 1990 is higher when compared to the same area in 2013. While the area under snow cover in the month of November was 40.96% of the total area, it was observed that in the month of December 2013 was 38.30, thus showing a declining trend in snow cover.
- In-depth survey of colonizing and invading *P. polystachyum* (commonly known as Himalayan knotweed) across an altitudinal gradient in different habitat in VoFNP and Lata-Khark area of NDBR and adjoining area have been carried out with regard to its impact on other species.
- The trend of insect outbreak on *Betula utilis* was observed in different season throughout the year which revealed that the outbreak of insect reached at its peak level in the month of June and remained up to the month of July in both the study site however, the magnitude of insect outbreak was higher in Tolma region as compared to Valley of Flowers.
- Defoliation by insect herbivory was quantified maximum (39.26%) in tree strata of *Betula* pure forest in Tolma region whereas, the tree strata of pure forest in valley of flower was less affected in which defoliation rate was observed (21.36%).
- Women's role and contribution in livelihood and environment management was analysed for developing coping strategies and understating the gaps between environmental policies and human actions in the Kedar valley. Above 73.9% respondents in four village clusters (each cluster have 10 villages) expressed that women may contribute a lot in improvement of the socio-economic conditions of the affected families.
- Two training programme (each of five days) were organized between April 2014 to March 2015 on Science Motivation for High School Science students in which about 70 students actively participated.

HIMACHAL UNIT

- 292 species of vascular plants, 135 economically important plants and 14 forest communities were recorded from Kanawar Wildlife Sanctuary. Aspect and habitat wise assessment of the floristic diversity along an altitudinal gradient. The species were analyzed for nativity, endemism, economic importance and various ecological parameters. The forest communities were represented by evergreen coniferous communities (*i.e., Cedrus deodara* and *Pinus wallichiana*); broad leaved evergreen communities (*i.e. Quercus gluca)* evergreen coniferous mixed community (i.e. *Pinus wallichiana-Cedrus deodara* mixed and *Cedrus deodara-Pinus wallichiana* mixed*).*
- Total 39 sites representing 5 populations of *Corylus jacquemontii* between 2,341– 2,621m, 16 populations of *Ferula jaeschkeana* between 1,724–3,690m, 4 populations of *Trillium govanianum* were studied between 2,724– 3,690m; 4 populations of *Lilium polyphyllum* were studied between 2,519– 3,316m and 10 populations of *Aconitum heterophyllum* between 3,880– 3,259m were surveyed and sampled in the Himachal Pradesh. In *Corylus jacquemontii* populations, total trees density ranged from 140-370 Ind ha^{-1}; the total shrubs density 0-360 Ind ha^{-1}; and total herbs density, 6.90-28.40 Ind m^{-2}; *Ferula jaeschkeana* populations total tree density ranged from 0-110 Ind ha^{-1}; total shrub density 0-290 Ind ha^{-1}; and total herb density, 10-83.30 Ind m^{-2}; *Trillium govanianum* populations, the total tree density ranged from 0-395.76 Ind ha^{-1}; the total shrub density 0-390 Ind ha^{-1}; total herb density, 13.26-28.05 Ind m^{-2}; *Lilium polyphyllum* populations total tree density ranged from 0-170 Ind ha^{-1}; total shrub density 100-304 Ind ha^{-1}; and total herb density, 17.20-86.20 Ind m^{-2}; and *Aconitum heterophyllum* populations total shrub density ranged from 0-238.7 Ind ha^{-1}; total herb density, 31.55-94.40 Ind m^{-2}.
- From Sainj Valley 417 species of vascular plants were recorded. Of these, 229 species were identified as medicinal, 68 wild edibles/food, 71 fodder, 51 fuel, 16 religious, 8 fibre, 9 making agricultural tools, 10 timber, 8 dye yielding and 12 miscellaneous purposes. 32 forest communities were recorded. The species were analyzed for various ecological parameters.
- Four representative sites (i.e., Parbati Valley, Upper Beas Catchment- above Manali, Great Himalayan National Park (GHNP), and Seraj Valley- Anni watershed) in Kullu district,

Himachal Pradesh have been selected for mapping community perceptions and vulnerability assessment of biodiversity and natural ecosystems. For the Community Perception study, a standard questionnaire was developed. Over 350 questionnaires are filled and analyzed. 627 vascular plants were recorded from GHNP (252 spp.) and Parbati Valley (375 spp.). 15 communities representing 7 aspects and 6 habitats from GHNP and 14 communities representing 6 aspects and 4 habitats from Parbati valley were delineated.

- In Upper Beas Valley, qualitative and quantitative assessment of vegetation was done. Total 176 species of vascular plants were recorded. Of these, 62 species were found to be bee/pollinators resources. From 20 sites 5 tree communities were delineated. The soil samples (25 Nos.) collected from the sampled sites were analyzed for pH, EC, moisture content, organic carbon & nitrogen. The pH ranged from 5.12-6.32, moisture content 4.30-31.29%, organic carbon 0.27-4.73% & nitrogen 0.09-1.19%.
- Insect/pollinators diversity was enumerated through scan sampling around the apple orchards in each season. Total 8 groups of pollinators i.e., European bee, Indian bee, syrphids, bumble bees, drone flies, blue bottle flies, butter flies, other wild bees, etc. were found. Pollinator density was recorded as insect visitation per 100 flowers. Amongst sites, maximum density of bees was found in Bashkola, followed by Dhamadhar, Raugi, Nashala, Mehliseri, Hirni & Karadsu. Phenological observations were recorded on leaf fall, leaf bud initiation, flower bud initiation and leaf initiation and pink flower bud initiation, flower opening, fruit setting and fruit maturation in the marked Apple, Plum and Pear trees of the six selected orchards. The Participatory Rural Appraisal exercise and questionnaire survey was conducted in seven villages to generate information on the ecosystem services.
- Floristic diversity of the undisturbed and disturbed sites of the Sacred Groves of Himachal Pradesh was assessed. Total 229 species of vascular plants were recorded. Of these, from Jamdagni Rishi Sacred Grove 62 species, Sangchul Rishi Sacred Grove 85 species, Hadimba Devi Sacred Grove 105 species, and Kalinag Sacred Grove 88 species were recorded. Total 3 communities i.e., *Cedrus deodara, Quercus floribunda*, and *Quercus leucotrichophora* were delineated from these sacred groves. For nutrient cycling, carbon content of litterfall was analyzed at seasonal interval. During summer the carbon content (%) in litter fall of Bhrigu Rishi, Sacred Grove in leaf, twig, branch and reproductive part was relatively higher than carbon content in winter. Carbon Sequestration was estimated in Bhrigu Rishi and Vasukinag Sacred Groves.
- Total 100 populations of *Arnebia euchroma* (5), *Dactylorhiza hatagirea* (19), *Podophyllum hexandrum (24), Angelica glauca* (7), *Aconitum heterophyllum* (13), *Picrorhiza kurrooa (12)* and *Rheum australe* (20) were studied between 2341-4587m amsl in the Lahaul & Spiti, Chamba and Kullu districts of Himachal Pradesh. Sixty four (64) distributional records, Bioclimatic and DEM variables were utilized for the prediction of potential areas of *Aconitum heterophyllum*, *Dactylorhiza hatagirea, Picrorhiza kurrooa* and *Rheum australe* with the help of ecological niche modelling packages. The model test yielded satisfactory results for *Aconitum heterophyllum* (AUC_{train} = 0.988 and AUC_{test}= 0.983±0.031) *Dactylorhiza hatagirea* (AUC_{train} = 0.972 and AUC_{test}= 0.950± 0.061), *Picrorhiza kurrooa* (AUC_{train} = 0.988 and AUC_{test}= 0.970) ±0.044 *and Rheum australe* (AUC_{train} = 0.984 and AUC_{test}= 0.968 ± 0.109).
- Total phenolics and flavonoid contents in methanol extracts of *leaf, stem and rhizome of Trillium govanianum* Wall. ex Royle collected from Kullu (2200m) and Thirthan Valleys (2300m and 2500m) of Himachal Pradesh were quantified and their antioxidant activities were evaluated using 1,1-diphenyl-2 pycrylhydrazyl (DPPH), 2,2'–azinobis,3 ethylbenzothiazoline-6-sulphonic acid (ABTS) and ferric reducing antioxidant power (FRAP) assays. Results showed that rhizome of *Trillium govanianum* is rich source of natural antioxidants and possess significant antioxidant properties.
- Household survey was conducted for Mohal Khad watershed with respect to individual information, demography, agriculture, livestock, water resources & disaster. Inventory of available water resources was prepared. Main source of water for agriculture and domestic use is Mohal khad and hand pumps and water-harvesting structures such as roof rainwater harvesting tanks. RS & GIS map for the watershed, drainage, stream order, Digital Elevation Model (DEM), flow direction, flow accumulation, contour, hill shade and aspect maps were prepared.
- Heavy metals of Cauliflower, cabbage, radish and tomato grown locally and sold in open urban markets of Kullu Valley and its adjacent areas were

analyzed and found contaminated with Cu, Zn, Cd, Pb and Cr. The concentrations (mg/kg dw) in above vegetables ranged between 1.9-72.1, 6-96.4, 0.06-5.7, 0.01-7.6 and 0.28-16.10, respectively. Health risk index was found more than a unit for Cu and Cd from the consumption of cauliflower in male, and tomato in both male and females, respectively. A pot based study was conducted to assess the effects of sulfur and farm yard manure application, singly and in combination on Cd accumulation and consequent response of radish *(Raphanus sativus* L. var. White icicle) grown on Cd contaminated, the farm yard manure application reduced Cd stress in test plants through altering their physiological and biochemical activities.

- Soil from apple orchards located at 1200m, 1800m and 2400m amsl altitudes were collected during dormant phase of apple growth, processed, digested and concentrations of Cr, Cu, Cd, Pb and Zn were determined. The concentrations of heavy metals were found maximum at 1800m. Per cent colonization of Arbuscular Mycorrhizae (AM) and fungal endophytes of roots of apple was studied. Higher colonization of AM and fungal endophytes were recorded as 94% and 75.33%, respectively at 2400m amsl i.e. Palchan. *Pseudomonas putida* and *Bacillus subtilis* were exposed to different concentrations of cadmium (Cd) ranging between 0-25µg ml^{-1} and their tolerance potential to Cd contamination was assessed using maximum tolerance concentration approach. Tolerance potential of above bio-inoculants was found up to 18 µgCd ml^{-1} and 20 µg Cd ml^{-1}, respectively.
- Ecotourism in GHNP was studied. Listing of the main stakeholders such as park administration, Biodiversity, Tourism and Community Advancement (BTCA) society, Sunshine adventures, 137 nature guides and porters, 20 registered home stays, 12 trout fish farmers, 56 groups of women comprising 535 members, 437 traditional beekeepers (both functional and nonfunctional), and 10 traditional potters was done. Questionnaire survey was conducted and responses guides/porters and tourists were analyzed.
- Ambient air quality (PM_{10}) and trace gases (NO_2, SO_2) of the hydropower projects in Sutlej basin were found under permissible limits in upstream (Shongtong HEP) and downstream (Rampur HEP). Water quality assessment of the affected areas showed the concentration of total hardness, Methyl Orange (M.O.) alkalinity, chloride, calcium and nitrate within desirable limits. The turbidity of the river water varied from 150 Nephelometric Turbidity Units (NTU) to 300 NTU indicating that water is not fit for human consumption due to high NTU. Soil samples of the River Ranganadi showed rich in organic matter and moderate concentrations of N, P and K. Socio-economic survey conducted in and around the project affected families. Assessment of the biodiversity was done and river discharge data of the River Ranganadi at Yazali site collected.
- Observations on trace gases such as surface ozone and its precursors, nitrogen oxides (NO+ NO_2), sulphur dioxide and carbon monoxide at Mohal (1154 m) and Bijli Mahadev (2500 m) were taken with the help of equipments. During a reporting period (2014), higher concentration of surface ozone was observed in the months of June, April and March with 26.23 ± 12 ppb, 24 .43 ± 11 ppb and 22.26 ± 12.82 ppb, respectively.
- Black Carbon (BC) was monitored at Tosh, the foothill of Parbati Glacier. The diurnal variation of BC showed two peaks; during morning hour (10 AM) and other evening hours (6PM). The highest mean value of diurnal BC was observed (2026.28 ng m^{-3}) at 10:00 hrs IST and minimum was (283.48 ng m^{-3}) at 04:00 hrs IST at Tosh site whereas the average concentration was 796.46 ± 91.29 ng m^{-3}. The average amount of ionic components i.e., chloride (Cl^-) 0.37 ppm, fluoride (F^-) 0.26 ppm, sulphate (SO_4^{2-}) 0.25 ppm, and nitrate (NO_3^-) 0.19 ppmr. On the other hand, the concentrations of the ammonium (NH_4^+) were 0.18 ppm, sodium (Na^+) 0.16 ppm, magnesium (Mg^{2+}) 0.04 ppm, potassium (K^+) 0.03 ppm and lithium (Li^+) 0.02 ppm. The analysis of landsat satellite imageries (1962 to 2014) showed an average snout retreat of 417 ± 144.56 m^2 which is considered to be melting at a rate of 32.08 m^2 per year.
- Arboretum, Herbal Gardens and Medicinal Plant Nurseries were strengthened through introduction of new accessions at Mohal, Doharanala and Kasol, Himachal Pradesh.
- Three volunteer programmes were organized jointly with Earthwatch Institute India in May (06-09), August (20-27) and October (09-18) 2014 and involved the volunteers in collection of data on different objectives of the project. Initially the volunteers were made aware about the project as whole and methodologies to be applied through LCD presentation. Then they were trained practically in the field. The programmes were organized in to four different modules; Module 1:

Introduction of Participants, Organizations and Programme briefing; Module 2: Deliberations/ Training; Module 3: Learning Sessions and Module 4: Field Surveys and Data Generations. The volunteers assisted the project research team in collection of data on qualitative and quantitative assessment of vegetation, Assessment of insect/pollinators diversity and density, phenological observation of the apple and associated crops; and different ecosystem services flowing from forest and agro-ecosystem to the inhabitants.

- Meeting with the group of different stakeholders was conducted especially with women saving credit groups (WSCGs) and for their capacity building and linking them with the entrepreneurship activities 5 days training programme (on product development) were formulated and submitted to Forest Department of Himachal Pradesh through GHNP administration for financial assistance for which they agreed.

SIKKIM UNIT

- The preparatory phase of international programme (GBPIHED-India and ICIMOD-Nepal), 'Khangchendzonga Landscape Conservation and Development Initiative in India' (KLCDI) successfully completed with very high productivity in terms of establishing strong cooperation and collaboration of various stakeholders, including Forest Departments of Sikkim and West Bengal as national partners, and developing feasibility assessment report, conservation and development strategies and strong long term implementation plan.
- First time, extensive investigations explored the habitat niches for behavioural and seasonal migration of pheasants in Khangchendzonga Biosphere Reserve (Sikkim) along high altitude zones.
- A threatened high value medicinal plant, *Aconitum ferox* identified for its population assessment, propagation and antioxidants assessment in Sikkim Himalaya.
- Meteorological profiler installed in Pangthang campus.
- Over 20 formal events were organized at regional, national and state level (workshop, consultations, meetings) with funding support from international, national agencies and in-house by the Sikkim Unit during the reporting year.
- Through multiple consultative process, for Khangchendzonga Landscape (Sikkim, Darjeeling and Jalpaiguri districts) in India, an extensive 'Feasibility Assessment' was made under Khangchendzonga Landscape Conservation and Development Initiative (KLCDI), India, and a report submitted by GBPIHED, Sikkim Unit to MoEF, Govt of India, New Delhi & shared with ICIMOD & partners
- For Khangchendzonga Landscape (Indian part) a comprehensive "Conservation and Development Strategy-Indian Part" developed under KLCDI-India programme (through LoA between GBPIHED and ICIMOD-Nepal) and submitted to MoEFCC, Govt of India for ICIMOD, Nepal.
- Implementation Plan of "Khangchendzonga Landscape Conservation and Development Initiative" in India was developed and submitted to MoEF&CC, Govt of India for ICIMOD, Nepal.
- Organized National consultation workshops and writeshop on 'Khangchendzonga Landscape Conservation & Development Initiative (India)

NORTH EAST UNIT

- The North East Unit has made visible progress in establishing ecotourism as an avenue for biodiversity conservation and livelihood development. Major achievements in this aspect included studying the status of ecotourism in terms of goals and impacts in selected study sites in Arunachal Pradesh and developing an ecotourism model integrating tourism with economy, culture and community conserved areas (CCAs) as a potential mechanism to promote sustainable livelihood and conserve biodiversity in Apatani Plateau (Arunachal Pradesh).
- A strong database has been created on ecotourism (status and trends of tourist flow over a period in NE States, survey of host and tourist attitude and perception, homestays, ecotourism polices, etc.) and the initiatives on ecotourism have facilitated and strengthened community initiatives for livelihood development, increased capacity of villagers, engagement and cooperation of local community in improved policy environment and knowledge base for innovative livelihood and biodiversity conservation.
- Towards addressing the issue of 'Transboundary Landscape' conservation, the unit organized one National Consultation Workshop and one Regional Consultation Workshop under on Brahmaputra-Salween Landscape Conservation and Development

Initiative (BSLCDI). The BSLCDI is now renamed as Landscape Initiative for Far Eastern Himalaya (Hi-LIFE).

- The Unit prepared three major documents towards operationalization of Hi-LIFE, namely 1. Feasibility Assessment Report - India, 2. Conservation and Development Strategy (CDS) and 3. Comprehensive Environmental and Socio-economic Monitoring Strategy (CESMS). The FA Report is major technical document that deals with delineation of the target landscape, description of target landscape, detailed feature of the *landscape,* drivers of change and impact assessments, existing biodiversity management and development practices, existing policy measures and enabling mechanisms, identification of priority interventions to support conservation and development initiatives, actions for enhancing regional cooperation, partners mapping and many other. The CDS highlights conservation and development based management interventions and planning needed in the defined geographic extent of the BSL landscape incorporating ecosystem management and livelihoods related interventions. It analyses existing state of the target landscape (i.e., bio-physical, socio-cultural, governance, institutional mechanisms, and policy dimensions), assesses threats, identifies priorities and proposes guidelines and specific strategies for conserving, maintaining, and promoting (i) biodiversity; (ii) cultural values, and (iii) eco-friendly sustainable and equitable development options. The CESMS highlights the need for scientific knowledge base generation and sharing, and included research and long term monitoring related interventions including regional data and information sharing interventions. It attempts to build regional and national capacity for environmental monitoring and long-term ecological/socioeconomic research, to promote the early identification of and response to potential adverse environmental impacts associated with various ongoing processes (including climate change), and to facilitate and encourage regional knowledge sharing and transboundary cooperation.
- The initiatives under taken towards strategic environmental assessment of hydropower projects in the Indian Himalayan Region have helped in the assessment and creation of good data base on biodiversity status in project areas in Arunachal Pradesh.
- With respect to study of ecological resilience and biotechnological applications of extremophiles from Himalaya, nutrients analysis of the four medicinal plants, i.e., *Spilanthes paniculata* (leaves & flower head), *Solanum spirale* (leaves), *Drymaria cordata* (whole plant except root) and *Solanum torvum* (leaves) have been carried out to find nutritional potential as they are edible and also used as vegetables. Study shows that these plants can be important source of protein and minerals for incorporation in human and animal diet.
- The Unit faculty is represented in a number of State Level Committees of Govt. of Arunachal Pradesh reflecting a strong interface between the Institute and the government and technical/expert support provided by the Unit to government in policy planning.
- Apart from Hi-LIFE Consultations, the Unit also organized two technology demonstration/ dissemination training programmes and the Unit staff participated or presented papers in more than 10 workshops/seminars.

APPLICATION OF R & D OUTPUTS IN DEMONSTRATION AND DISSEMINATION

Integrated Eco-development Research Programme (IERP) in the Indian Himalayan region (1992 - Long Term Scheme, MoEF&CC, Govt. of India)

Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India entrusted the responsibility of Integrated Action Oriented Research, Development and Extension Programme (termed 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 6 ongoing/completed projects were released to different organizations after careful examination of Utilization Certificates (UCs) and Statement of Expenditures (SEs).
- Annual Progress Reports (APRs) of 1 on-going projects was 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 (namely, Uttarakhand and Meghalaya) of the IHR.
- Twelve IERP projects were on-going in 4 States (namely, Assam, Himachal Pradesh, J&K, and Uttarakhand) of the Indian Himalayan region.
- Follow-up action on 40 project files (old/fresh/on-going/miscellaneous, etc.), excluding routine correspondences of about 322 were initiated/completed during the year 2014-15.

Strengthening and Management of ENVIS Centre on Himalayan Ecology at the Institute headquarters (1992 - Long Term Scheme, MoEF&CC, Govt. of India)

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 Forest (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

- The Centre has quantitative and qualitative databases on various aspects of Himalayan Ecology
- Addition to existing databases i.e., Himalayan Weather Profiler of selected meteorological stations, and linkages to other observational databases, subject experts located in different parts of Indian Himalayan Region, Young Researchers working in the Himalayan region, Glossary database on Himalayan Environmental related issues
- Time series databases of IHR states on demography, forests, wastelands, livestock, minerals, industries, etc.
- ENVIS Centre Publications i.e., ENVIS Newsletters Vol. 11(1-4), ENVIS Bulletin Vol. 22, 2014, State at a Glance: Himachal Pradesh, 2014, Research Abstracts on Himalayan Ecology, 2014
- Redesigned and upgradation of layout of ENVIS website (http://gbpihedenvis.nic.in)
- Addition of the new sections in website viz., Kids' corner; E-sections (e-books, reports, etc.), Himalaya in Media- print media coverage on Himalayan environmental, ecological and related issues, Information of Subject Experts, Upcoming Academic Events for wider publicity and encouragement to participation, Introduced the Bhuvan Portal link, Major activities on Man-Animal Conflict (a major issue in rural Himalaya), Swachh Bharat Mission
- Build linkages on national as well as international level with other information sources
- About 125 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 around 2170 abstracts.
- Collected around 110 news-clippings (Bilingual) on Himalayan environment related issues were collected from various national and regional newspapers for the News and Views section of the ENVIS Bulletin (Vol. 22, pp. 1-97, 2014).
- About 60 queries, related to Himalayan environment and development, were responded to the individuals/institutions, etc. during the year 2014.
- All available information on various aspects of Himalayan Ecology, which were collected and compiled during the year, were disseminated to 325 users through electronic and print media.

Central Laboratory Services

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 the water and soil samples are detected through Atomic Absorption Spectrophotometer (Make- Varian AA280Z, equipped with graphite tube atomizer). Quantification of aromatic and volatile compounds are carried out using Gas Chromatograph (make- Chemito, Ceres 800 plus). Institute is also having the facility of analyzing carbon, hydrogen, nitrogen and sulfur through CHNS-O analyzer (make- Elementar, Vario EL-III). Facility of UV-Vis spectrophotometer (make- UV 5704, Electronics Corporation of India Ltd.) is available for soil, water & plant analysis. The Institute has extended these services for other organizations (NGOs and other Government Organization) on payment basis. In the financial year 2014-15, Institute has collected Rs. 48000/- as a central laboratory service charge from 10 organizations (2 - Govt. Organization, 8 - NGOs). Apart from this, the Central Lab has also facilitated Institute research work (In-house and

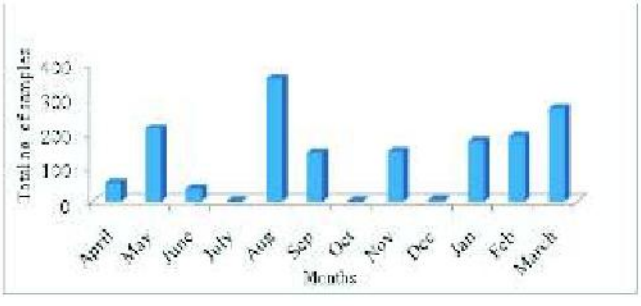
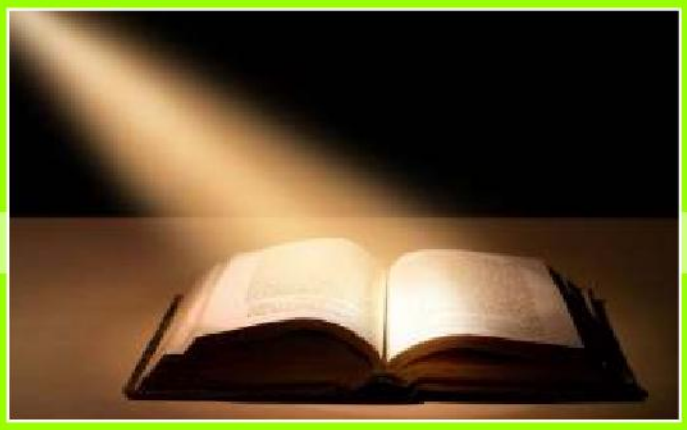


Figure 39. Graphic representation showing total samples analysed under CentralLaboratory Services in financial year 2014-15.

external funded projects) in the form of sample analysis using AAS, GC & CHNS. In the financial year 2014-15, total 1589 samples (equivalent to Rs 3.46 lakh) were analysed. Figure 39 shows month wise number of sample analysed for Institute as well as other organizations.

Strengthening and Maintenance of the Central Library at HQ

The Central Library of the Institute at its headquarters, at the end of financial year 2014-2015, has 16,546 books. The library is subscribing a total of 91 periodicals (51 Foreign and 40 Indian). For 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, 245 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.



MISCELLANEOUS ITEMS

1. SCIENTIFIC PUBLICATIONS
(I) SCIENTIFIC JOURNALS
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Participation in Different Events

Events	HQ	Units				Total
		NE	Sikkim	Garhwal	HP	
National						
• Symposia/Conference/Workshop	26	8	24	17	19	94
• Training Courses	8	2	2	12	7	31
• Meetings	30	5	26	40	12	113
• Participation as a Resources Person	20	7	23	18	44	112
• Any Other	31	1	44	-	35	111
International	12	1	8	3	4	28

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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, 2015, 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, 2015 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 2015.**

(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

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. In place of Income Tax Act 1961 and Income Tax Rules.

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 : 19/06/2015

Place : Almora

For Anil Shalini & Associates
(Chartered accountants)

Anil Kumar Shukla
FCA Partner
M No. 075418
FRN. 009960C

G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
BALANCE SHEET AS ON 31ST MARCH 2015

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
LIABILITIES			
CORPUS / CAPITAL FUND	1	113308796.69	95836449.46
RESERVE AND SURPLUS	2	405545815.49	408340285.60
EARMARKED / ENDOWMENT FUNDS	3	0.00	0.00
SECURED LOANS & BORROWINGS	4	0.00	0.00
UNSECURED LOANS & BORROWINGS	5	0.00	0.00
DEFERRED CREDIT LIABILITIES	6	0.00	0.00
CURRENT LIABILITIES AND PROVISIONS	7	115391097.03	93674666.07
TOTAL		**634245709.21**	**597851401.13**
ASSETS			
FIXED ASSETS	8	405545815.49	408340285.60
INVEST. FROM EARMARKED/ENDOWMENT FUND	9	104227276.69	87774172.72
INVEST. OTHERS	10	0.00	0.00
CURRENT ASSETS , LOANS, ADVANCES ETC.	11	124472617.03	101736942.81
MISCELLANEOUS EXPENDITURE			
TOTAL		**634245709.21**	**597851401.13**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES & NOTES ON ACCOUNTS	25		

AUDITOR'S REPORT
As per our separate report of even date annexed.
For: Anil Shalini & Associates
CHARTERED ACCOUNTANTS

(Anil Kumar Shukla)
FCA PARTNER
M.N0.075418
FRN : 009960C

DATED : 19.06.2015
PLACE :ALMORA

(DR. P.P. DHYANI)
DIRECTOR

19.6.2015

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

19/6/15

(SURYA KANT)
FINANCE OFFICER

G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
INCOME & EXPENDITURE A/C FOR THE YEAR ENDED 31ST MARCH 2015

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
INCOME			
Income from Sales/Services	12	261188.00	60583.74
Grants/Subsidies(net off exp)	13	173950320.41	151735964
Fees/Subscriptions	14	0.00	0.00
Income from Investment	15	0.00	0.00
Income tfr from Fixed Assets fund	-	24156971.55	23267360.35
(to the extent of depreciation & WDV of asset sold)		0.00	0.00
Income from Royalty, Income from Inv. Publication etc.	16	0.00	275.00
Interest Earned	17	11527112.23	2124907.00
Other Income	18	5684047.00	5876511.00
Increase (decrease) in stock of Finished goods and work in progress)	19	0.00	0.00
TOTAL (A)		**215579639.19**	**183065601.09**
EXPENDITURE			
Establishment Expenses: a) Institute	20	88526998.00	78319286.00
b) Projects		13240661.00	10908350.00
c) F.C (Projects)		4596477.00	3407623.00
Administrative Expenses :a) Institute	21	42854225.41	37159797.00
b) Projects (As per Annexure)		12077170.00	12022310.00
c) F.C (Projects)(As per Annexure)		10530716.00	5713473.00
Expenditure on Grants, Subsidies etc.	22	2124073.00	4205125.00
Interest			
Depreciation (Net Total at the year-end-as per Sch. 8)		24156971.55	23267360.35
TOTAL (B)		**198107291.96**	**175003324.35**
Balance being excess of Income over Expenditure (A - B)		**17472347.23**	**8062276.74**
Transfer to special Reserve			**0.00**
Transfer to/ from General Reserve			**0.00**
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Other Income)		**9081520.00**	**8062276.74**
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Corpus Interest Income)		**8390827.23**	**0.00**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	25		

AUDITOR'S REPORT
As per our separate report of even date annexed.
For: Anil Shalini & Associates
CHARTERED ACCOUNTANTS

(Anil Kumar Shukla)
FCA PARTNER
M.NO.075418
FRN: 009960C
DATED : 19.06.2015
PLACE :ALMORA

(DR. P.P. DHYANI)
DIRECTOR

19.6.2015

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

19/6/15

(SURYA KANT)
FINANCE OFFICER

G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
RECEIPTS & PAYMENTS A/C FOR THE YEAR ENDED 31ST MARCH 2015

RECEIPTS	CURRENT YEAR	PREVIOUS YEAR	PAYMENTS	CURRENT YEAR	PREVIOUS YEAR
I. Opening Balances			**I. EXPENSES**		
a) Cash in hand	38540.53	52844.53	**a) Establishment Expenses**	76983888.00	65079973.00
			i) Institute		
b) Bank Balances			**b) Administrative expenses**		
			a) Institute	22511088.00	23673316.00
i) In current accounts	0.00	0.00	b) RMD(Rev) expenses	16693195.00	14623096.00
ii) In deposit accounts (Corpus Fund)	442204.81	31666.81	c) Payments for current liabilities(gratuity/leave)	28154.12.00	4358819.00
iii) Savings accounts	47808329.74	33518861.66	**C. Capital expenditure**		
c) Advances & Others	22360993.84	104283937.01	a) Purchase of Fixed Assets	1276518.00	18440765.00
(As per annexure Attached)			b)Expenditure on Capital Work in Progress	0.00	5300000.00
F.C. ACCOUNT			c) Acquirement of land (Lease money)		
A) Cash in hand	900.33	9004.33	**II Payments made against funds for various proj.**		
b) Cash at bank	16086723.36	2110183.93	**Expenditure State govt. projects**		
c)FC Advances	5459208.67	2580181.67	a) Capital	7421941.00	3579894.50
II. Grants Received			b) Revenue:		
a) From Government of India	130000000.00	140000000.00	Establishment exp	13080104.00	10790428.90
i) Institute & IERP			Administration exp	1206610.00	11838896.00
			Expenditure FC projects		
b) From Other agencies	65896043.00	34473479.00	**a) Capital**	1175542.00	1460557.00
c) From other sources (from FC)	131111878.64	27192252.43	**b) Revenue:**		
III. Income on investments from			Establishment exp	4432282.00	3297585.00
a) Corpus Fund(Received from Institute)	8062276.74	1503131.00	Administration exp	10630716.00	5713473.00
IV. Interest Received			**IERP grant released**	2124073.00	4205125.00
a) On Bank deposits savings a/c	3800760.00	2088120.00	**III Investments and deposits made**		
b)On term deposits a/c	2491450.16	5136875.00	Corpus Fund	23389000.00	34780900.00
c) Loans, Advances etc.	370120.00	553558.00	**IV Refund of Surplus money/Loans**		
			a) To the Government of India	2107044.00	800833.00
V. Other Income			b)To Others/ security/ caution money	140000.00	241800.00
(As per annexure Attached)	5998235.00	5087091.74	**V Other payments**		
VI. Amount Borrowed			Other Payment to Instt. FC Proj	829404.00	287437.00
VII. Any other receipts.			Unspent Balance (FC)	39616.48	0.00
			Refund of EMD	0.00	0.00
			Fund transfar to Corpus fund	8062276.74	4503131.00
a) Other Receipt FC a/c	13500.00	14404.00	**VI Closing balances**		
b) Receipts Current Liabilities	6577.00	190159.00	**a) Cash in hand**	30404.04	38540.53
c) IERP grants refunded by grantee Org.			**b) Bank Balance**		
d)Construction Fund			i) In Current account		
e) Corpus Fund FDR'S	19709000.00	21982306.00	ii) In deposit accounts (Corpus Fund)	29331.71	99234.81
f) Caution Money	8500.00	3500.00	iii) In savings accounts	71844063.98	47808329.74
g) Security Deposit					
h) EMD	89750.00		**C) Advances and others**	27119163.35	22591993.84
i) Royalty	0.00	275.00	**FC Project**		
j) Sales Tax / VAT	6709.00	3891.00	a) Cash in hand	15624.33	900.33
k)Service Tax	13576.00	0.00	b) Bank Balance	3595548.37	16086723.36
			c) Advances and others	12870100.82	5459208.67
			Adjustment of previous year closing Advances	0.00	83280892.77
TOTAL	**332539097.82**	**387769385.05**	**TOTAL**	**332539097.82**	**387769385.05**

AUDITOR'S REPORT
As per our separate report of even date annexed.
For: Anil Shalini & Associates
CHARTERED ACCOUNTANT

(Anil Kumar Shukla)
FCA PARTNER
M.NO.075418
FRN: 009960C
DATED : 19.06.2015
PLACE :ALMORA

(Dr. P.P. DHYANI)
DIRECTOR

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

(SURYA KANT)
FINANCE OFFICER

G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
SCHEDULE FORMING PART OF BALANCE SHEET AS ON 31ST MARCH 2015

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	542536.00	135634.00	0.00	678170.00	3390856.00	3526490.00
2	**BUILDING:**										
	a) On Freehold Land	214751988.00	0.00	0.00	214751988.00	40186089.01	3500457.40	0.00	43686546.41	171065441.59	174565898.99
3	**PLANT MACHINERY & EQUIPMENT**										
	a) Scientific Equipments	183748422.11	11465486.00	0.00	195213908.11	98529136.37	9064474.70	0.00	107593611.08	87620297.03	85219285.29
4	**VEHICLES**	10124840.30	0.00	0.00	10124840.30	8387270.57	992877.83	0.00	9380148.39	744691.91	1737569.73
5	**FURNITURE FIXTURES**	28232828.40	1802496.00	0.00	30035324.40	19249668.12	1901236.03	0.00	21150904.15	8884420.25	8983160.28
6	**OFFICE EQUIPMENT**	29995112.35	979557.00	0.00	30974669.35	17501172.50	2942593.59	0.00	20443766.09	10530903.26	12493939.85
7	**COMPUTER/PHERIPHEARLS**	1174435.00	1210522.00	0.00	2384957.00	55785.66	113285.46	0.00	169071.12	2215885.88	1118649.34
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	52122.55	2895.70	0.00	55018.24	5943.76	8839.46
9	**LIBRARY BOOKS**	107565316.50	5904440.00	0.00	113469756.50	49257886.40	5389813.43	0.00	54647699.84	58822056.66	58307430.10
10	**TUBE WELLS & W. SUPPLY**										
11	**OTHER FIXED ASSETS**										
	GLASS / NET HOUSE	3911549.00	0.00	0.00	3911549.00	3255591.66	113703.41	0.00	3369295.07	542253.93	655957.34
	TOTAL OF CURRENT YEAR	**583710118.89**	**21362501.00**	**0.00**	**605072619.89**	**237017258.84**	**24156971.55**	**0.00**	**261174230.40**	**343898389.49**	**346692859.61**
	PREVIOUS YEAR	**560426012.89**	**23284106.00**	**0.00**	**583710118.89**	**213737138.07**	**23267360.35**	**0.00**	**237004498.42**	**346692859.60**	**346688874.96**
	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	61647426.00	0.00	0.00	61647426.00	0.00	0.00	0.00	0.00	61647426.00	61647426.00
	ASSET UNDER INSTAL/TRANSIT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	T O T A L	**645357544.89**	**21362501.00**	**0.00**	**666720045.89**	**237017258.84**	**24156971.55**	**0.00**	**261174230.40**	**405545815.49**	**408340285.61**

Anil Shalini & Associates Chartered Accountants DELHI

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

STATEMENT OF OPENING & CLOSING BALANCES

PARTICULARS	OPENING AMOUNT	CLOSING AMOUNT
Grant in aid in transit (Biotech-XIII)	184000.00	184000.00
Cheque in transit: (HP Unit)	125000.00	0.00
Cheque in transit: (G Unit)	0.00	0.00
Cheque in transit: (Sk Unit)	200000.00	0.00
Cheque in transit: (N.E. Unit)	277465.56	0.00
Advances		
Electrecity Charges Recoverable	4575.00	4575.00
House Building Advance	1669351.00	1154815.00
Motor cycle/Car Advance	103975.00	103975.00
Festival Advance	38625.00	42750.00
Computer Advance	9000.00	0.00
Income tax deducted at source	191498.00	191498.00
Units of Institute:		
Sikkim Unit	-49630.83	-63012.83
HP Unit	-63896.00	14691.00
Garhwal Unit	0.00	0.00
NE Unit	160.78	73083.00
FDR (Margin Money/LC A/C)		
Institute	0.00	0.00
DST NMSHE	0.00	878000.00
DST SERB JCK H. P. Unit	0.00	2687000.00
SAC S. Trafdar G. Unit	0.00	536000.00
TOTAL:	**2690123.51**	**5807374.17**

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

Brought forward	2690123.51	5807374.17
Due Staff/ other IC A/c		
Sh. C. M. Sharma (Imprest)	0.00	5000.00
Dr. A. K. Sahani (T.T.A)	65000.00	0.00
Dr. R. C. Prasad (L.T.C)	100800.00	0.00
Dr. S. C. Ram (L.T.C)	71145.00	0.00
STUP Consultant	(7435.00)	(7435.00)
M/S International Trade Links, Mumbai	34328.00	34328.00
LICOR INC USA	54460.00	0.00
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
Adv. a/c of Airport Handling Service (SERB JCK H. P. Unit)	0.00	186835.00
VPKAS Almora (Instt.)	26560.00	26560.00
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
Siltop 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.)	222000.00	222000.00
NRSA Hyderabad- Grant in Aid (NNRMS Proj.)	638441.00	638441.00
NRSA Hyderabad (ISRO GBP SSS)	350000.00	350000.00
NRSA Hyderabad (DST-KK-I)	7400.00	7400.00
Vanicia Enterprises (MOE&F NBA RSR)	7100.00	7100.00
CCU New Delhi	10123178.00	10123178.00
NRSC Hyderabad (SERB GCSN)	200000.00	200000.00
Security Deposit NE Unit	1750.00	1750.00
Adv. a/c of NRSC Hydrabad (Snow & Glacier KK)	0.00	62020.00
EE R E S Almora (MOE&F IBG) RSR	3402000.00	3402000.00
EE R E S Almora Institute	1571000.00	1571000.00
WWF New Delhi (UNDP-CEC GOI) NE Unit	-31930.00	-31930.00
Adv. a/c of M/s Mahindra & Mahindra Mumbai	0.00	1853206.00
E E R E S Almora (HRDI) D.B. Project	59000.00	59000.00
Adv. a/c of Chief Secretry Nagaland (Mountain Division)	1500000.00	0.00
Adv. a/c of Meteorological Department	8000.00	8000.00
Adv. a/c of Chief Coservator Eco Toursm D. Dun (Mountain Division)	500000.00	500000.00
Adv. a/c of NRSC Hydrabad (Project No. 04)	48000.00	48000.00
Adv. a/c of of FRI Dehradun MoE&F (NNRMS)	805000.00	626104.00
Adv. a/c of Contration Division II Pay Jal Nigam (MoE&F Botanical Ga	1495800.00	2493000.00
FC Advances to Units	(2160107.67)	(1883148.82)
TOTAL	**22590993.84**	**27119163.35**

FC Advances:

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
GBPUA&T, Pantnagar, PDF-B-GEF	266564.00	266564.00
XSPUH&F Solan, PDF-B-GEF	150956.00	150956.00
Uttrakhand State Biodiversity Board ICIMOD-RSR (LOA-I)	1702000.00	3327500.00
Adv. a/c of VPKAS PDF B GEF	0.00	268410.00
Adv. a/c of Dr. R. S. Rawal (ICIMOD RSR KSLCDI	0.00	65000.00
Adv. a/c of Dr. G. C. S. Negi (ICIMOD RSR KSLCDI	0.00	50000.00
Adv. a/c of Uttarakhand Forest Deptt. ICIMOD RSR KSLCDI	0.00	4405000.00
Adv. a/c of Himalayan Gram Samiti ICIMOD RSR KSLCDI	0.00	1273950.00
FC ADVANCES TO UNIT	2160107.67	1883148.82
	5459208.67	**12870109.82**

Anil Bhatia & Associates
Delhi
Chartered Accountants

INSTITUTE SUPPORTING STAFF

HEAD QUARTERS

Mr. Anil Kumar Yadav	Administrative Officer
Surya Kant Langayan	Accounts Officer
L.M.S. Negi	Office Superintendent (Admn.)
Sanjeev Higgins	Technical Gr. – III(2)
Mahesh Chandra Sati	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.
Suraj Lal	L.D.C.
Jagdish Singh Bisht	Technical Gr. – II(1)
Chandra Lal	Driver
K.N.Pathak	Technical Gr. – I(3)
Pan Singh	Peon
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

P.P.Dhyani	Director	Plant Physiology; Restoration Ecology
Kireet Kumar	Scientist-G	Environmental Engineering; Hydrology
S.K. Nandi	Scientist-G	Plant Physiology; Biochemistry
R.C. Sundriyal	Scientist-F	Plant Ecology; Rural Ecosystems
Anita Pandey	Scientist-F	Microbiology
D.S. Rawat	Scientist-F	Settlement Geography; Rural Ecosystems
R.S. Rawal	Scientist-F	High Altitude Ecology; Conservation Biology
R.C. Prasad	Scientist-F	Library & Documentation
G.C.S. Negi	Scientist-E	Forest Ecology; Watershed Management; EIA
Subrat Sharma	Scientist-D	Agroecology; Remote Sensing / GIS
Paromita Ghosh	Scientist-D	Plant Science; Soil Science
I.D. Bhatt	Scientist-D	Plant Physiology; Phytochemistry
R.K. Singh	Scientist-D	Information Technology
Ranjan Joshi	Scientist-D	Ecology Economics; Resource Valuation
Rajesh Joshi	Scientist-D	Mathematical Modeling
K.C. Sekar	Scientist-D	Plant Taxonomy; Animal Taxonomy
Shilpi Paul	Scientist-D	Molecular Biology; Plant Biotechnology
Vasudha Agnihotri	Scientist-C	Soil Science; Plant Analysis; Instrumentation
Sandipan Mukherjee	Scientist-C	Climate Change; Ecosystem Services
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-F & In-charge	Plant Taxonomy; Conservation Biology
J.C. Kuniyal	Scientist-E	Development Geography; Waste Management
R.K. Sharma	Scientist-D	Policy Analysis; Environmental Management
Sarla Shashni	Scientist-C	Rural Entrepreneurship and Small Business
Vaibhav Eknath Gosavi	Scientist-B	Hydrology; Watershed Management
Kishore Kumar	Tech. Grade IV (1)	Zoology

SIKKIM UNIT

H.K. Badola	Scientist-F & In-charge	Morphoanatomy; Conservation Biology
K.K. Singh	Scientist-F	Plant Physiology; Stress Physiology
Mithilesh Singh	Scientist-C	Plant Tissue Culture; Bioprospecting

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