ANNUAL REPORT

2015-2016

RESEARCH | DEMONSTRATION | CAPACITY BUILDING

गोविन्द बल्लभ पंत हिमालय पर्यावरण एवं विकास संस्थान

G.B. Pant Institute of Himalayan Environment & Development

An Autonomous Institute of Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India

Kosi-Katarmal, Almora 263 643, Uttarakhand, INDIA

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Member Secretary

Nominated by the Director, GBPIHED
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Scientist 'F'/Scientist-in-Charge
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CONTENTS

FOREWORD

The mandate of the institute presents new challenges as well as opportunities to pursue R&D activities and development of roadmap that is able to address and reconcile important environmental concerns of the Indian Himalayan Region (IHR). The region is very sensitive to climate change and there is growing evidence that mountains are experiencing changes in temperature higher than the global average. At the backdrop of such pronounced changes the institute has evolved with more innovative and collaborative national and international research. The institute has demonstrated a multi-scale approach, with strong interconnections between local/regional/global dimensions and trans-boundary interconnections. The decisive path taken up is from research to development and dissemination, which attempts to address the diverse needs of several stakeholders, dependent on the Himalaya for its ecosystem services. It has also made sincere efforts in identifying problems, developing region-specific approaches, demonstrating their efficacy in the fields and disseminating information to various stakeholders.

The year 2015-16, witnessed implementation of a new national mission, several new initiatives, execution of Memorandums of Understanding (MoUs), and other innovative steps to strengthen the on-going R&D programmes and activities. Under the National Mission on Himalayan Studies (NMHS), a Central Sector (CS) Grant-in-Aid Scheme, (Govt. of India) attaches the highest priority to better understand and protect this unique but highly fragile ecosystem. It aims to provide much needed focus, through holistic understanding of system components and their linkages towards addressing the key issues relating to conservation and sustainable management of natural resources. Ultimate goal is to improve quality of life and maintain ecosystem health in the region.

Among the different environmental issues with specific R&D targets, the Institute focused on (i) development of vulnerability database with reference to Strategic Environmental Assessment (SEA) of hydropower projects and addressing issues on changing water resource scenario; (ii) establishment of eco-tourism model for livelihood improvement by involving diverse components, such as nature, adventure, cultural, pilgrimage, leisure, and agro-tourism, etc. (iii) understanding biodiversity patterns and processes under changing resource use and climate scenario in IHR and its ecological and social implications; (iv) assessing alpine ecosystem dynamics and impact of climate change in Indian Himalaya; and (v) promoting conservation and sustainable use of biodiversity using biotechnological approaches, etc.

Moreover the Institute continued to strengthen and promote research outreach, via capacity building programmes of different stakeholders on environment-friendly technologies through Rural Technology Centre (RTC) and its extension programmes. 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. kept the developmental cycle rolling with active participation of diverse stakeholders. In addition, increasing pace and presence of the Institute's R&D results in peer-reviewed scientific journals, of national as well international repute, are examples of conscientious efforts, bearing testimony of institute's raising standards.

As the Director of this premier Institute, it is my consistent endeavor to strengthen the existing programmes and formulate new ones, thus fulfilling the commitment as envisaged in the Institute's Vision Document. I take this opportunity to acknowledge the valuable support and directions provided by the members of the Apex Bodies, the Scientific Advisory Committee, the Governing Board, the Society, and all my colleagues in the Institute HQs and Regional Units for their untiring efforts. Valuable suggestions and critiques of readers are always welcome to keep the Himalayan journey interactive and enlightening in all respects.

(P.P. Dhyani)
Director

MAJOR ACHIEVEMENTS (2015-2016)

- Vulnerability database developed with reference to Strategic Environmental Assessment (SEA) of hydropower projects in the Sutlej basin. Studies undertaken on black carbon and other aerosols measurements over snow and impact on melting of the Parbati Glacier in the Kullu Valley assessed.

- Empirical studies initiated on ground water control behaviour through drilling shallow well in hard rock in the Dugargad watershed.

- Floristic diversity of the Upper Beas Catchment (51 sites), Parbati valley (115 sites), Sainj Valley (48 sites), Great Himalayan National Park (35 sites) and Sacred Groves (42 sites) was assessed and analyzed for community patterns, nativity, endemism, use patterns and vulnerability.

- An ecotourism model has been developed at Apatani Plateau in Arunachal Pradesh for better livelihood options with several components, such as nature, adventure, cultural, pilgrimage, leisure, and agro-tourism, etc.

- A total of 75 populations of different medicinal plants, i.e., *Dactylorhiza hatagirea* (8), *Podophyllum hexandrum* (24), *Angelica glauca* (16), *Aconitum heterophyllum* (9), *Picrorhiza kurrooa* (6) and *Rheum australe* (12) were studied between 2345-4002 m asl. A total of 64 distributional records, bioclimatic and digital elevation model (DEM) variables were utilized for the prediction of potential areas of *Aconitum heterophyllum, Dactylorhiza hatagirea, Picrorhiza kurrooa* and *Rheum australe* using ecological niche modelling.

- Towards contributing for sustainable development goals, under goal 2 - end hunger, achieve food security and improved nutrition and promote sustainable agriculture, assessment of nutritional and nutraceutical potential of selected wild edible plant species of Indian Himalayan Region was attempted. Initial results revealed that several species have nutritional and medicinal value and, therefore, can become potential source for nutraceutical and pharmaceutical industries.
- Propagation packages of different threatened and high value medicinal and multipurpose species (i.e. *Nardostachys jatamansi, Aconitum ferox, Carpinus viminea, Bergenia cilliata*, have been developed for mass multiplication and thereby promoting cultivation and reintroduction in the natural habitat.

- Characterization of a polyextremophilic bacterium i.e., *Pseudomonas chlororaphis* with respect to plant growth promoting (PGPR) characteristics has been finalized.

- First time, extensive investigations explored the habitat niches for behavioural and seasonal migration of Blood pheasant and Satyr Tragopan in Khangchendzonga Biosphere Reserve Sikkim.

- To build capacity of diverse stakeholders, the Institute organized 26 training programmes for different users groups (viz. farmers, govt. officials, NGOs, students, army personnel, and others) that benefitted 1422 persons (Female 628, Male 794).

- Towards promoting outreach, Institute strengthened its initiatives pertaining to: (i) Himalayan Research Fellowships (i.e., 89 JRFs and 30 RAs in 12 organizations created), (ii) Himalayan Young Researchers Forum (organized 2nd meet of young researchers - representation of 9 states), (iii) People's Representative meet (2 meets of Himalayan Parliamentarians, 1 meet of Himalayan legislators organized), and (iv) Himalayan Popular lecture series (organized 5 popular lectures on topical issues of Himalayan environment and development).

Publications:

1. Peer Reviewed Scientific Journals		
National	-	41
International	-	53
2. Chapters in Books/Proceedings	-	60
3. Authored/Edited Books/Booklets/Bulletins/Monographs	-	19
4. Popular Articles	-	12

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 is the core issues covered under most programmes conducted by the Institute. A conscious effort is made to mobilize a variety of stakeholders (students, researchers, academicians, farmers, citizens, policy makers, and others) together with the development processes through different initiatives. 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 2015–16 is as follows.

WATERSHED PROCESSES AND MANAGMENT (WPM)

During the year the major R&D activities of the Watershed Processes and Management Theme focused on evolving an understanding of glacier recession and dynamics, hydrological functioning of glaciers and mid-Himalayan watersheds, general water resource scenario across mid-altitude zone in IHR, linkages of glacier dynamics and hydrology, role of tributary glaciers in recession and hydrodynamics, possibilities of improving water allocation and use efficiency, identification tectonic deformation strain fields, and farming systems their productivity issues and impact of climate change. The activity-wise major achievements of the theme are as under.

Under the study 'Ecological, social and policy implications of changing water scenario in the Indian Himalayan Context' efforts were made to develop the current water scenario through field measurements and perception study, hydrological assessments, climatic records, inventorization of water resources and indicator observations. The water requirements of six demand sites namely Someshwar, Almora, Lamgara, Khairna, Betalghat, and Ramnagar in Kosi watershed was assessed which varied from $6.80*10^7$ l/yr (minimum) in Lamgara to $4.82*10^9$ l/yr (maximum) in Ramnagar. Perceptions and river water flow measurements revealed summer months as the water scarcity period. In Himachal people ascribed less investment in water resource conservation and management as the major reason for the water scarcity. In the project 'Farming systems and changing climate regime: Impact of biophysical and social drivers on the farm yields in Central Himalaya' the important physical, social, and biological drivers/ factors affecting the productivity of major agricultural and horticultural crops pertinent to study area were identified. The time series data on crop area of three major crops i.e. wheat, rice, and Madua vis-à-vis drivers was statistically analyzed to see the impact of individual factors. The human perceptions on climate change were analyzed against socio-economic variables and revealed better response with age, education, and awareness of climate parameters i.e. temperature/precipitation, etc. Similarly, the adaptation response was positively affected by household size, livestock ownership, irrigated land, and economic investments, and gender of household. In the MoES funded project –'Geo-dynamics and hydro-chemical study of Gangotri Glacier System' DGPS observations on glacier recession were recorded through continuous monitoring of snout and glacier surface. For Gangotri glacier an average retreat rate of 10.24 m/yr for period 2005-2015 was deduced. In the study 'Operation of permanent and campaign mode GPS stations for quantification of tectonic deformation field in Himalayan terrain GPS monitoring of 6 identified permanent stations located at Almora, Gangtok, Nainital, Kullu, Ziro and Srinagar-Garhwal was continued to measure their relative drift and hence the strain fields/ build-up with respect to the reference stations (at Hyderabad and Bangalore). GPS field campaigns through revisiting identified locations/ control points, 10 in Gori Valley and 10 in Kali Valley in a wide spatial range from Shivaliks to Trans-Himalaya were carried out for understanding of local level strains. The velocity

of permanent sites IISC, HYDE was observed to be ~ 52 mm/year and that of GBPIHED stations ranged between 40 mm/yr to 47 approximately.

BIODIVERSITY CONSERVATION AND MANAGEMENT (BCM) AND ECOSYSTEM SERVICES (ES)

During the reporting period this theme focused on understanding biodiversity patterns and processes in the Indian Himalayan Region under changing climate scenario. Intensive biodiversity data sets were generated under diverse aspects. Studies in Kanawar Wildlife Sanctuary (HP) and Kanchendzonga Biosphere Reserve (Sikkim) contributed for strengthening information base on floristic diversity and community composition, and investigations 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 Hat-Kalika watershed. More importantly the data sets generated on abundance and regeneration of these species in forests 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 in Uttarakhand. Through a project on vulnerability assessment of floristic diversity of the Parbati valley in H.P. concluded that anthropogenic pressures and changing environmental conditions may lead to the extinction of five different plant species in near future. Rapid sampling of the floristic diversity in Sainj Valley recorded 330 species of vascular plants, of these 161 species were native, 8 species endemic and 60 species were near endemic to the Indian Himalayan Region. Through all India coordinated research project on Sacred Grove and Ecosystem Services Assessment, floristic diversity data sets for 42 sites (27 undisturbed and 15 disturbed) for floristic diversity between 1460 – 2053 m amsl in Bhrighu Rishi, Rupasana Devi, and Jamdagni Rishi, Peej Sacred Groves in H.P. were collected. 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 (H.P.), Nanda Devi Biosphere Reserve (U.K.) 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 H.P. were investigated. At the landscape level, studies in Kailash Sacred Landscape (KSL) in U.K., and Kanchedzonga Landscape in Sikkim 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, U.K., Mohal, Doharanala and Kasol in H.P. and Pangthang, Sikkim. Under the Ecosystem Services theme the focus was on climate change impacts on ecosystem services in the Indian Himalayan region. Studies on 8 selected forest species (dominant canopy and sub canopy) across the altitudinal gradient revealed that timing and extent of leafing was highly dependent on ambient temperature across the north and south aspects of the four forest types. In all the eight species studied, 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 for all the species. This great 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.

CLIMATE CHANGE (CC)

Climate Change Theme is one of the youngest themes of the Institute which was introduced this year. The vision of the theme is self sustenance by 2020 with a leading role in climate change research and advisory in the Indian Himalayan Region. The mission statement of the theme is - "Bridging between research and practice on impacts of climate change in identified key sectors in the Himalaya." Research has been initiated in climate sensitive sectors- (i) natural vegetation - monitoring of alpine and treeline vegetation, and development of climatic envelopes of sensitive plant species, and (ii) social sector – vulnerability assessment on water resources in rural landscape and demonstration of adaptive strategy for management. It is envisaged that outcome of the integrated action of the theme will provide adaptation and mitigation options to impacts of climate change with respect to current policy context (national and state level) for the Indian Himalayan Region. With its inception resources have been generated through extra-mural funding.

ENVIRONMENTAL ASSESSMENT & MANAGEMENT AND ENVIRONMENTAL GOVERNANCE AND POLICY (EAM & EGP)

The Theme of Environmental Assessment and Management and Environmental Governance and Policy (EAM & EGP) successfully achieved its targets during 2015-16. The ongoing activities pertaining to the EAM & EGP theme during reporting period were mainly focused on 7 projects out of which 2 belonged to in-house and 5 externally funded projects mainly from PRL Ahmedabad, and SPL, VSSC, Thiruvanthapuram under ISRO GBP, DST, New Delhi and National Mission for Sustaining the Himalayan Ecosystem (NMSHE), New Delhi. In-house projects like (i) strategic environmental assessment (SEA) of hydropower projects in the Himalayan Region aims at vulnerability assessment, land hazard zonation within a stretch of 582 km^2 from Rampur to Khab in the Satluj basin and impacts of HEPs activities in downslope regions especially the fish species has been identified due to introduction of a series of projects to provide guidelines for framing policy and to influence the same for policy, plan and programme. This study primarily took into account the Sutlej basin in Himachal Pradesh, and the Ranganagi hydroelectric project in Arunachal Pradesh. The second in-house project under Mountain Division of the theme is titled (ii) 'climatic variables and their impact on Environmental Flow in the river Sutlej basin in Himachal Pradesh'. This project deals with water quality assessment during pre- and post-monsoon season in the Sutlej basin. In the Tangling village, respondents perceived that the livelihood options of the local people do not directly depend on the river Sutlej because they still use traditional water springs as their major water source. About 55% of the total villagers perceived fishes were disappearing due to construction activities like dams, tunnels, roads, etc. The project activities from third to fourth 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. The externally funded projects were: (iii) gaseous air pollution in the background site of sprawling urban environment of Himachal Pradesh, (iv) aerosol climatology over the northwestern Indian Himalayan region, Himachal Pradesh, and (v) black carbon and other aerosols loading, and their impact on melting of the Parbati Glacier in the northwestern Himalaya, India.

SOCIO - ECONOMIC DEVELOPMENT (SED)

- An ecotourism model was developed at Apatani Plateau in Arunachal Pradesh and strengthened by adding various cultural items which are based on nature, adventure, cultural tourism, pilgrimage, leisure, agro-tourism, etc. As many as 305 respondents were assessed in 12 villages in Apatani Plateau, while 100 hosts were assessed in 14 villages of West Kameng District.
- A SWOT analyses has been carried out for recording the tourist flow in summer season as well as winter season for various tourist places in Uttarakhand.
- An assessment of tourist arrival at Great Himalayan National Park (GHNP) in Himachal Pradesh and their positive and negative impacts on park and surrounding areas was studied through conversing with 90 respondents.
- Documented land, soil and water management practices like rice-fish cultivation, forest management strategy, shifting cultivation (*jhum*), patches (*Patat* system) of land for crop production, etc. which are used locally by the tribal communities of Arunachal Pradesh in Apatani.
- Documentation of local land races, traditional agricultural tools, storage items and other implements has been initiated in Bageshwar (Uttarakhand) where communities have high dependence on forest for fuel, fodder, leaves for animal bedding, medicinal plants, timber for house construction, and other NTFPs.
- Documentation of traditional bio-resource use pattern, traditional bamboo basketry art and traditional handicraft items in Lahaul & Spiti, Kullu and Mandi districts of Himachal Pradesh have been initiated.
- Documentation of *Terminalia chebula, Berginia ciliata, Zinziber officinale, Hordeum vulgare, Taraxacum officinale, Eupatorium adentophorum* and various other plants in traditional health care system in central Himalaya have been done.
- A one-day workshop cum training programme on "Sustainable harvesting, collection practices and product development of Wild Rosehips" has been organized; 500 women participated and were trained on importance of rosehips, its collection practices, sustainable harvesting techniques, and drying and storage methods.
- One thousand saplings of 21 tree species (viz. Banj, Utis, Tajpatta, Ritha, Phalyant, Bottlebrush, Sadabahar, Bamboo, Mulberry, Padam, Deodar,

Chinnar, Bedu, etc.) have been planted in Nanda Van at Almora, Uttarakhand to improve the degraded land and after one year, the survival of plants was recorded as 79% at the highly degraded site whereas it was 84% at the less degraded site.

BIOTECHNOLOGICAL APPLICATIONS (BTA) & ENVIRONMENTAL PHYSIOLOGY (EP)

The themes Biotechnological Applications and Environmental Physiology are focusing on the utilization of biotechnological methods for improving the productivity, developing propagation protocols for mass multiplication, assessing physiological and biochemical attributes of the high value plants, and identification and characterization of microbial diversity with respect to their biotechnological applications and conservation. During the reporting year, the themes focused on the development of synthetic seed production in *Nardostachys jatamansi*, propagation protocols of *Bergenia ligulata*, *Valeriana jatamansi*, *Podophyllum hexandrum*, *Aconitum ferox*, *A. heterophyllum*, *Trillium govanianum*, *Rhododendron* spp., *Paris polyphylla*, *Pittosporum eriocarpum*, *Corylus jacquemontii, Swertia chirayita*, *Michelia excelsa*, *Spondias axillaris,* etc., assessing nutritional and antinutritional properties of *Paeonia emodi*, *Spilanthes axillaris*, morphological and physiological responses of tissue culture raised *Valeriana jatamansi*, etc. Use of microbiological techniques for the isolation and characterization of microbes from different crops field was also carried out in the reporting year. For instance, a psychrotolerant, wide pH tolerant and halotolerant strain of *Pseudomonas chlororaphis* GBPI_507 (MCC2693), isolated from the wheat rhizosphere growing in a mountain location in IHR, has been investigated for its antimicrobial potential with particular reference to phenazine production and plant growth promoting traits. The benzene extracted compound identified as phenazine-1-carboxylic acid (PCA) through GC-MS in the exhibited antimicrobial properties against Gram positive bacteria and actinomycetes. Molecular studies confirmed production of PCA by the bacterium GBPI_507 through presence of *phzCD* and *phzE* genes in its genome. For thermophilic bacteria, the growth curve studies with respect to amylase production are in progress. Pure cultures of bacteria, actinobacteria and fungi are being maintained in a microbial culture collection established in Microbiology Laboratory and regularly being accessioned by National/International Depositories. The themes are also focusing on the investigation of nutraceutical potential of wild edible fruits so that the same can be used for supplementing the diet of Himalayan people. Utilization of ecological niche modeling for prediction of suitable habitat and reintroduction of threatened plant species in Himalayan region is ongoing process. The theme is also working on the optimization of drying conditions for medicinal plants produce so that the suitable cost effective technology for drying the produce can be provided to the farmers. 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

- A total of 40 technologies were collected, tested/modified and maintained at different Rural technology Centres (RTCs) at Headquarters, Triyuginarayan (Garhwal Unit), and Pangthang (Sikkim Unit) with a view to replicate and/ or disseminate.
- A total of 26 (21 at HQs, 4 at Garhwal Unit and 1 at Sikkim Unit) training and awareness programmes were conducted for different user groups (and 1422 persons covering 07 districts and 114 villages of Uttarakhand, and 01 district of Sikkim state were trained.
- Developed a model nursery in which about 2.75 lakhs plants of *Valeriana wallichii* and *Inula racemosa* were raised at RTC, Triyuginarayan. About seventy five thousands seedlings of *Valleriana wallichii* were distributed to the interested farmers of village Tarsali (district Rudraprayag) and village Pokhri (Pauri district) for large scale domestication and cultivations in the farmers field and facilitated marketing of the final product through Emami Pvt. Ltd.

1. INTRODUCTION

During the year 2015-16, 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), Unit (Srinagar-Garhwal), Sikkim Unit (Pangthang) and NE Unit (Itanagar). More recently to look into mountain issues more holistically and bring in mountain perspective in plans and policies, the fifth unit of the Institute has been established at MoEF&CC, New Delhi. Over the years, the Institute has taken significant strides in identifying problems, developing region-specific approaches, demonstrating their efficacy in the field and disseminating information to various stakeholders. The diverse problems thus addressed were related to ecology, resource conservation, traditional practices, livelihood opportunities, land restoration, propagation protocol development, biotechnological interventions, etc. The Institute implements its activities through core funds provided by the Ministry of Environment and Forests (MoEF), Govt of India, and the projects financed by external funding agencies (National and International). The Institute also supports activities of various partner Institutions 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). Recently in July 2015, the Institute has created four new themes namely (1) Environment Governance and Policy (EGP); (2) Ecosystem Services (ES); (3) Climate Change (CC); and (4) Environmental Physiology (EP) in order to strengthen the research and development activities of the Instititute. All these 10 themes have been grouped under 4 different groups. These include, (1) Watershed Processes and Management, Environmental Assessment and Management and Environment Governance and Policy (WPM, EAM & EGP); (2) Biodiversity Conservation and Management, Ecosystem Services and Climate Change (BCM, ES & CC); (3) Socio-economic Development and Knowledge Product and Capacity Building (SED &KCB); and (4) Biotechnological Applications and Environmental Physiology (BTA&EP).

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 2015–2016 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

Awareness on mitigation of climate change impact

A two-days training and capacity building programme on mitigation of climate change impact on agriculture and livelihood through participatory approach was organized by Garhwal unit of GBPIHED at Pokhari village, district Pauri Garhwal, Uttrakhand between 16-17 March, 2016. The workshop provided an umbrella for sharing experience and ideas among wider stakeholders such as scientists, officials of state government line departments, villagers, NGOs, and students in the context of climate change impact on traditional farming system and promotion of organic cultivation and climate resilient technologies to cope the adverse impact of climate change. Shri Harak Singh Rawat, Additional Commissioner and CDO, district Pauri Garhwal was the chief guest of the programme. Scientist in-charge of the Unit briefed about the factors responsible for climate change and its impact on different sectors directly linked to livelihood of the people while providing appropriate measures and strategic action to cope with current situation by adopting eco-friendly technologies at local level. About 135 participants from different sections of the society participated in the programme. The participants were motivated and encouraged to adopt simple eco-friendly technologies for livelihood enhancement. In concluding session of the programme, open discussion was held among the stakeholders to identify the important factors/drivers for climate change and vulnerabilities that the farmers are facing and suggested the areas and possible options.

Promoting natural resource based livelihood

A two-days training and capacity building programme on promoting natural resource based livelihood in disaster affected areas of Kedar Valley was organised by Garhwal Unit of GBPIHED between 28 to 29 March 2016 at RTC, Triyuginarayan, Rudraprayag. Sh. Vikram Singh Rawat, President, Pradhan Association and Shri Vijay Lal, Pradhan, Triyuginarayan were the Chief guest and Guest of honour of the programme. The programme highlighted the potential interventions to be taken in the region to restore means of livelihood of the locals and developed an interaction between different stakeholders and scientists. Dr. R K Maikhuri, Scientist in-charge addressed the issues covering different sectors of livelihood underlying due to natural disaster in Kedar valley and the possible options and strategies for re-construction and improvement of the livelihood of the local people by wise utilization of natural resources and their management through introduction of simple technologies. The participants were imparted live demonstration and training about protected cultivation, organic composting, MAPs cultivation, water harvesting technologies, value addition of wild bioresources and ecotourism etc, for livelihood diversification and income generation.

Popular Lecture Series

The Institute organized 5 popular lectures by eminent personalities on the topical issues of Himalayan Environment and Development, including (a) Sustaining Himalayan ecosystem and the emerging issues and challenges (by Padma Bhushan Shri Chandi Prasad Bhatt, April 22, 2015) at Indian National Science Academy, New Delhi; (b) Sustainable use of forest resources - the main mantra of economic development of north-eastern region (by Prof. P.K. Das, Director, North Eastern Regional Institute of Science and Technology, September 10, 2015) at Itanagar, Arunchal Pradesh; (c) Biodiversity: concept, threats and conservation (by Prof. U.S. Rawat, Vice Chancellor, Sri Deb Suman University, Uttrakhand, September 10, 2015) at Srinagar, Garhwal; (d) Changing agriculture pattern in north-western Himalaya: Challenges and Issues (by Prof. K.K. Katoch, Vice Chancellor, Ch. Sarvan Kumar HP Agri. Univ., Palampur, Sept. 10, 2015) at Kullu, HP; and (e) The Himalayan environment at cross road Sh. Sonam Wangdii (Former Chief Secretary, Govt. of Sikkim, September 10, 2015) at Gangtok, Sikkim.

International Day for Biological Diversity

A field Demonstration cum Training was organized for celebrating the International Day for Biological Diversity (IBD, May 22, 2015). Celebration was largely focus onto "biodiversity for sustainable development", theme of the year. Students from Delhi Public School (DPS), Itanagar joined the celebration and visited the Multi-Technology Demonstration Centre, Midpu, Arunachal Pradesh. Students were exposed to low cost agricultural land and water management and low cost energy options in hill agriculture. At Sikkim unit the day was celebrated with students, teachers and researchers and a special talk on the theme was delivered. Also, a drawing competition for the students on the theme was organized and participants were exposed to arboretum area of the

campus. Similar programmes were organized in HQs Kosi-Katarmal, HP and Garhwal unit.

World Environment Day

The World Environment Day was celebrated at GBPIHED-HQs at Kosi-Katarmal, Almora and all the four regional units with the UN theme "Seven Billion Dreams, One Planet, Consume with Care" on 5th June 2015. A brianstorming session at HQs was organized with scientists and researchers and discussed on the various issues related to natural resource management. At Garhwal Unit the day was celebrated with students, local NGOs, and senior citizens of the region. Participants were exposed to ongoing R&D activities of the unit and emphasized more on ecotourism development, issues related to climate change and its mitigation strategies and ecosystem services. At NE Unit, the day was celebrated with students and teachers of Manu Academy and delivered a lecture on the WED theme. At HP Unit, the day was celebrated with students and teachers from different government and public schools of Kullu Valley and Institute staff. At Sikkim Unit, a brainstorming session was organized and Dr. G. Sharma (The Mountain Institute, Gangtok), Dr. D.K. Agrawala (Botanical Survey of India, Sikkim Himalayan Research Centre, Gangtok) and Dr. H.K. Badola delivered lecture on the theme concluded that "*Respect the Nature and judge our action*".

Interaction meeting on Science and Environment

An Interactive meeting was organized in Sikkim unit on May 6, 2015 with Principal Secretary, and officers of Department of Science Technology and Climate Change, Govt of Sikkim and scientists and scholars of the unit to discuss the various on-going scientific and environment issues of the state. Dr Badola appraised the house on the implementation of special initiatives and successful completion of preparatory phase of the Khangchendzonga Landscape Conservation and Development Initiative in Indian part. Following this, the Principal Secretary, Dr Mainra emphasized the importance of ecotourism as a strong tool for biodiversity conservation. He shared concisely the account of the activities that are being carried out by DST Sikkim, mainly in the field of Bioinformatics. Dr Mainra further raised the issue of glacial lake outburst, which is very critical and said that one sector of DST is working on the climate change and studies of Avalanches. Dr Mainra shared his willingness on working in collaboration with GBPIHED for the benefits of the state. In addition, the issues on endemic plants of the state, eco-tourism, and bioprospection were discussed.

Himalayan students' nature awareness camp

In order to facilitate the development of a culture of creative nature based learning, nature awareness camps were organized at Nature Interpretation and Learning Center of the Institute during May 20-22, 2015. In this campaign, a total of 66 students comprising of 45 male and 21 female from 11 schools participated. Similarly, three workshops during June 8-27, 2015 in three batches under the Department of Science & Technology, Government of India sponsored project entitled "Regional Innovation Science Hub for Innovators (RISHI)" were organized at the Institute. A total of 50 young innovators (18 female, 32 male) from 9th to 12th standard, representing 30 schools across 9 districts of Uttarakhand participated.

Scientific Advisory Committee (SAC) Meeting

XXIst Meeting of the SAC of the GBPIHED was held (July 28-29, 2015) under the Chairmanship of Prof. S.P. Singh, Former Vice Chancellor, H.N. B. Garhwal University, Srinagar. Prof DC Upreti; Dr. SK Srivastava (BSI Nominee); Er. Kireet Kumar; Dr. HK Badola and Dr. JC Kuniyal (GBPIHED Nominee); Dr. Rangini Warrier, Advisor, MoEFCC (Special Invitee) 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. P.P. Dhyani and confirmation of minutes of XIXth SAC Meeting. The Director GBPIHED, Dr. P.P. Dhyani, welcomed the Chairperson, the Members of the SAC, and the Institute Faculty for the 21st meeting of SAC. He introduced Ms Rangini Warrier, Advisor, MoEFCC, Govt of India, and appreciated her efforts to attend the meeting of SAC. The Director further requested all SAC members and participating scientists for their brief introduction. He emphasized that the Institute scientists are committed to achieve scientific excellence. The Director briefed about the agenda of the meeting and requested the SAC to critically evaluate progress of on-going programmes and offer their valuable and constructive suggestions. It was indicated that the investigators have made all efforts to address the issues raised in the previous SAC. The Chairperson, Prof. SP Singh, thanked the Institute for giving this opportunity of intense scientific interactions. He mentioned that the Institute is in good phase and applauded efforts of the Director and his team who are untiringly engaged with R&D pursuits. Following this, Dr. P.P. Dhyani, the Director of the Institute, briefed about the vision and mandate of the Institute and highlighted the organizational structure. Highlighting the major outcomes of 2014-15, Director

GBPIHED informed the house that the Institute is currently executing R&D activities on 9 in- house umbrella projects and 54 externally funded projects. Amongst these, the Task Force on Forest Resources and Plant Biodiversity under 'National Mission on Himalayan studies', which is being coordinated by GBPIHED, is very important. It was informed that the Institute has recently entered into LoA with Earthwatch Institute, India. He also highlighted the achievements under Institute's New Initiatives and mentioned that the first Himalayan meet of peoples' representatives is scheduled on 10th September 2015. Dr. Dhyani informed the SAC that based on the publications on Himalaya (1989-July, 2015), GBPIHED ranked 2nd in India and also 2nd in the world despite its relatively young age and lesser availability of resources. The SAC appreciated the achievements of the Institute and encouraged the faculty to further improve quality and culture of research for betterment of the region. Upon request from the Director, the chairman released the KSLCDI Newsletter 'Sangju' prepared under the KSLCDI of the Institute. This was followed by individual presentation of the projects. The Chairman appreciated the progress of the projects and invited all the scientists to provide their inputs so as to make: (i) the process of SAC more participatory and fruitful; (ii) Institute's R&D more visible and utilizable. The SAC expressed a high level of satisfaction on overall progress made and approved the Annual Report of the Institute for the year 2014-15.

Annual Day Celebration

The Institute celebrated its 27th Annual Day by commemorating the 128th birth day of 'Bharat Ratna Pt Govind Ballabh Pant' on September 10, 2015 at the Institute headquarters at Kosi-Katarmal, Almora. The day was also celebrated at the regional units of the Institute where Popular Lectures on regional issues were organized. At Institute headquarters, the Union Minister (Environment, Forest and Climate Change) Hon'ble Sri Prakash Javadekar, inaugurated the function. Sri Bhagat Singh Kosiyari (Member of Parliament and Ex-CM Uttarakhand), Mr Ajay Tamta (MP Almora –Pithoragarh Constituency), Mr Ashok Lavasa, IAS (Sectretary MoEF&CC, Govt of India), Dr David Molden Director General International Centre for Integrated Mountain Development (ICIMOD) Kathmanu (Nepal), Mr Hem Pande, IAS (Special Secretary, MoEF&CC), and Prof S P Singh (Former Vice Chancellor HNB Garhwal University) were amongst the important dignitaries present in the function. On this occasion, the G B Pant Memorial Lecture of the year titled - 'Climate Plus Change: Actions for Adaptation and Transformation for the Hindukush Himalayan Region', which was the 22nd lecture in G B Pant Memorial Lecture Series, was delivered by Dr David Molden, the Director General - ICIMOD. While suggesting various adaptation and preparedness measures to combat climate change, he also emphasized on the need to do science with the 'Spirit of Satyagraha' which Pt Pant have successfully demonstrated to fight the infringements on human rights and for the struggle for the freedom of the country. The Hon'ble minister in his Presidential address referred to the contributions of Pt Pant for freedom struggle, efforts he made as Parliamentarian in the form of constitutional debates, and his vision for development of India. He appreciated the R&D work of the Institute and made an announcement for upgradation of the Institute into a 'National Institute of Himalayan Ecology and Sustainable Development'. Nearly 250 persons participated in the function.

Himalayan Young Researchers Meet

Himalayan young researchers' forum for connecting researchers to bring transformation in research culture across Himalaya has been implemented and second meet of Himalayan Young Reserch Forum has been convened at Kosi-Katarmal during September 15-17, 2015. In this meeting a total of 63 participants from 23 different organizations of 9 Himalayan states [Arunachal Pradesh, Assam, Himachal Pradesh, Jammu&Kashmir, Nagaland, Sikkim, Tripur, Uttarakhand, West Bengal (Darjeeling)] participated.

Himalayan Legislators' Meet

Himalayan Legislators meet in collaboration with GLOBE-India was organized on October 8, 2015 at Itanagar, Arunachal Pradesh. In this meeting emphasis was made on the need for (a) Himalayan states to come together for common cause of development in the region and (b) adequately compensating to the Himalayan states for carbon sink value of forest cover maintained, and other services provided by Himalayan Ecosystem, (c) agreement for special provisioning in national policies and programmes to have mountain specific norms for programme implementation, (d) formation of PAN Himalayan Legislator's forum, (e) decision to facilitate preparation of District Disaster Management Plans for 41 districts of mountain states and (f) form or identify a knowledge sharing platform for Himalayan Legislators

Multistakeholders' Himalayan Sustainable Development Forum

GBPIHED as technical Secretariat of HSDF, organized the 1st Regional Meet (Dehradun, Aug 4, 2015) of HSDF and brought forum into functioning/

operationalized the Meet was inaugurated by Sri Harish Rawat, Chief Minister Uttarakhand. The Forum deliberated upon the 3-themes of topical interest i.e., (a) Climate Change and Disaster Risk Reduction; (b) Tourism and Climate Change; and (c) Environmental Governance for Effective Climate Change Adaptations. The Second Regional Consultation of Multi-Stakeholders Himalayan Sustainable Development Forum (HSDF) organized on October 5, 2015 at NIED&PR-NERC, Guwahati, Assam, India with the following deliverations (a) operationalization of the HSDF (b) synthesis report on identified sectors such as climate change and disaster risk reduction; tourism and climate change and environmental governance for effective climate change adaptation, (c) knowledge network to support national and state action plans for climate change under NMSHE, and (d) institutional framework for strategic adaptation plan

Participatory Rural Appraisal

Strengthening the transboundary programme, 'Khangchendzonga Landscape Conservation and Development (KLCDI) –India', a Training of Trainers (ToT) cum Participatory Rural Appraisal (PRA) on socio-economic assessment for contributing in developing Participatory Natural Resource Management Plan (PNRMP) for identified pilot sites (3 Nos.) was organized by the GBPIHED, Sikkim Unit, in collaboration with The Mountain Institute (TMI)-India from 26-31 October 2015 in Gorkhey Village, Darjeeling West Bengal and in Ribdi-Bhareng GPU in West Sikkim. A total of 17 participants representing Forest Department (West Bengal), Himalayan Nature and Adventure Foundation (HNAF), TMI-India, Mutanchi Lom Aal Shezum (MLAS) and GBPIHED, Sikkim Unit gained appropriate knowledge on the application of Participatory Rural Appraisal (PRA) tools for capacity building of the stakeholders while evaluating the change in socio-economic patterns. Around 27 participants from Gorkhey and 26 from Ribdi-Bhareng GPU attended the event.

International Mountain Day

A training, education and awareness program was organized on the UN theme "Promoting mountain products for better livelihoods" on occasion of International Mountain Day (December 11). The event was celebrated with the students and teachers of Vivekananda Central School (VCS), Itanagar. At Garhwal unit, the day was celebrated with students from Industrial Training Institute (Srinagar), local entrepreneurs, and NGOs, primarily engaged in cultivation, processing, and marketing of mountain products developed from agro and wild bioresources. Dr. R. K. Maikhuri, in his keynote speech highlighted the issues and challenges faced by the mountain communities. The institute is working closely with the local progressive farmers and developing their skill in the area of value addition and conservation of bioresources at its Rural Technology Centre. Chief Guest Mr. Lokendra Datt Anthwal stressed the need for strong value chain in the Himalayan region that includes collection of valuable natural resources on sustainable manner, their value addition, processing, and marketing as ecotourism products. At Himachal unit the day was celebrated with different Central and State Government Organizations/Departments, Principals, Teachers and students, NGOs, representatives of local Institutions, farmers and Unit Staff.

India-ICIMOD week

On the occasion of International Mountain Day, the Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt of India, in close collaboration with G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) and International Centre for Integrated Mountain Development (ICIMOD), organized a one-week partnership programme during 11–15 December 2015 at the MoEF&CC premises, Indira Paryavaran Bhavan, Jor Bagh, New Delhi. On the International Mountain Day, the event was inaugurated by the Hon'ble Chief Minister, MoEF&CC Shri Prakash Javadekar in presence of other senior officials within and in related ministries, policy-makers, and diverse sections of stakeholders. The opening remarks were presented by Dr. P.P. Dhyani (Director, GBPIHED), Mr. Basanta Shrestha and Dr. Eklabya Sharma (from ICIMOD). The Keynote Address entitled "Our Mountains, Our Future", presented by the Prof. Jayanta Bandyopadhyay, demanded the attention of the participants on the Himalayan issues. The programme also displayed several activities showcasing ICIMOD's engagement in India through partnerships, exploring and seeking convergence with other ongoing national programmes. A soft launch of Climate + Change (C+C) Exhibition and an outstanding display of various mountain products from all Himalayan States of India added the values and significance of the event. The overall event was divided into total five Technical Sessions on priorities *viz*., transboundary landscapes, strengthening skill development for the promotion of mountain goods and services, mountain water security, changing atmosphere and cryosphere, and Partnerships for regional spatial data infrastructure. Thus, the event comprising several unique technical sessions provided an effective platform for mutual learning, sharing, and networking opportunities among national partners

along with synergy-building with national priorities. A special session on the way forward concluded the event with the valuable advices and suggestions from Dr. P.P. Dhyani (Director, GBPIHED), Mr. B.M.S. Rathore (Chief Policy Advisor, ICIMOD), Dr. David Molden (Director General, ICIMOD), and further remarks by the Secretary MoEF&CC Shri Ashok Lavasa. The Hon'ble Minister, MoEF&CC Shri Prakash Javadekar gave the final speech on the overall success of the event.

Livelihood enhancement through technological interventions

A one day training and capacity building programme was organized by Garhwal Unit of GBPIHED on livelihood enhancement of farmers through locally available agro and wild bioresources and their value addition on 7 February 2016 at Randhar, district Rudraprayag. Scientist In-charge welcomed the participants and delivered his lecture on the potential of natural resource, strategies for sustainable utilization and management of these resources to enhance livelihood through adopting the best practices demonstrated at RTC. A total of 55 stakeholders of different walk of life such as farmers, students, NGOs, members of line departments of the region participated in the programme. Various issues related to sustainable utilization and management of bioresources and linking them with livelihood of the stakeholders were shared among the stakeholders during field demonstration and training.

Training and capacity building programme

A one day training and capacity building programme on socio-cultural and climate change impact on agriculture system and coping and mitigation through simple climate resilient technological interventions was organised by Garhwal Unit of GBPIHED on 29 February 2016 at Nyalsu, Rampur, district Rudraprayag. The major objectives of the training programme were to interact and share experiences and knowledge with stakeholders about the changes taking place in the farming systems and role of government institutions and developmental programmes in strengthening agricultural sector, to understand and analyse the major factors responsible for change, governments (state and central level) action and response to provide amicable solution and to understand the stakeholders perception, and response about climate variability/change and its impact on mountain farming system including local adaptation measures/strategies if any. A total of 150 participants attended the training programme. The programme identified the need for capacity building for farming communities in the region, review current and future plans for adapting strategies and discussed how to best implement strategies at the community level.

Citizen Science Programmes

Two Citizen Science Programmes for volunteers were organized from April 8-16, 2015 and October 25-November 02, 2015. In the first group, 07 participants from different countries (Canada, US, Japan,) and in second group, 11 participants from US, Netherland, Poland participated. The programme comprised 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 participants were appraised through comprehensive presentation on methodologies to be used for the qualitative and quantitative assessment of biodiversity including insects/pollinators; monitoring phenology of the selected species; and quantification of the selected ecosystem services flowing to the agro-ecosystem through Participatory Rural Appraisal (PRA) and also presented the salient achievements of the project. Practical demonstration about the qualitative and quantitative assessment of the vegetation, assessment of preferential forage of insect/pollinators' and assessment of the insect pollinator diversity were given in the Institute's Arboretum. The Volunteers were also given brief presentation on pollination, pollinators and their importance for food. The volunteer groups generated information on qualitative and quantitative assessment of biodiversity, ecosystem services, phenology, etc.

3. RESEARCH AND DEVELOPMENT PROGRAMMES

Group: Socio Economic Development (SED) & Knowledge and Capacity Building (KCB)

The SED & KCB Group addresses important mountains specific challenges, be it environmental, socio-cultural or economic; and emphasizes on sustained management of natural resource, generates mountain specific knowledge on priority problems, demonstrate appropriate landuse models, promote good practices through peoples' participation, undertake policy advocacy, and ensure capacity building of communities. The intent is to promote equitable, inclusive, and sustained growth by promoting ecological and economic security, and sustainable development in the Indian Himalayan Region (IHR). Thus the overall focus of the Group falls well within the framework of world Sustainable Development Goals (SDGs). In the reporting year the Group has continued to work on eco-tourism and biodiversity conservation approach for sustainable livelihood and environmental management in IHR by taking in depth studies in Arunachal Pradesh, Sikkim, Uttarakhand and Himachal Pradesh. It has also taken capacity building of mountain communities for use and management of natural resources at Rural Technology Complex (RTCs), which is designed as per the need of community, environment and local government's developmental needs. The Group initiated two new projects in the reporting years; viz. "Network programme on convergence of traditional knowledge system for sustainable development of Indian Himalaya Region" supported under National Mission on Sustaining Himalayan Ecosystems (NMSHE), and "Standardization of post harvest technology for wild rose hips and promotion as sustainable livelihood option among poor self help women groups in Kullu Valley, Himachal Pradesh". Besides a model demonstration on "Restoration of ecological balance in the degraded & fragile ecosystem through development of Nanda Van at Almora" was also taken. These projects broadly undertake interdisciplinary R&D investigations, blend traditional ecological knowledge and scientific knowledge, and design location specific livelihood improvement and natural resource management strategies. A brief presentation of major accomplishment in each of the project is provided in subsequent pages. To facilitate all R&D activities, the group works with network of partners at local, regional, and national level.

Group: Watershed Processes and Management (WPM), Environment Assessment and Management (EAM) and Environment Governance and Policy (EGP)

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, trainings programmes, library and Information Technology (IT) services, which also help significantly in human resource development, are among the other core areas of the R&D activities.

Group: Biodiversity Conservation and Management (BCM), Ecosystem Services (ES) & Climate Change (CC)

The importance of biological resources for human sustenance and welfare is tremendous and beyond question since immemorial. With increasing human population and demand for bioresources, its sustainable and judicious use is essential for the long-time survival of the mankind. This holds extremely important in the IHR, 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 flora and fauna, and is considered a "hot-spot" of biodiversity. It also contributes significantly to livelihood and to the economic well-being of the people. However, in the

changing world scenario there is an increasing emphasis on the need for increasing food production, pharmaceutical and other products, along with industrialization, which has compelled biologists to contemplate on issues like conservation of biodiversity, climate change, ecosystem service, etc. The group focuses on aspects of biodiversity conservation and management, ecosystem services and climate change perturbations in the IHR.

Group: Biotechnology Applications (BTA) & Environmental Physiology (EP)

The conservation and sustainable utilization of biological resources have emerged as the priority agenda keeping in view the ecological and economical importance of biodiversity for maintaining the environmental balance and socio-economic development of the inhabitants. At least 40% of the world economy and 80% of the need of poor people are derived from the biological resources. However, the continuous depletion of the resources due to natural calamities coupled with unsustainable harvesting has posed serious threat. Therefore, a need arises to conserve these resources through developing high throughput technologies so that these resources could be conserved in a multiplier mode. The group Biotechnological Applications and Environmental Physiology is largely focusing on developing propagation protocol of the threatened and high value species, assessing their physiological and biochemical attributes at diverse altitudinal range and develops suitable biotechnological methods for improving the rural economy of the IHR.

The group is also co-ordinating the National Mission on sustaining Himalayan Ecosystem (NMSHE) Task force 3 : Forest Research and Plant Bio-diveristy where the focus is on (i) cracking data based, (ii) Establish long term monitoring system, (iii) assess valuesabilig and modeling and (iv) building capacity of disease group of stakeholder with regards is forest resawces and for biodiveristy

Theme

Watershed Processes & Management (WPM)

The Watershed Processes and Management Theme acknowledges the importance of watershed as a naturally defined geo-hydrological and management unit, ideal for systemic study of dynamics of watershed services and implementation of management interventions for improved ecosystem performance in the hilly regions particularly the IHR. The Himalayan watersheds which support a variety of land-uses such as agro-forestry, terraced agriculture, jhum farming, and industrial and urban settlements within IHR are also vital for maintaining the perennial rivers and their tributary streams that originate from Himalaya and contribute significantly towards survival and sustenance of economy and civilizations in the plains of North India. The services provided by these watersheds are the outcome of complex interplay of interactions involving geology, hydrological regimes, vegetation, and human activities; many ecosystem components and features such as topography, glaciers/ water bodies, forests, altitude, terrain, and climate etc., contribute significantly towards the make-up, availability, and quality of the watershed services and service flows which are crucial for the economic development and general well being. The Theme aims to conserve and enhance these ecosystem services of Himalayan watersheds for dependent societies and economic systems through in-depth understanding of complex watershed processes by assessment of watershed hydrology, soil and nutrient dynamics, contributions and linkages of ecosystem types and components, and by way of improved institutional performance, participation, and devising management strategies for an efficient water use and allocation. The activities of the Theme tend to cover all these components through study of glacier hydrology and dynamics, hydrological modeling, implementation of management interventions, and advocacy of appropriate water and land-use policies/ policy solutions.

Objectives

- To study the dynamics of the watershed processes and identification of critical ecosystem elements and limiting factors affecting the watershed functions and processes and their climatic connotations.
- To develop ways and means of optimal uses of watershed services for improved economic and ecological viability.
- To evolve understanding of the issues related to social processes, institutions, and political economy-ecology of watershed management in Himalayan context.
- To enhance watershed health through people's participation, technological interventions, and adaptive management

Ecological, social and policy implications of changing water resource scenario in the Indian Himalayan context (2012-2017, In house)

The water availability in IHR in terms of quality, quantity and year round provisioning, is on decline. The evidences can be gleaned from depleting springs and their diminished flow, shrinking wetlands, dried up streams, changes in annual/seasonal flow patterns and loss of perennial character of many streams and rivers. This situation is more critical in the rain-fed watersheds. The declining availability of water due to changing demand and supply factors is supposed to bring alteration in geo-hydrological regimes and

watershed ecology, which have negative ramifications for growth of hill agriculture, urbanization, tourism, hydropower development, and the subsistence of the hill populace of IHR. The solution to this diminishing availability of water and mitigation of scarcity impacts lies in improvement of watershed health and hydrological functions, and efficient allocation and use of water resources. Therefore, the watershed development projects are now focused towards intensifying land uses using available water and improvement of neglected ecosystem services through integrated planning with the advance uses of GIS based models/ applications, and understanding of hydrological processes of the watershed. This project attempts to explore these issues through a set of watershed and sub-watershed level case studies across the IHR which includes Kosi Watershed in Uttarakhand (29^0 22' 41.60" to 29^0 52' 20.81" N, 79^0 02' 38.21" to 79^0 51' 15.08" E; 1868.64 km^2) and a small watershed i.e., Mohal Khad at Kullu (Himachal Pradesh). The project focuses on the interface of water demand for major land-uses vis-à-vis water availability with its future scenario at the basin scale

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 responsible for and susceptible to such change.
- Analyses of the consequences of the changing water resources on society and adaptation measures employed at local and policy level, and
- To develop policy options and adaptive water management action plans for addressing the challenges identified above in the context of Himalayan Mountains

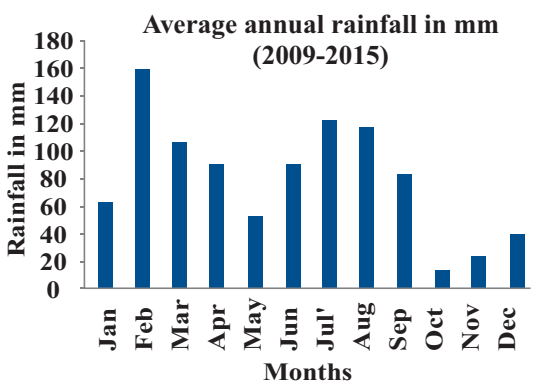
Achievements

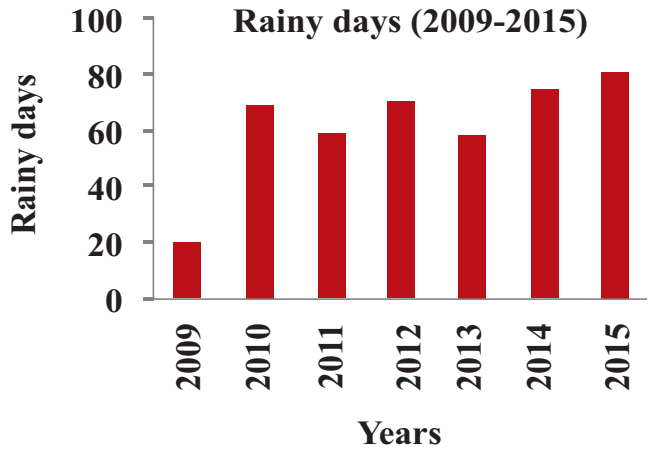
- In Kosi watershed a household survey for assessment of water demand for different land-uses in 150 villages of 6 demands sites was carried out. The results of the overall demand are compiled in Table 1; the highest water use rate of 4.8210^9 l/yr was recorded in Ramnagar demand site, and the lowest water use rate of 6.8010^7 l/yr (minimum) was recorded for the Lamgara area.

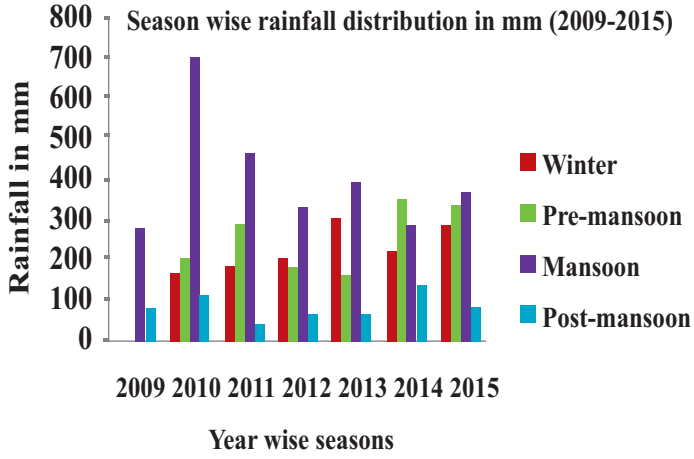
Table.1. Annual Water Use Rate of six demand sites of Kosi watershed

S. No.	Demand Sites	Annual Water (Liters) Use Rate
1	Someshwar	1,51,75,56,120
2	Lamgara	6,79,99,865
3	Almora	1,75,06,26,777
4	Khairna	24,24,27,525
5	Betalghat	11,28,74,060
6	Ramnagar	4,82,48,10,900

- The monitoring of monthly water discharge of river Kosi at Betalghat site was continued for the year 2015-16, for estimation of annual and seasonal changes in water discharge and indirect assessment of water availability for allocation planning amongst different uses. The mean monthly discharge values revealed the highest discharges for July and August months i.e. monsoon period, which were 1.50 cu m/sec and 1.18 cu m/sec, respectively. The lowest rate of discharge of 0.48 cu m/sec was observed during summers in May 2015.
- In Mohal Khad watershed in Himachal Pradesh a perception survey of 302 households of 12 villages of the watershed was carried out to know the status of water availability, its demand /supply, and management issues etc. The villagers acknowledged the decrease in water availability; 45 % of villagers attributed it to decrease in rainfall, 6% related it to decrease in surface water sources. The majority of villagers (>48%) felt that less investment on development and maintenance of water resources as the primary reason of shortfall. Villagers face maximum water scarcity in May and June; 42% villagers manage this by arranging water from remote location, around 10% villagers reduce/optimize water use as per availability. The rainfall trends of Mohal watershed for the period 2009-15 mapped in Fig 1, the preliminary analyses shows increasing rainfall trend with increase in extreme event rainfall.







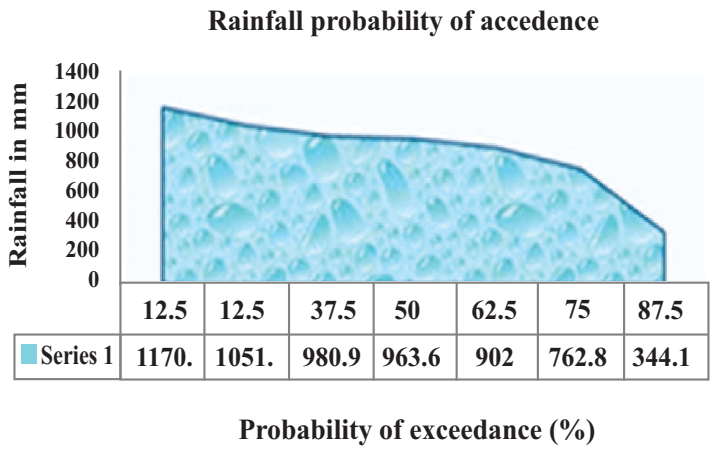


Fig. 1 Rainfall distribution of Mohal station (2009-2015) (* Data available from July 2009)

Farming systems and changing climate regime: Impact of biophysical and social drivers on the farm yields in Central Himalaya (2012-2017, In house)

The Indian Himalayan Region (IHR) is a distinct and eco-sensitive geographical region where about 70% of the population lives in rural areas. This segment of the population in the Himalaya is dependent mainly on agriculture, horticulture and animal husbandry and, about 85% of the total agriculture of the central Himalayan region comes under rain fed category. Although in recent past, a decreasing trend in the land based yield of major crops (such as rice, wheat etc.) of this region has been observed with increasing trend in the cash crop or fruit production (such as soyabean, walnut etc.); socio-economy, agro-practice, landholding, governmental policy along with few bio-physiological and climatological parameters are presumed to be responsible for this change. However, knowledge of accurate and significant drivers and their degree of influence on the changes of the land based yields is ambiguous. Therefore, identification and quantification of drivers affecting land based yields of major agri and horticulture crops of this region is of superior importance and requires multiplicity of approaches with detailed knowledge of the system. Therefore, a study assessing impact of biophysical and social drivers on the farming systems was carried out in the Almora district of Uttarakhand state. The determinant analyses of Farmers' perceptions and adaptations were conducted in three different villages namely; Kantli (1750m amsl), Dhaniyakot (1064m amsl), and Dabrasaural (769m amsl) located in Kosi watershed representing different agro-climatological zones in central Himalaya. A total of 193 HHs were surveyed from three villages (56 in Kantli, 83 in Dhaniyakote, and 54 in Dabrasaural) to determine the factors influencing adaptation as a response to climate change. Farmers' adaptation and training programmes were further carried out in Garhwal Himalaya.

Objectives

- Quantification of biophysical and social drivers affecting rain fed land based yields of major crops in central Himalaya.
- Assessment of vulnerability of the land based yield with respect to changes in significant drivers.
- Sensitivity assessment of the land based yield with respect systematic changes in the identified drivers.
- Identification of the key determinants of climate change perceptions and adaptation of the farmers of central Himalayan region using a mathematical

framework of farmer's perception on climate change and adaptation measures

Achievements

- Drivers of agro-productivity were broadly categorized into three parts: (i) Physical drivers, (ii) Biological drivers and (iii) Social drivers. Each driver was further categorized into different parameters and data were collected for these parameters as a time series from 1990 to 2010. A simple linear interpolation method was used to fill the data gaps. Including the district level yield data, all the drivers of agro-productivity were mathematically normalized to produce non-dimensional values between 0-1. The statistically significant positive correlation was observed between crop area of Rice, Wheat & Madua and Grazing land. Similarly, statistically significant negative correlation was observed between crop area of Rice, Wheat & Madua and current fallow, other fallow & other utilized land (Fig 2).

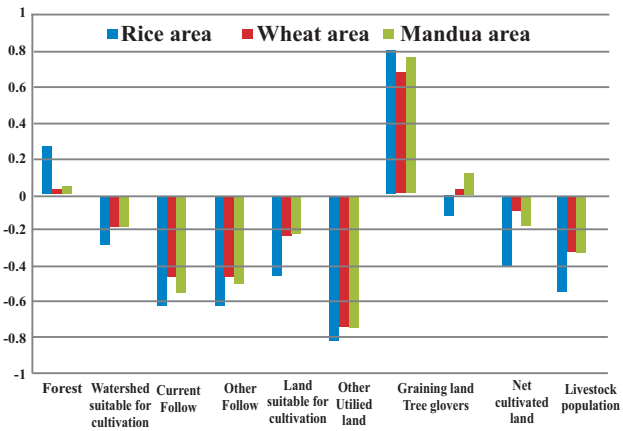


Fig. 2. Correlation coefficients between cropping area of major cereals (Rice, Wheat and Madua) within different land cover classes of Almora district for the period 1990-2010

- Using the conditional probability analyses, critically low yield of rice for the study area was found to be due the increase in the (i) grazing land (P_{con} = 0.6) and (ii) current fallow (P_{con} = 0.85) associated to shrinkages in cropping area, (iii) decrease in the June-September total rainfall (P_{con} = 0.63) and increase in the average surface air temperature of March to September (P_{con} = 0.71) and, (iv) decrease in soil pH (P_{con} = 0.8). Similarly, the district level critical low yield of wheat was found to be due to enhancement in (i) grazing land (P_{con} = 0.8) and (ii) utilized land other than agriculture (P_{con} = 0.83) (iii) increase in the November-December average surface air temperature (P_{con} = 0.66), and (v) decrease in soil pH (P_{con} = 0.8).
- The logistic regression model was developed to analyze the factors affecting farmers' perception to climate change. As hypothesized, farmers' perception of climate change was found to be positively related to age, education and information on change in climate (including temperature and rainfall), farm income and access to information. However, the model results indicated that only education, age of the head of household, information on changes in temperature and precipitation were key determinants or significant factors positively affecting the perception of farmers about climate change (Table 2).

Table 2. Results of perception model indicating relationship of socio-economic and awareness variables with perceptions about climate change

Results of Selection Model			
	Coefficient values		
Explanatory Variables	Kantli	Dhaniyakot	Dabra Saural
Education	0.29**	0.13*	0.17*
Age	0.24**	0.27 **	0.22 **
Information on change in Temperature	0.43 *	0.39 *	0.49 *
Information on change in Rainfall	0.25 *	0.45 *	0.34 *
Farm Income	0.01	0.001	0.001
Access to Information	0.02	0.01	0.09
Constant	0.2	-0.9	3.3
Total Observations	56	83	54
Chi-Square	21.6	26.8	22.4
Level of Significance	0.05	0.01	0.05

**Significant at 95% level of confidence, *Significant at 90% level of confidence

- Results of the Logistic regression adaptation model showed that most of the explanatory variables and their coefficient values were statistically significant ($p<0.05$). Results from outcome mode indicated that household size, livestock ownership, irrigated land, economic investments (significant at 95% level of confidence) and gender of head of household (significant at 90% level of confidence) were key determinants which positively influenced adaptation decision of farmers in the study villages.

Geodynamics and hydro-chemical studies of Gangotri Glacier System, Garhwal Himalaya (2013-16, DST, New Delhi)

The Himalayas contain largest concentration of snow and glaciers other than the polar region. According to the various reports numbers of mountain glaciers are retreating due to climate change and global warming. Fluctuations in the recession rate of the glaciers during recent years have initiated widespread discussions, especially in context to global warming and its effects. Our study areas are mainly Gangotri glacier and Chaturangi glacier. The Gangotri glacier system comprising of Gangotri Glacier located at $30^0$43'10" to $30^0$55'50" N, $79^0$4'55" to $79^0$17'18"E, and its tributary glaciers Raktavarna, Chaturangi, and Thelu etc. comprise one of the largest and important glacier system in the central Himalaya. The river Bhagirathi and many small & large streams that originate from here merge into Ganges river system contribute to the subsistence and economic development of the Himalayan region and North Indian plains. The study of the Glacier system is therefore crucial for understanding of water scenario and futuristic planning. The geodynamic changes in Glacier basin bring multidimensional changes in glacier ecology, which affect the glacial discharge, flow patterns of associated streams/ rivers, the sediment loss and the hydrochemistry of the stream and melt-water discharge. The tributary glaciers also play an important role in glacier system hydrology and study of their role in system dynamics therefore needs to be understood. This study, as an extension of an DST sponsored study which was carried out by the Institute to understand the ecosystems of Gangotri, Thelu and Raktvarna valleys, envisages to corroborate this aspect through analyses of long term dynamics of Gangotri glacier system and its impact on bio-physical and chemical components of the glacial environment. The study aims to scrutinize - whether the present dynamics of glacier (to be measured by precise snout monitoring using DGPS) 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 various downstream usages.

Objectives

- Assessment of impacts on geo-hydrological features through monitoring of snout and glacier surface by using precision surveys for retreat/ glacier flow estimation
- Investigation of hydrology and quantification of suspended sediments in the melt water streams of tributary glaciers/streams for estimation of erosion rate and its possible relation with glacier dynamics
- Study of glacier chemistry and CO_2 levels thru assessment of temporal and spatial solute dynamics of the glacier
- Study of relationship between solute dynamics and glacier dynamics.

Achievements

- The analyses of available recession data on Gangotri do not show uniformity in the pattern of recession rate. The variable recession rate of the glacier seems to be the affect of excessive forcing of melt water from the tributary glaciers. The results of DGPS surveys carried out reveal the average retreat rate of Gangotri glacier at around 10.24 m/yr for the period 2005 to 2015. The presence of geo-morphological features associated with glacier recession provides the evidence of glacier expanse up to the Gangnani village (35 km. downstream of the snout) in the Geological past.
- The observations on glacial discharge and suspended sediments were recorded for Gangotri and Chaturangi glaciers. The estimates of total melt water yields and suspended sediment for year 2015 for the Gangotri glacier catchment derived from 150 days' observations were found to be 354.42×10^6 m^3 and 93.99×10^4 t respectively, and that for the Chaturangi glacier catchment for an 120 days observations were 193.41×10^6 m^3 and 61.31×10^4 t, respectively. The total discharge and sediment statistics showing the rate of erosion through the glacier is compiled in Table 3.

Table 3. Total discharge volume and suspended sediment concentration of Gangotri and Chaturangi glacier.

Month	Discharge Volume ($\times 10^6$ m^3)		Total Suspended Sediment ($\times 10^4$ t)	
	Gangotri	Chaturangi	Gangotri	Chaturangi
May	17.92	-	0.28	-
June	36.16	15.11	2.85	1.49
July	120.98	38.78	42.95	8.88
August	138.69	106.63	43.27	44.89
September	40.67	32.89	4.64	6.05
Total	354.42	193.41	93.99	61.31

- The reason for variation in daily variation discharge and suspended sediment of the two rivers during the observation period JD 130 to 270 (Fig. 3 & 4), was probably due to different quantities of melt-water released from the winter snowpack, and differences in temperature patterns, atmospheric compositions, topographic attributes and the surrounding rocks or soil matter. Relatively lower volumes of total discharge were due to weak summer and frequent snowfall during the summer resulting in less melting.

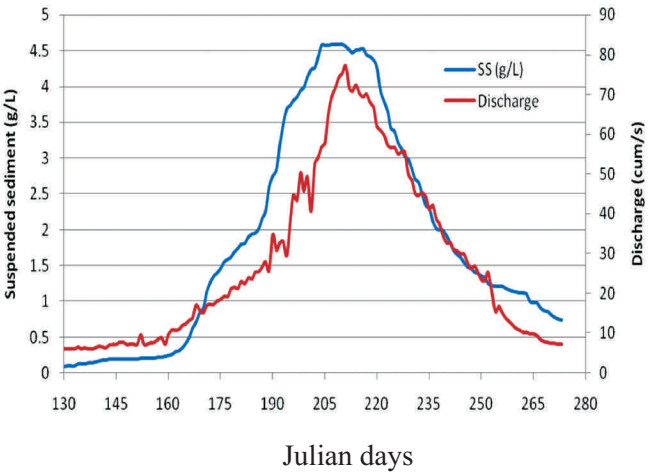


Fig 3. Variation between discharge and suspended sediment of Bhagirathi river (Gangotri glacier)

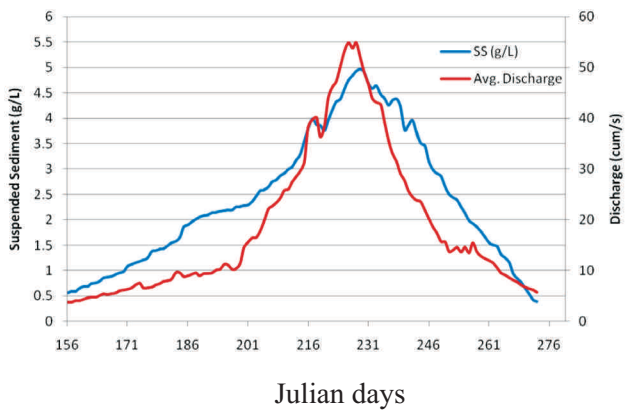


Fig 4. Variation between discharge and suspended sediment of Chaturangi glacier

Operation of permanent and campaign mode GPS stations for quantification of tectonic deformation field in Himalayan terrain (2012-17, Ministry of Earth Sciences)

This project proposal is designed to delineate the deformation field in the Himalayan urban centers, including some notable land slip zones with high resolution continuously operating GPS systems set up at 6 sites, namely Almora, Gangtok, Nainital, Kullu, Ziro and Srinagar-Garhwal across the Indian Himalayan Region. The study is also designed to monitor and estimate the deformation rate/strain field in the Uttarakhand Himalaya through a comparison of data sets with the recent GPS measurements by reoccupying the existing GPS campaign stations along the Gori and Kali valleys from the foothills of Shivaliks to the Trans-Himalayan Region. In Himalaya, the zones along the Main Boundary Thrust (MBT) and Main Central Thrust (MCT) and the Trans-Himadri Thrust (THT) that delimits the northern boundary of the great Himalaya, are the three highly vulnerable zones prone to recurrent landslips and earthquakes, and several damaging landslides have occurred in the region. This project aims to ascertain whether the Lesser Himalaya and Siwalik Himalaya is deforming coherently with respect to the main Himalayan thrusts.

Objectives

- To maintain and operate existing permanent GPS stations at Kullu (Himachal Pradesh), Almora (Uttarakhand), Nainital (Uttarakhand), Srinagar (Garhwal, Uttarakhand), Pangthang (Sikkim), and Ziro (Arunachal Pradesh) for quantification of the tectonic deformation field by experimentally determining the displacements of these fixed sites (urban centers) by using with high resolution GPS Geodesy.
- 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. 5) was carried out and analyses with reference to other campaign sites initiated. Field GPS campaign for 10 sites along Gori valley and 10 sites along Kali valley in Kumaun Himalaya completed and data was processed using GAMIT/GLOBK software. Coordinates and baseline of all campaign sites are determined with millimeter accuracy.

Fig 5. Permanent GPS station at Ziro (AP)

- The precise position and velocity of the permanent sites in ITRF08 reference frame are 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 (Fig 6).
- 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.

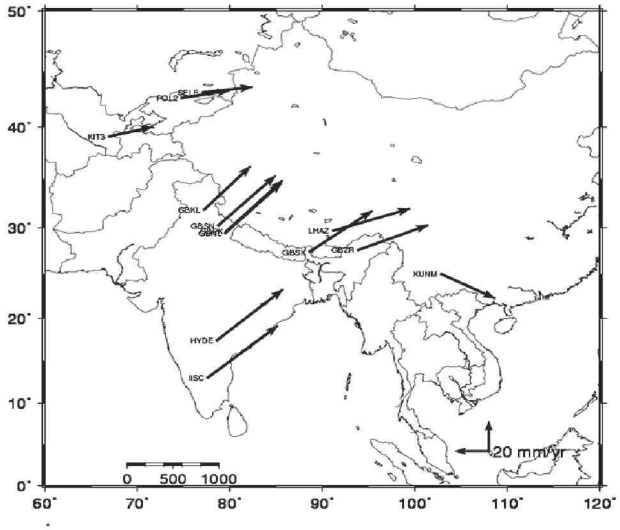


Fig 6. Velocity of permanent stations and reference IGS stations in ITRF08

Summary of Completed Projects/ Activity

- Installation of triangular thin plate weir for measurement of stream outflow at a daily time step at the small microcatchment in Dugargad microwatershed.
- Revival of the older V-notch and construction of guard wall to arrest the silt load (Fig. 7).
- Maintenance of rectangular weir at the outlet of the selected watershed at Paidul
- Geological Mapping of Uregi watershed
- Drilled shallow well in Hardrock (Dugargad watershed)
- Carried out initial pump test and slug test of hardrock aquifers

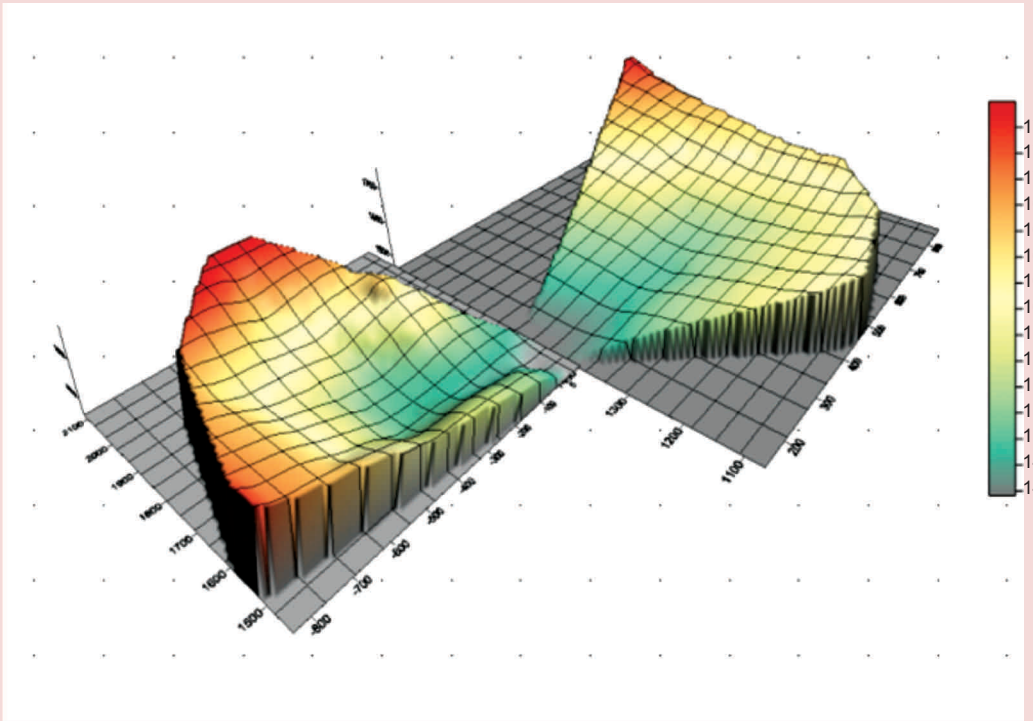


Fig.7. Microcatchment selected for model conceptualization.

Theme

Biodiversity Conservation and Management (BCM) & Ecosystem Services (ES)

The Himalayan Mountains are globally recognized amongst 34 Global Biodiversity Hotspots having enormous ecological and economic importance that has sustained people through generations. Recognizing the importance of mountain biodiversity for a number of ecological functions and the ensuing ecosystem services (ES), and its vital linkages with long-term human welfare, in keeping with the broad guidelines provided under Convention on Biological Diversity (1992) and Aichi Strategic Plan for Biodiversity 2011-2020, including Biodiversity Targets, this theme has given broad emphasis on linking conservation of Himalayan biodiversity with sustainable development goals considering the interplay of Climate Change and ES. Thus, the BCM & ES Themes holds a "Vision" of "Conservation and management of biodiversity for sustaining people and ecosystem services of IHR". To realize this vision, the newly created BCM & ES Theme aims at to cater to the need of a range of stake holder's right from rural communities to policy makers at local, regional and national levels through pursuing the following objectives: (i) Compilation of knowledge products on biodiversity conservation and management to strengthen science-policy-practice linkages; (ii) Strengthening data-base through inventorization and prioritization of biodiversity (flora and fauna), population status of rare, endangered and threatened category of species, threat assessment (due to biotic interference, invasion of weeds, forest fire, etc.) and use pattern of non-timber forest products (NTFPs); (iii) Assessment of biodiversity across diverse ecological conditions such as cold deserts, wetlands and aquatic systems, arboreal habitats etc.; (iv) Documentation of case studies and indigenous knowledge on conservation and sustainable management of biodiversity; (v) Projection of trajectories of change in important biodiversity elements (species and populations) due to anthropogenic and CC impacts and strategies for safeguarding ecosystems, species and genetic diversity using advance methodologies /techniques/approaches across the representative vegetation types/landscapes; (vi) Quantification and valuation of ES emanating from ecosystem/landscape scale and developing payment for ecosystem services (PES) mechanisms for biodiversity conservation; (vii) Establish long-term ecological monitoring sites (e.g., GLORIA) to monitor selected structural (e.g., species composition, epiphytic flora, regeneration) and functional (e.g., phenology, biomass/productivity) aspects of selected vegetation types across bio-physical and disturbance gradients; and (viii) Promote awareness and capacity building of a range of stakeholders for participatory conservation and sustainable use of biodiversity.

Understanding Biodiversity Patterns and Processes Under Changing Resource use and Climate Scenario in Indian Himalaya – Ecological and Social Implications (2012-17, In house)

Biodiversity in the IHR is depleting gradually due to habitat degradation caused by various anthropogenic activities coupled with the changing environmental conditions. All these factors make the IHR 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 action plan for the conservation and sustainable use of biological diversity under changing climate and land use land cover change. Keeping in view the importance of biodiversity of the temperate, sub-alpine and alpine regions and its vulnerability to the global climate change, this 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 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 (KWLS), Himachal Pradesh

- Total 19 sites were sampled in the KWLS between 1,868-2,695 m. Maximum sites were represented by shady moist, dry forest and bouldary habitats (04 sites, each), followed by riverine and degraded habitats (02 sites, each). Seven (07) sites were represented in North West aspect, 06 sites in South West, 02 sites each in North East, North West and West aspects.
- A total of 12 forest tree communities were identified based on Importance Value Index and relative density from the KWLS. Total tree density ranged from 80-510 Ind. ha^{-1} and total basal area ranged from 0.478-117.35 m^2ha^{-1}. Shrub and herb density ranged from 440-2260 Ind ha^{-1} and 15.35-68.65 Ind. m^{-2}, respectively (Fig. 8). Species diversity index (H') for trees ranged between 0.271-2.073, saplings, 0.66-1.838, seedlings, 0.60-2.50, and for shrubs and herbs from 0.88-2.70 and 1.39-3.46, respectively. Concentration of dominance (CD) for trees ranged between 0.151-0.884, for saplings 0.178-1.00, and for seedlings 0.204-5.00. Concentration of dominance (CD) for shrubs and herbs ranged from 0.09-0.61 and 0.02-0.16, respectively. Species richness was highest in *Picea smithiana* community, followed by *Pinus wallichiana*.
- A total of 231 species (Angiosperms: 221; Gymnosperms: 07; and Pteridophytes: 02) were economically important and used as medicine (90 spp.), wild edible/food (31 spp.), fodder (48 spp.), fuel (31 spp.), timber (5 spp.), religious (05 spp.), fiber (07 spp.), agricultural tools (06 spp.) and some others (9 spp.).
- Soil was sampled from 19 sites and after physico-chemical analysis soil moisture content ranged between 5.86-9.556%, pH ranged between 5.94-6.55, total nitrogen 1.4-2.29% and organic carbon 0.69- 6.23%.

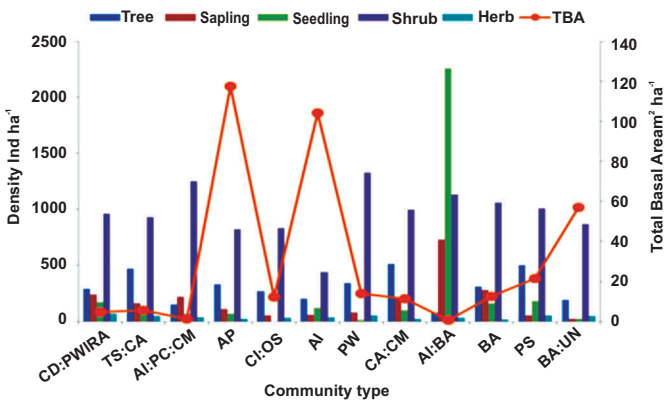


Fig. 8. Total Density of Trees, Saplings, Seedlings, Shrubs and Total Basal Area of forest communities in KWLS; AP= *Abies pindrow*; AI=*Aesculus indica*; BA=*Betula alnoides*; CD=*Cedrus deodara*; CJ= *Corylus jacquemontii; CM= Cornus macrophylla;* CA=*Celtis australis*; TS=*Toona serrata*; PS=*Picea smithiana*; PW=*Pinus wallichiana*; QS = *Quercus semecarpifolia*; RA=*Rhododendron arboreum*; UN=*Ulnus nitida*; and *PC= Prunus cornuta*

Headquarters, Uttarakhand

- Second GLORIA long-term monitoring sites in Byans valley, with four summits area in different altitudes was established (Table 4 & Fig. 9). Plant

diversity revealed the occurrence of 63 plant taxa belonging to 51 genera and 25 families. Maximum species richness was found in Shyang summit area (42), followed by Chaga (40), Kuti (38) and Eurong (25).

Table 4: Summits of GLORIA Active Target Region in Byans Valley, Uttarakhand, India

Locality Summit code	Altitude and geographical location	Vegetation Zone	Plant species richness
Shyang (SHY)	3999 m Lat: 30°18.573 N Long: 80°45.830 E	Lower alpine: above tree line *Danthonia cachemyriana*	42 taxa (35 genera, 23 families)
Kuti (KUT)	4038 m Lat : 30°18.336 N Long: 80°45.528 E	Transition between the lower and upper alpine *Danthonia cachemyriana, Juniperus indica* dominated	38 taxa (29 genera, 20 families)
Chaga (CHA)	4062 m Lat: 30°18.615N Long: 80°45.951 E	Upper alpine the top region *Juniperus, Danthonia* and *Potentilla* dominated	40 taxa (34 enera ,19 families)
Eurong (EUR)	4154 m Lat: 30°18.645 N Long: 80°45.165 E	Transition between upper alpine and nival *Danthonia cachemyriana* and *Juniperus indica* dominated	25 taxa (20 genera,16 families)

Fig. 9. Establishment of GLORIA protocol in Byans Valley

- In Byans valley, a total of 19 plants (3 trees and 16 shrubs) are collected for fuel by the local communities. The collection ranges from 5625 kg/ household (HH)/ year to 7929 kg/ HH / year. Total collection of tree species was maximum in case of *Abies pindrow* (643.32 kg/ HH / year), followed by *Pinus wallichiana* (540.67 kg/ HH / year). In case of shrubs species, *Junipers communis* (733 kg/ HH / year), *Juniperus wallichiana* (395 kg/ HH / year), *Juniperus indica* (62 kg/ HH / year), *Berberis jaeschkeana* (64 kg/ HH / year) are collected. The density of highly preferred fuel wood tree species was recorded highest for *P. wallichiana* (408 Ind./ha), followed by *A. pindrow* (283 Ind./ha), *Betula utilis* (340.3 Ind./ha); the shrub species, *J. communis* (248.2 Ind./ha), followed by *J. wallichiana* (283.1 Ind./ha), *J. indica* (271 Ind./ha) and *B. jaeschkeana* (1495.0 Ind./ha) (Fig. 10).

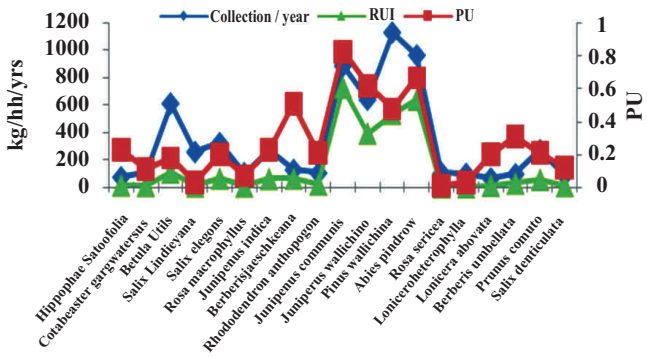


Fig. 10. Fuel wood collection in Byans valley

- In temperate forests of Hat-Kalika (Distt. Pithoragarh, UK) a total of 61 plants (14 trees, 18 shrubs and 29 herbs) were recorded, of which 44% were native to Himalayan region. In Banj – Oak forest, the density of tree ranged from 585-828.5 Ind./ha, Chir-Pine (880-1089 Ind./ha) and Sal forest (670-740 Ind./ha). Total basal area ranged 24.28-36.8 m^2/ha in Banj – Oak forest, 44.40-49.05 m^2/ha in Chir – Pine and 29.74-33.10 m^2/ha in Sal forest.
- Lopping disturbance intensity in this watershed was recorded maximum (61%) in lower zone (800-1200 m) falling in unprotected forest area, and minimum (16%) in protected areas having five years under management in higher elevations (>1600 m). Grazing intensity was recorded maximum at higher elevations (66%) in protected forests from past twenty-five years and minimum in protected forests from past five years in middle elevations.

- Among a total of fifteen villages studied in the Hat-Kalika watershed a total of 29 plants (26 trees and 3 shrubs) belonging to 18 families were recorded, of which 10 species were native to the Himalayan region. While analyzing the resource use pattern, *Pinus roxburghii* (1075 kg/HH/year) was utilized maximum, followed by *Quercus leucotrichophora* (466 kg/HH/year), *Myrica esculenta* (262 kg/HH/year) and *Lyonia ovalifolia* (255 kg/HH/year). Among shrubs, *Rhus parviflora* (96 kg/HH/year), *Berberis asiatica* (6 kg/HH/year) were highly utilized from nearby forest area.
- Average fuel wood consumption at three different altitudinal zones revealed highest consumption in lower zone (800-1200 m) 2467 kg/capita/year, followed by middle zone (1200-1600 m) 2155 kg/capita/year and high altitude zone (1948 kg/capita/year).
- Total 70 medicinal plants were recorded having potential use in the watershed. Among which 25 are trees, 13 shrubs, 30 herbs and 2 climbers.

Kanchendzonga Biosphere Reserve (KBR), Sikkim

- Quantitative assessment of vegetation and prioritization of faunal elements using standard protocol was targeted for Yuksom-Black Kabur transect (1780 m - 4810 m) in KBR, west Sikkim. So far, 15 sites were investigated from 1800-4010 m. Total 98 woody species were recorded. Observations were also made on pheasants' availability, abundance, encounter rates and their habitat interaction pattern.
- Importance Value Index (IVI) of 15 sites (Yuksom-Black Kabur transect, west Sikkim) and their dominant species were quantified for different forests, viz., *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 mixed broad leaved forest below 3367.7m.
- Woody species diversity, tree species richness, species evenness, abundance and density of woody species were quantified. The regression analysis between woody species richness and altitude of the study sites showed strong relationship (r^2=0.743, $p<0.05$; Fig. 11).
- A new transect, Kusong - Panch Pokhri (north Sikkim, KBR) was selected for quantitative assessment of vegetation using same protocols. Ten sites were investigated. So far, data analyzed for the four sites along 3706 - 3183 m and total 34 woody species (including 11 species of Rhododendrons) were recorded.

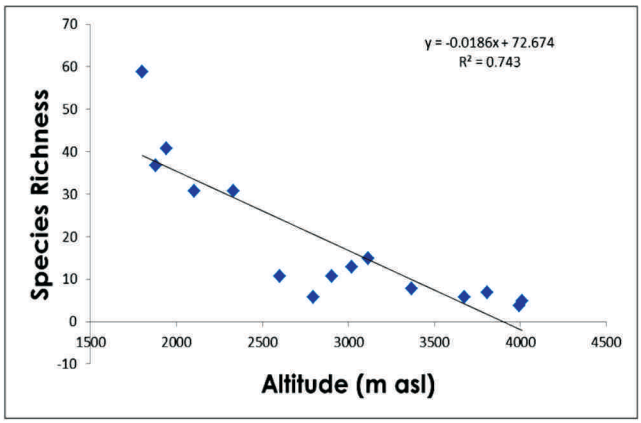


Fig. 11. Woody species richness and altitudes of study sites within Yuksom-Black Kabru transect in KBR (west Sikkim)

West Kameng, Arunachal Pradesh

- Surveys were conducted for information generation on utilization pattern of plant diversity. Information on 20 species belonging to 19 genera and 18 families was gathered through interviews and involving knowledgeable persons for the identification and collection about the useful plant species.
- Bark, Fruits, Leaves, Resin, Rhizome, Roots, Stem, Tubers and Whole plant were used for curing various ailments i.e., constipation, indigestion, cough, throat infection, cracks, wound, cold, fever, itching, swelling, fracture, asthma, dysentery, diarrhea, blood pressure, etc. Some species are used as vegetables and dye.

Vulnerability Assessment of Biodiversity and Natural Ecosystems in Selected Sites of Kullu District, Himachal Pradesh (2014-17, Swiss Development & Cooperation, Switzerland Embassy, New Delhi)

The Himalaya, a young and intricate series of mountains, is well recognized for its floral and faunal diversity, aesthetic, geo-hydrological and cultural values. The IHR with its unique topography, climatic conditions, diverse habitats and altitudinal rise constitutes an important part of this hotspot. While biodiversity of this region is depleting fast due to

habitat degradation caused by various anthropogenic activities coupled with the changing environmental conditions, the diverse ecosystems prevailing in the region are increasingly being recognized for their provisioning, cultural, regulating, and supporting services to both upland and lowland inhabitants. Climate Change has been recognized one amongst the most confounding factor in shaping the future of mountain ecosystems and local people. With the predicted future changes, the need to understand the intensity and direction of consequences of on-going and potential impacts of changes on the composition, structure and functioning of biodiversity in the region is urgently required. In addition, the biodiversity components of the tropical, sub-tropical, temperate, sub-alpine and alpine regions are severely affected by anthropogenic activities. All these factors coupled with natural calamities make the biodiversity of IHR vulnerable that calls for immediate actions towards assessing biodiversity for vulnerability.

Objectives

- To map community perceptions on risk, hazard and climate change in selected sites of Kullu district
- To assess biodiversity and natural ecosystems for vulnerability in selected sites of Kullu district
- To analyze, synthesize and document the information

Achievements

- The present study has been carried out in Parbati valley (1544 – 3407 m) and Upper Beas catchment (2100 - 4280 m) of Kullu district in Himachal Pradesh. In Parbati valley, 475 species and in Upper Beas catchment 415 species were found economically important those are used as medicine, wild edible, fodder, fuel, house building, timber, agricultural tools, fibre, religious and various other purposes.
- Vulnerability assessment of floristic diversity of the Parbati valley identified 05 species as Critically Endangered; 11 Endangered, 90 Vulnerable and 188 Near Threatened; and in Upper Beas Catchment, 09 species Critically Endangered; 14 Endangered and 47 Vulnerable. Continued anthropogenic pressure and changing environmental conditions may lead their extinction in near future.
- The forest communities near to habitation were more vulnerable than the communities distant from the habitations. This is due to the dependence of the communities on forests for their sustenance in various ways. The sub-alpine communities were more vulnerable due to heavy snow fall, avalanches, and climate change.
- The altitudinal shift of the species such as *Betula utilis, Abies pindrow, Populus ciliata, Aesculus indica, Pinus wallichiana,* etc. and changing patterns of the composition and structure of the forest communities have been observed. This could be as a consequence of the climate change.
- For mapping community perceptions 791 respondents representing 31 villages and 370 households from Parbati valley and 13 villages and 421 households from Upper Beas catchment were taken using a structured questionnaire.
- The analysis and synthesis of information revealed that in agriculture sector the genetic erosion of agriculture, horticulture and vegetable crops is due to change in diversification of agriculture, change in life style and altitudinal shift of the high value cash crops. The major factors are rise in temperature, protracted rain fall, pest and diseases and decreasing intensity of snow fall.
- Biodiversity is decreasing due to high anthropogenic activities, natural calamities and climate change. 70% respondents believe that the weather is getting gradually warmer. Similarly, 67% respondents agreed that the onset of summer and monsoon has advanced during the last 10 years. Winter season has become shorter and warmer as revealed by 70% respondents. Overall, the inhabitants feel that climate change has influenced the life style of the inhabitants, and they have started adapting towards climate change.

All India Coordinated Research Project on Sacred Grove Ecosystem Service Assessment of Ecosystem Services in Sacred Groves of Himachal Pradesh, North Western Himalaya (2012-17, MoEF&CC, New Delhi)

The IHR forms the major part of Himalaya and comprises of three bio-geographic zones and 8 bio-geographic provinces due to its typical physical features and environmental conditions. The unique topography, diverse habitats and large altitudinal range (200-8,000 m) support the representative, natural, unique and socio-economically important biodiversity. The region 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 has been established across the IHR and representative biodiversity rich areas have been notified as Biosphere Reserves, National Parks and Wildlife Sanctuaries for the *in situ* conservation of ecosystems, habitat and species, respectively. 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.

Objectives

- To assess, identify and characterize ecosystem services provided by the sacred forests
- To assess and characterize the biodiversity of selected sacred forests for conservation
- To assess and quantify the prominent ecosystem services/service flows (i.e., nutrients: organic carbon, NPK on the soil and leaf litter, medicinal, wild edibles, fuel and fodder plants) of sacred forests
- To identify and characterize drivers impacting ecosystem services of sacred forests
- To value 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 42 sites (27 undisturbed and 15 disturbed) sampled for floristic diversity between 1460 – 2053 m altitude in Bhrighu Rishi, Rupasana Devi, and Jamdagni Rishi, Peej Sacred Groves. Maximum sites (19) were represented by Shady moist habitat, followed by Dry (10), Bouldary (9) and Riverine (4). Twelve (12) sites were represented in North East aspect, 07 sites in East, 06 each sites in North & North West, 05 sites in South East, 04 sites in South and 02 sites in South West. The slope varied from 10-55. A total of 240 species of vascular plants (36 trees, 51 shrubs and 153 herbs) belonging to 92 families and 181 genera were recorded.
- In general, 5 communities *Cedrus deodara, Quercus floribunda*, *Q. leucotrichophora*, *Cedrus deodara - Quercus floribunda mixed* and *Cedrus deodara - Pinus wallichiana* mixed communities have been identified based on IVI values from the Bhrigu Rishi, Rupasana Devi and Jamdagni Rishi Sacred Groves. Variation in total number of species among sacred groves was observed, i.e. Bhrighu Rishi Sacred Grove (total 82 species); Rupasana Devi Sacred Grove (92 species); and Jamdagni Rishi Sacred Grove (66 species).
- Carbon stock was estimated in Rupasana Devi and Jamdagni Rishi Sacred Groves. 2 undisturbed and 1 disturbed site were each sampled in Rupasana Devi and Jamdagni Rishi Sacred Groves. Both in Rupasana Devi and Jamdagni Rishi Sacred Groves, the first plot showed highest number of trees, total basal area, above ground biomass, carbon stock (50% AGB), below ground biomass, and carbon stock (50% BGB). The details of above ground biomass, below ground biomass, and carbon stock in the forest stand of Rupasana Devi and Jamdagni Rishi Sacred Groves are shown in Table 5.
- Cultural service of the Rupasana Devi, Bhrighu Rishi, Jamdagni Rishi, Kamru Nag were assessed through interviews. Information on origin of Sacred Grove, association and ethnicity, management of Sacred Grove, belief systems associated with the Sacred Groves, interface between people and Sacred Groves and ecotourism was gathered.

Table 5. The details of above ground biomass, below ground biomass, and carbon stock in the forest stands of Rupasana Devi and Jamdagni Rishi Sacred Groves

Sacred Grove		Plot No.	No. of trees	Total Basal Area (m^2/400 m^2)	Above ground biomass (kg/400 m^2)	Carbon stock (50% AGB) (kg/400 m^2)	Below ground biomass (kg/400 m^2)	Carbon stock (50% BGB) (kg/400 m^2)
Rupasana Devi	UD	1	16	2.88	39769.83	19884.91	11533.25	5766.62
		2	20	2.39	31922.24	15961.12	9257.45	4628.73
	D	1	10	1.22	16315.75	8157.88	4731.57	2365.78
Jamdagni Rishi	UD	1	17	9.34	98471.44	49235.72	28556.72	14278.36
		2	14	6.90	86191.59	43095.80	24995.56	12497.78
	D	1	12	1.85	22501.03	11250.52	6525.30	3262.65

Abbreviations used: UD= Undisturbed and D= Disturbed

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 (2012-17, Himachal Pradesh Power Corporation Limited)

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 project 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 GHNP of the Sainj Hydro-Electric Project are very rich in flora and fauna. Therefore, a 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-Electric Project area in Sainj Valley
- To monitor the floristic diversity
- To assess the economically important biodiversity
- To assess status and distribution pattern of the native and endemic species
- To assess the floristic diversity for threat categories
- To assess the impact of Sainj Hydro-Electric Project on the flora and fauna of the GHNP in particular, and Sainj Valley in general
- To suggest suitable management plan for the conservation of biodiversity

Achievements

- Rapid sampling of the floristic diversity in Sainj valley recorded 330 species of vascular plants (herbs 214 spp., shrubs 71 spp., trees 31 spp. and ferns 14 spp.) belonging to 84 families and 198 genera. Asteraceae (41 spp.), Rosaceae (32 spp.), Lamiaceae (31 spp.), Poaceae (18 spp.), Polygonaceae (10 spp.) and Ranunculaceae (09 spp.) were species rich families. The dominant genera were *Carex* (08 spp.), *Polygonum* (06 spp.), *Anaphalis, Artemisia, Erigeron, Nepeta, Salvia, Potentilla, Rosa* (05 spp.) and *Viburnum, Jasminum, Cotoneaster, Rubus, Spiraea* and *Polystichum* (04 spp.). 161 species were native to the Himalayan Region; remaining species were non-natives. 08 species were endemic and 60 species were near endemic to the IHR.
- 20 tree communities were recorded and maximum sites (10) were represented by *Pinus wallichiana* community, followed by *Cedrus deodara* (09 sites), *Quercus semecarpifolia, Prunus cornuta* (03 sites each), and *Picea smithiana*, *Quercus leucotrichophora*, *Taxus baccata* ssp. *wallichiana, Pinus wallichiana - Picea smithiana* mixed (02 sites, each). The remaining communities were represented by 01 site only.
- Species richness was maximum in *P. wallichiana* (172 spp.) community; followed by *C. deodara* (128 spp.) community. It was lowest in *P. roxburghii* (20 spp.) community. Maximum shrubs were recorded in *P. wallichiana* (31 spp.) community, followed by *C. deodara* (21 spp.) community. However, comparatively lesser number of species was recorded in *Aesculus indica* (03 spp.) community.
- 143 species of fauna belonging to 55 families and 122 genera were recorded. These species were distributed within different classes i.e., Mammalia (27 spp.), Aves (66 spp.), Amphibia (03 spp.) Reptilia (04 spp.) and Insecta (51 spp.). Among mammals dominant families were Bovidae (03 spp.), Mustelidae (02 spp.) Canidae, Felidae, Muridae and Ursidae (02 spp., each).

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 (2014-19, Sainj Hydro-Electric Project, Himachal Pradesh Power Corporation Ltd., Sarabai)

The IHR with its unique topography, diverse habitats and varied altitudinal range (200-8000 m, amsl) supports representative, natural, unique and socio-economically important floristic diversity. The IHR harbours about 18,440 plant species, of which 1748 species of medicinal plants, 675 wild edibles, 960 orchids and 155 sacred plants. The high anthropogenic pressure coupled with changing environmental conditions have resulted in rapid depletion of economically important species in the region. Along

with this 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 the periphery of Great Himalayan National Park, Sainj Valley. The adjacent areas towards the GHNP of the Sainj Hydro-Electric Project are very rich in flora and fauna including threatened species. Construction of Hydro-Electric projects have adversely affected the habitats and sustenance/security of inhabitants. Considering the high rate of habitat degradation and population depletion of economically important species in their natural habitats, it has become essential to adopt *in situ* and *ex situ* conservation measures. Therefore, the present study has been proposed for conservation of some selected species namely *Desmodium gangeticum*, *Delphinium denudatum* and *Polygonatum verticillatum* through population assessment, standardization of propagation protocols, promoting mass multiplication, hardening and establishment of seedlings and plantlets of these species in *in situ* and *ex situ* conditions.

Objectives

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

Achievements

- Total 19 sites, 11 sites containing populations of *P. verticillatum* between 1,714 – 2,200 m and 13 sites containing populations of *D. denudatum* between 1,563-1,926 m were sampled in surrounding areas of Sainj Hydro-Electric Project in the Sainj valley of Himachal Pradesh.
- In *D. denudatum* populations, richness of shrubs ranged from 2-11 and herbs, 10-33, and in *P. verticillatum* populations richness of shrubs ranged from 4-27 and herbs from 7-37. In *P. verticillatum* populations, total shrubs density ranged from 780-2570 Ind. ha^{-1} and total herb density, 36.15-122.6 Ind. m^{-2}. In *D. denudatum* populations, total shrubs density ranged from 70-1750 Ind. ha^{-1}, total herb density, 22.35-122.6 Ind. m^{-2} and relative density (%) from 1.12-14.79 %. Among the populations, soil moisture ranged from 9.09- 49.36%; pH, 5.48- 7.69; total nitrogen 0.02-0.70% and organic carbon, 0.96- 9.20 %.
- Young plantlets of *P. verticillatum* along with tubers were collected and established in herbal garden at Mohal. Seeds of *D. denudatum* were collected, dried at room temperature and stored in refrigerator and seed germination experiment conducted.

Assessment and Quantification of Forest Ecosystem Services with Special Emphasis on Pollination in the Indian Himalayan Agro-ecosystems (2012-15, Earthwatch Institute, India)

The Himalayan region is one of the 34 Global Biodiversity hotspots. The IHR forms a major part of this hotspot. On account of its unique topography, diverse habitats and large altitudinal range, IHR supports representative, natural, unique and socio-economically important biodiversity. The region represents tropical, sub-tropical, temperate, sub-alpine, alpine and tundra ecosystems/biomes. These ecosystems provide provisioning (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 these 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

- One Citizen Science Programme was organized jointly with Earthwatch Institute India, from 8th-16th April, 2015. Qualitative assessment of the vegetation was carried in and around the orchard study sites and sampled plots in upper Beas Valley and also assessment of bee flora in the selected orchards and surrounding areas was done. A total of 83 species of plants representing trees, shrubs and herbs including ferns were recorded. Out of which 33 were found to be bee/pollinators foraging resources based on the visitation of bees/pollinators on the flowers of these plants.
- Total 8 sites/plots were selected and sampled for the quantitative assessment of vegetation. From the study sites 4 tree communities were delineated based on the Importance Value Index (IVI). The identified communities were : *Cedrus deodara* (2 sites), *Pinus roxburghii* (4 sites), *Pinus wallichiana* (1 site) and *Cedrus deodara* - *Picea smithiana* mixed (1 site).
- Amongst the tree communities, total tree density ranged from 5.12 (*P. wallichiana*) - 7.81 (*C. deodara*) (Ind./100 m^2) and total basal area 31.11 (*P. roxburghii*) – 57.83 (*C. deodara* - *P. smithiana* mixed) m^2ha^{-1}; total shrub density ranged from 5.66 - 19.60 Ind./100 m^2 and total herb density ranged from 28.36 - 67.03 Ind./m^2. The soil samples (8 Nos.) collected from the sampled sites were analyzed for pH, EC, moisture content, organic carbon and nitrogen. The soil pH ranged from 6.14 - 6.53, moisture content 2.21 - 21.27%, organic carbon 0.75-2.43% and nitrogen 0.09-0.56%.
- 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 Kradsu, Nashala, Bashkola and Raugi orchards during apple flowering.
- Pollinator density was recorded as insect visitation per 100 flowers. Across the study sites, maximum density of Indian honey bees was found in Kradsu followed by Nashala, Bashkola, Raugi, Dhamadhar, Mehiliseri and Hirni (Fig. 12). For the assessment of preferential floral species of insects, plants in the flowering stage were selected at different orchards and then were observed for 15 minutes for the insect visitations. This exercise was replicated four times on the same species but on the different individuals at a site. In the Hirni orchard, the preferred foraging plant was *Impatiens grandiflora*, in Raugi orchard, *Tagetes minuta,* in Mehliseri orchard, and *Galinsoga parviflora* in Bashkola orchard.
- Phenological observations were recorded on leaf fall, leaf bud initiation, flower bud initiation and leaf initiation and 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.

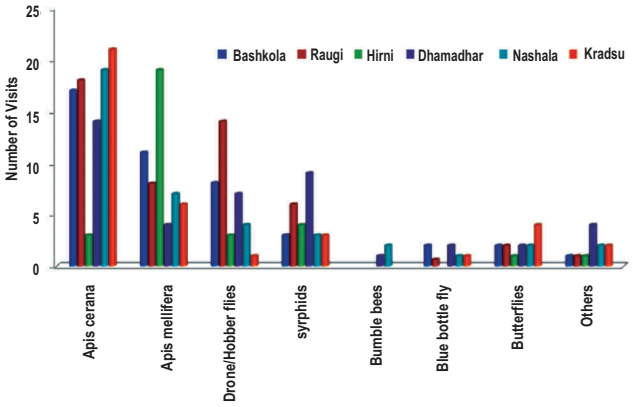


Fig. 12. Diversity and average density of insect pollinators at all orchard sites observed on 100 open flowers in April, 2015.

Scientific Research on Changing Climate and its Impact on Floral Diversity and Ecosystem Services (Pollination) at Kullu region of IHR – a Citizen Science Initiative (2015-18, Earthwatch Institute India)

Humankind benefits from a multitude of resources and processes that are supplied by natural ecosystems known as ecosystem services. Among these, pollination is one of the significant provisioning services in the maintenance and promotion of biodiversity that supports life on Earth. Pollinators provide valuable ecosystem services in the form of pollination essential for sexual reproduction of wild and domesticated plants and maintenance of biodiversity. 87 species of the world's leading food crops i.e., fruits, vegetables or seeds depend upon animal pollination, representing 35% of global food production. The production value of one ton of pollinator-dependent crop is approximately five times higher than one of those crop categories that

do not depend on insects. Globally, bees and other associated pollinators diversity is gradually declining due to climate change, habitat loss and fragmentation, land management practices, agro- chemicals, pesticides and diseases. Pollinators decline has adversely affected the productivity of pollinator dependent fruit and agro-horticultural crops. For instance, decline in pollination services has been now identified as an important issue worldwide. It applies equally for the agro-ecosystems of the IHR, which calls for a systematic study on pollinators and other forest ecosystem services in the region.

Objectives

- To assess the vulnerability of plant diversity including medicinal plant diversity in relation to anthropogenic and climate change scenarios
- To develop ecological niche models for threatened biodiversity elements
- To monitor the seasonal foraging patterns of pollinators and assess the impact of habitat alteration on pollinator population and production
- To create awareness among the inhabitants and citizens to ensure their participation in conservation and management of plant diversity, medicinal plants and bee flora in Kullu
- To engage target stakeholder groups in research - Community members, farmers, students, teachers, volunteers and scientific community

Achievements

- Citizen Science Programme was organized jointly with Earthwatch Institute India, from 25th October to 2nd November, 2015. Qualitative assessment of the vegetation was carried in and around the orchard sites and sampled plots and also assessment of bee flora in the selected orchards and surrounding areas was done (Fig. 13). A total of 46 species of plants representing trees, shrubs and herbs including ferns were recorded. 26 species were found to be bee pollinators foraging resources based on the visitation of bees/pollinators on the flowers of these plants.
- The insect pollinators' diversity and density were assessed in and around selected orchards of Apple by scan and visual sampling method. The results showed highest visitation rate of *Apis cerana,* followed by *Apis mellifera*, drone, butterflies, syrphids, etc. in all orchards except in Hirni and Kradsu where highest visitation rate of *A. mellifera* was observed.
- Assessment of preferential floral species of the insect pollinators, the plants in the flowering stage were selected at different orchards and then were observed for 15 minutes for the insect visitations. This exercise was replicated on the same species but on the different individuals at one orchard. The preferred foraging plants during October to December, 2015 were *Rabdosia rugosa* (Dhamadhar, Raugi and Nashala Orchards), *Galinsoga parviflora* (Hirni and Bashkola Orchards) and *Fagopyrum esculentum* (Mehiliseri Orchard). The preferred foraging plants during the month of January were *Prinsepia utilis*, followed by *Brassica campestris* by syrphids. The preferred foraging plants during February were *B. campestris,* followed by *P. utilis* and *Veronica biloba* by *A. cerana,* followed by drones and syrphids. The preferred foraging plants during March were *B. campestris*, followed by *Trifolium repens* and *Zaphyranthes candida* by *A. cerana,* followed by drones, syrphids and *A. mellifera*.
- Phenological observations of Apple were recorded on leaf fall, leaf bud initiation, flower bud initiation and leaf initiation and pink flower bud initiation and flower opening in the selected orchards.

Fig. 13. Citizen Scientist engaged in various activities of Citizen Science Programme.

Promoting Pollinators Using Community Based Conservation Approach at Kullu, (Himachal Pradesh) (2015-16, Earthwatch Institute, India)

To utilize the outcome of GBPIHED – EWI project entitled "Assessment and Quantification of Forest Ecosystem Services with Special Emphasis on Pollination in the Indian Himalayan Agro-ecosystems" on biodiversity, ecosystem services, phenology, bee flora and various management practices for the conservation and management of bee flora and

pollinators, a new project entitled "Promoting Pollinators using Community based Conservation Approach at Kullu (Himachal Pradesh)" funded by SHELL has been initiated by GBPIHED-EWI. The project activities will strengthen the conservation of important pollinator species and bee flora, investment in the next generation by engaging young people and women groups, and develop their knowledge in identification of important pollinators and bee flora.

Objectives

- To strengthen conservation outcomes by conserving important pollinators and bee flora
- To invest in the next generation by engaging youths and women groups of the region
- To deliver value to communities
- To enhance the personal experience of SHELL employees

Achievements

- Total 9 sites i.e., 1 site each in Karadsu and Raugi villages and 7 sites in Nashala village of Upper Beas valley, Kullu district were selected and surveyed. In these sites, density and diversity of the pollinators was observed which showed that before cultivation of bee flora the density and diversity of the pollinators were relatively low.
- Mustard and Coriander have been cultivated in nine sites during November and December 2015 to maintain the insect pollinators in different seasons. Selection of the bee flora is done based on availability and preference by the bees/pollinators. The seedlings of Mustard and Coriander were observed in February 2016. Growth was observed in the month of March of this year and fully bloomed crop was observed in the month of April 2016. The survival rate of the crops was up to 80-90%. After complete cultivation of bee flora the record of the density and diversity of the pollinators was observed which has been increased to a larger extent. Various observations of 15 minute each on different individuals of all species of pollinators were taken in both the crops and the results of insect pollinators study revealed maximum density of *Apis cerana* during March and April. Drone flies and syrphids in all the study sites have high visitation rate on the Mustard and Coriander flowers as compared to other flowering plants.
- Total 25 Bee boxes of Indian Honey Bee (*A. cerana*) were purchased and distributed to the 22 apple orchardists from 7 villages i.e. Kradsu, Nashalla, Ghurdaur, Archhandi, Dobi, Bashkola, Kathayal Gram and Ghurdaur of Kullu District. The bee hives distributed to the farmers contained complete colonies of *A. cerana* (i.e., queen and six frames with wax having eggs, brood, male drones and female workers) and these will be monitored to check the population increase of bees in the area.
- Four Awareness-cum-Training Programmes on "Biodiversity Conservation, Ecosystem Services and Climate Change with Special Reference to Pollinators in Himachal Pradesh" were organized at Nashala, Archhandi and Fruit Growers Association, Mahili. Total 55 farmers including 11 participants of Citizen Science Programme XII at Nashala (30.10.2015); 63 farmers, Yuvak Mandal and Mahila Mandals at Nashala (19.03.2016); 160 farmers including Panchayat Pradhan, Youth Group, Mahila Mandal of different villages at Archhandi (24.03.2016) and 80 participants (Students, Teachers, Officials and Members of Fruit Grower's Association, Scientists, Research Scholars, staff of the Institute at Mahili (26.03.2016) participated in the Training Programme.

Assessing the Floristic Diversity and Ecosystem Values of Selected High Altitude Wetlands of Indian Trans Himalaya (2015 - 18, MOEF&CC, New Delhi)

Wetlands are among the most threatened ecosystems in the world yet among the least protected ecosystems and disappearing at a rate of 2-3% every year. The Indian Trans Himalayan region (spread over 1,86,000 km^2) harbors a number of wetlands and lakes with high biodiversity potential, which are classified under High Altitude Wetlands (HAWs) of India. Trans-Himalayan HAWs are of great importance, especially for the endemic and threatened plant species, migratory birds, wild animals and also for the people living in and around the region. HAWs play a buffer between glacial melt waters and outflows of rivers and streams. Therefore, any change in these wetlands can have a knock-on effect on biodiversity elements. In recent years, these HAWs are under severe anthropogenic pressure leading to adverse impacts on these fragile ecosystems. Considering the above, the project targeted Chandra Tal, Suraj Tal (Himachal Pradesh), Tso Moriri, Pangong Tso, Tso Kar Lake, Tisgul Tso and Chushul marshes (Jammu & Kashmir) HAWs located in the Trans Himalayan Region of India.

Objectives

- To document and assess the floristic diversity of selected wetlands
- To investigate the dynamics of floristic changes in selected wetlands
- To analyze the ecosystem services emanating from the selected wetlands
- To inculcate awareness and sensitize local inhabitants on issues pertinent for conservation of selected wetland ecosystems

Achievements

- **Chandra Tal wetland:** Through field survey and analysis of literature a total of 60 species under 47 genera and 19 families (53 dicots and 7 monocots) were reported in this wetland (Fig. 14). Among these 19 families, family Asteraceae was dominant with 12 species, followed by Ranunculaceae, Gentianaceae, Polygonaceae and Poaceae of 5 species each (Fig. 15). Literature review indicated that the 22 medicinal species were used for curing different ailments.

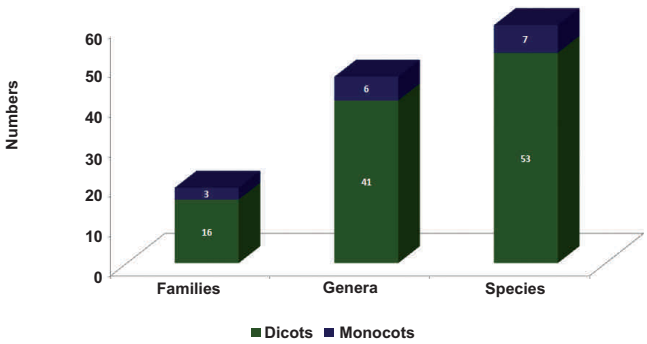


Fig. 14. Floristic diversity in Chandra Tal

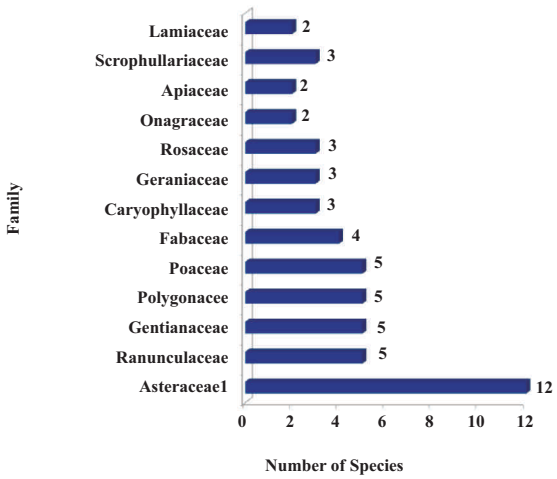


Fig. 15. Dominant families

- **Tso Moriri wetland:** Review of secondary literature and analysis of herbarium records on Tso Moriri wetland revealed a total of 94 plants under 63 genera and 27 families (Fig. 16). Among these, 81 were dicots and 13 monocots. Among these 27 families, family Asteraceae dominated with 20 species followed by Brassicaceae (10 species) (Fig. 17). A total of 45 species were used for different medicinal purposes.

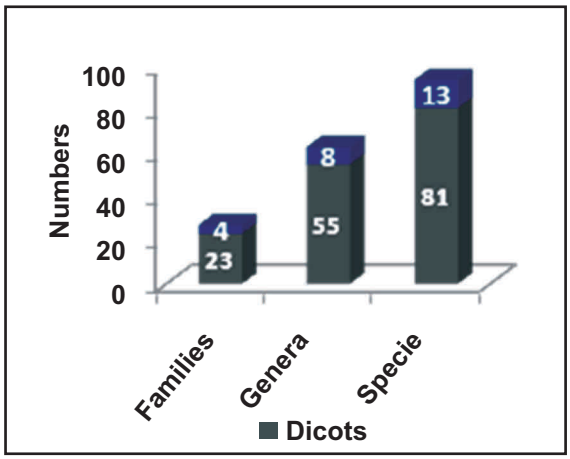


Fig. 16. Floristic diversity in Tso Moriri

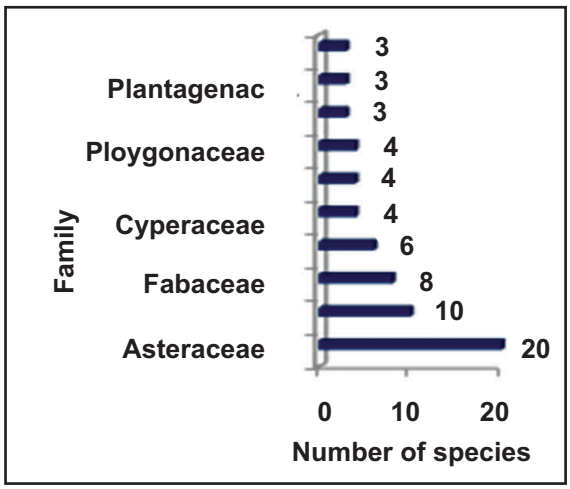


Fig. 17. Dominant families

Climate Change Impacts on Ecosystem Services in the Indian Himalayan Region (2012-17; In-House)

The Himalayan region is important on account of its unique topography, micro-climatic conditions and strategic location, and represents one of the "Global Biodiversity Hotspots'. The richness of endemic flora and fauna with restricted distribution and life support values (ecosystem goods and services) of this region are highly valuable for the global community in

general, and for the regional inhabitants (both highland-lowland), in particular. However, in the recent decades under the changing climate the forest ecosystem services such as provisioning of NTFPs to support the local livelihoods, biological diversity, C-sequestration potential etc. have altered. Realizing the above, the present project was undertaken across an altitudinal gradient (300 – 2100 m asl) on major forest ecosystems of Kumaun Himalaya (*Shorea robusta, Pinus roxburghii, Quercus leucotrichophora* and *Quercus floribunda* forests) for selected life cycle phases (phenophases) of eight species to relate the timing of these events with weather patterns and CC. Also impacts of CC on recreational services connected with the forested landscapes are likely to be affected. Protection of the forests to boost natural regeneration and planting forest blanks with suitable mix of species would restore them and also generate ES in longer run. This project integrates all these aspects to improve understanding on the impacts of CC on mountain forest ecosystems and come up with certain mitigating measures. In these efforts people's perception of CC adaptation and mitigation measures would be helpful to devise strategies to cope up with the CC impacts.

Objectives

- Study early indicators of CC on forest vegetation through phenological studies 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

- Timing and extent of leafing in the 8 selected forest species (dominant canopy and sub canopy) across the altitudinal gradient was found highly dependent on ambient temperature across the north and south aspects of these four forest types (Fig. 18). In all the eight species studied 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 for all the species. This great 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.

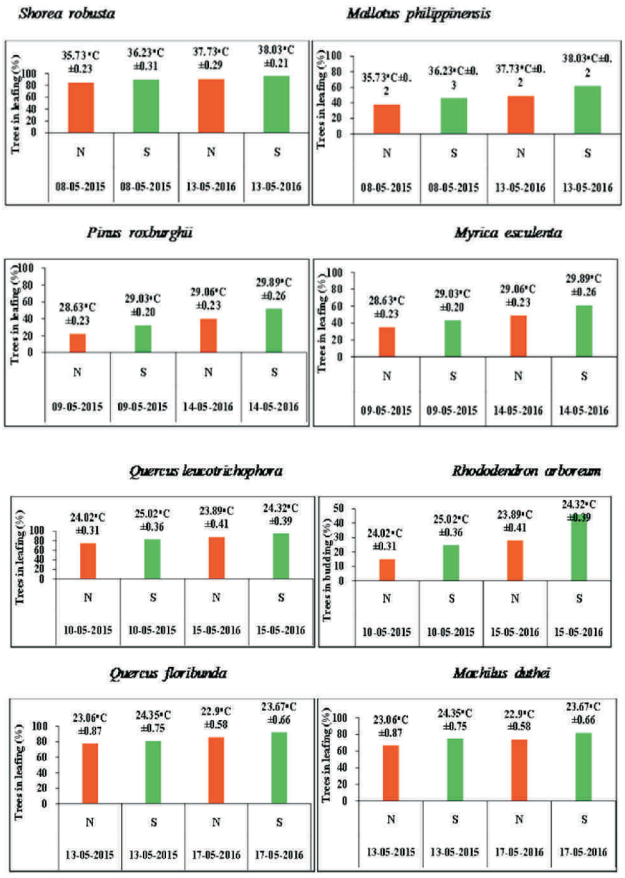


Fig. 18: Impact of ambient temperature (given on the top of the bars) on leafing in trees across the four forest types in Kumaun Himalaya (the dates of phenological records are given in X axis). N= North aspect; S= South aspect of the studied forests.

- Household surveys on impacts of climate change on agriculture and animal husbandry among 134 families in 45 villages of Garur Ganga watershed in Bageshwar district of Uttarakhand for a decade (2005- 2015) revealed that cow (2.03 - 1.15) and buffalo (1.2 - 1.0) population per household has declined but goat population has increased from 3.2 - 3.9 per household. Irrigated land has declined by over 30%, and also the production of wheat (2.7 - 2.4 t/ha) and rice (5.1 - 3.8 t/ha) has declined in irrigated land. The rainfed land has however increased but wheat (0.41 - 0.26 t/ha) and rice (0.68 - 0.34 t/ha) production has declined substantially.

- Soil quality build-up following enrichment plantation of 10 selected broadleaf species in canopy gaps of an old-growth chir Pine forest in terms of soil components and processes such as soil nitrogen dynamics studied in March 2015 at Nanda Van (Almora) revealed that the rate of N-mineralization ranged from 4.26±0.67 to 5.98±0.58 mg kg^{-1} dry soil $month^{-1}$ and rate of nitrification from 1.05±0.16 to 2.97± 0.53 mg kg^{-1} dry soil $month^{-1}$ in the pure Pine and enriched Pine stand planted with broadleaf species, respectively (Table 6). The mineral N content ranged from 7.47±1.15 to 9.11±1.14 mg kg^{-1} dry soil in the pure Pine and planted Pine stand, respectively indicating a positive effect on soil nutrient quality and microbial biomass and population.

Table 6: Biochemical characteristics of soil in pure Pine stand and Pine stand planted with broadleaf species

Soil Parameters	Pure Pine Stand	6 month old enriched Pine Stand
Mineral- N (mg kg^{-1} dry soil)	7.47±1.15	9.11±1.14
N- mineralization (mg kg^{-1} dry soil $month^{-1}$)	4.26±0.67	5.98±0.58
Nitrification (mg kg^{-1} dry soil $month^{-1}$)	1.05±0.16	2.97±0.53
Ammonium Oxidizers (MPN x 10^3 g^{-1} dry soil)	0.18±0.02	0.23±0.01
NitriteOxidizers (MPN x 10^3 g^{-1} dry soil)	0.17±0.01	0.25±0.04
Microbial Biomass C (µg g^{-1} dry soil)	81.33±1.51	85.66±1.25
Microbial Biomass N (µg g^{-1} dry soil)	12.40±0.61	14.8±0.57

- Recreational services of forests vis-a-vis impacts of CC around Nainital town involving primary surveys with 300 tourists and 198 businessmen on perceptions on background elements of the environment were synthesized (Table 7). The assertions and ranking reveal that scenic view of lakes in the area, climate, and the combined aesthetics of lake and surrounding forest are the most enamoring features contributing to the tourism. The summer season collectively contribute to over 60% of the annual earnings of the various businessmen suggesting that the recreational services of Nainital and its vicinity suburban areas has a high economic relevance for the business community.

Table 7: Ranking of tourists' perception on natural attributes (N=300)

S. No.	Natural ℓatures	Acknowledgement as enamouring attributes (%)	Derived ranking
1	Scenic view of lake	64.33	I
2	Aesthetic ambience of forests in the lake background	22.33	VI
3	The flats	25.33	VII
4	Combined aesthetics of lake, flats, and background forest	65.00	IV
5	Governor house and surrounding environment	16.33	VIII
6	Scenic view of mountains and valleys from hill tops	74.00	V
7	Cool and refreshing environment	96.33	II
8	Lake areas in the vicinity	96.67	III

Kailash Sacred Landscape Conservation and Development Initiative (2013-2016, ICIMOD, Kathmandu)

The Kailash Sacred Landscape (KSL), one amongst seven transboundary landscapes (TBL) in HKH, is recognized globally for its bio-physical and socio-cultural diversity. The overwhelming spiritual and sacred values make this landscape one of the most revered sacred landscapes of the world. Unfortunately, the landscape is equally known for its extreme vulnerability to changing faces of development and global climate. As a result, the rich and unique biological diversity, the ecosystem goods and services, and the value based cultural heritage of the landscape are severely threatened. Realizing the global importance of KSL, three countries (i.e., China, India and Nepal), which share this landscape, have endorsed the Regional Cooperation Framework (RCF) for implementation of Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI). It has been conceived with a vision and its set objectives to initiate and promote transboundary biodiversity and cultural conservation, ecosystem management, sustainable development, and climate change adaptations within the region. Following a thorough consultation amongst the representative organizations/ experts from partner countries (i.e., China, India and Nepal) an approximately 31,175 sq km area the Greater Mt Kailash region, has been delineated as the KSL. This covers the remote south-western part of the Tibetan Autonomous Region (TAR) of China, and adjacent parts of north-western Nepal, and north-eastern parts of Uttarakhand state in India.

Objectives

- Strengthen transboundary regional cooperation by institutionalizing the elements of the regional cooperation framework
- Mainstream sustainable ecosystem management approaches and practices at all levels into national policies and plans in the context of climate change in the KSL
- Build the capacity of key institutions for long-term environmental monitoring and socio-economic research for better planning and decision making
- Contribute to establishment of a regional knowledge sharing platform to support evidence-based decision making at regional and national levels

Achievements

- Eight sacred forests of KSLCDI sites in Pithoragrah district (Chanapande, Dharapani and Dhungabhool in Chandak-Aonlaghat watershed and Uprara, Jajut, Chitgal, Mahakali temple and Chamunda Devi in Hat-Kalika watershed) were investigated for Carbon stock in forest biomass (above + belowground). It was computed maximum (661 T/ha) for Chamunda Devi sacred forest and minimum (107 T/Ha) for Chhanapande sacred forest (Fig. 19).

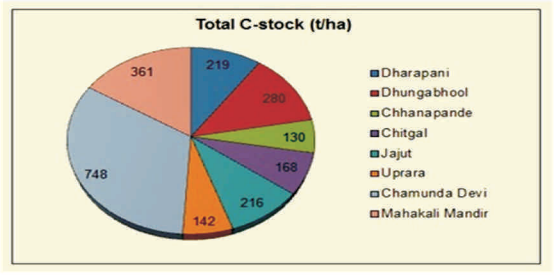


Fig. 19. Carbon stock in vegetation + soil pool across 8 sacred forests in two identified watersheds

- In the soil pool the maximum C stock (87 T/ha) was estimated for Chamunda Devi sacred grove and minimum (23 T/Ha) for Chhanapande sacred forest. Thus the total C-stock (vegetation + tree roots + soil) was estimated maximum for Chamunda Devi sacred forest (748 T/ha) and minimum (130 T/ha) for Chhanapande sacred forest**.**
- A Training Workshop on Participatory Assessment of Forest Ecosystem Services was conducted at Hat-Kalika watershed on 29.12.2015 which was attended by 55 people of six villages (Fig. 20)**.** In this Workshop on-site training was imported on community people (particularly women) relating to estimation of C stock in vegetation and soil.

Fig. 20. Training of community people in Hat-Kalika watershed for assessment of ES

- Per capita water availability (33.3 lpcd) estimated for Gorang valley is found to be less than the prescribed minimum limit (55 lpcd) under National Rural Drinking Water programme (NRDWP)-2013 by MoDW&S, Government of India. Highest consumption of water in Gorang valley is observed for domestic sector (49%) followed by livestock (39%) and drinking (12%) sectors (Fig. 21a).
- During the lean period (i.e., during March to June), lowest availability of water is experienced in the valley, therefore, villagers are forced to adapt by various coping mechanisms such as, collection from distant points (44%), reduction in usages (34%), construct water tanks and rely on hand pumps (16%), and rainwater harvesting (6%) (Fig. 21b).

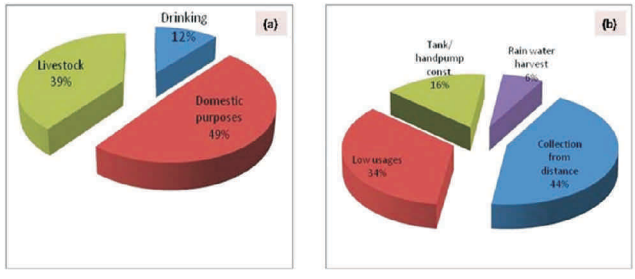


Fig. 21: Patterns of water use and adaptive measures by society in Gorang Valley **- (a)** Water utilization, and (b) adaptive measures to meet water requirement during lean months

- Scarcity of water in study area affects women, mostly (78%) involved in collection of water, in many ways such as importing on their domestic (32%) and agriculture (29%) activities, health (31%) and education (8%). In nutshell, scarcity of water in Gorang valley has increased drudgery of women and has also affected their health adversely.
- In Gorang valley some villages are vulnerable to water availability on supply-demand ratio, therefore, a community based participatory approach was initiated in village Digtoli (pilot site) to develop spring-shed management keeping in view the hydrogeology of the area. Rapid hydro-geological study suggests that majority of locally confined aquifers are controlled by fractures and most of the springs occur at the intersection of aquifer with depressions or fractures (Table 8).
- The ground level implementation of spring-shed management for spring recharge at the pilot site is being carried out by State Forest Department of Uttarakhand.

Table 8: Characteristics of various springs in Digtoli village of district Pithoragarh

S. No.	Spring Name	Spring Type (occurrence)	Spring Type (geological)	Spring Type (seasonality)
1	Shivalaya (a)	dhara	depression	Perennial
2	Shivalaya (b)	naula	depression	Perennial
3	Shivalaya (c)	naula	depression	Perennial
4	Naunipani	dhara	fracture	Perennial
5	Panigair	dhara	depression	Seasonal
6	Shin gadera	dhara	depression	Perennial
7	Sarhad	naula	fracture	Perennial
8	Pandali	naula	fracture	Perennial
9	Kafalipaani	dhara	fracture	Seasonal
10	Khet 1	dhara	depression	Seasonal
11	Khet 2	dhara	depression	Perennial
12	Bajni	dhara	contact	Seasonal
13	Padpani	naula	fracture	Perennial

Threat Assessment and Conservation of Himalayan Silver Birch (*Betula utilis* D. Don): A Keystone Species in Timberline Zone of Central Himalaya, Uttarakhand (2012-15, SERB-DST)

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. The timberline 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 sensitive to climate change and grows in moist cool conditions under complex and unique habitat and also has socio-cultural and religious value to people inhabited in the region. It generally grows in sub-montane to alpine near to moist places with the association of *Cedrus deodara, Taxus baccata, Pinus wallichiana, Asculus indica, Abies pindrow, Acer acuminatum, Sorbus aucuparia, Prunus cornuta* and *Salix spp.* 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. Unfortunately, due to legal and illegal exploitation from wild, anthropogenic pressure and lack of knowledge about sustainable harvesting of useful bioresources (as many of them has been listed under the categories of rare, threatened, endangered) are at the verge of extinction. 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.

Objectives

- 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 and phenology
- To determine land-use changes in distribution of *B. utilis* and associated species at two points of time using remote sensing data.

Achievements

- A total of 278 plant species belonging to 66 families and 166 genera were recorded. Of these, 52 families and 149 genera belonging to angiosperm, 4 families and 5 genera of gymnosperms and 10 families and 13 genera of pteridophytes were recorded between 3000-4200 m asl from valley of flower National Park and Nanda Devi Biosphere Reserve of NDBR. Among the flowering plants (angiosperm and gymnosperms), the life forms were recorded as 4.6% trees, 18.77% shrubs and remaining 76.63% herbs and forbs.
- In the pure *B. utilis* forest at the south aspect of VoF-NP, *B. utilis* and *R. campanulatum* had 'fair regeneration' while *A. pindrow* and *A. caesium* had 'good regeneration'. However, at north aspect *R. campanulatum*, *A. pindrow* and *S. sikkimensis* had 'good regeneration' and *B. utilis* showed 'fair regeneration' pattern. However, ND-NP out of four species, *R. campanulatum* showed 'good regeneration' and rest three species viz., *B. utilis*, *A. pindrow* and *T. baccata* exhibited 'fair regeneration' at south aspect. While in the north aspect two species viz., *R. campanulatum* and *A. pindrow* exhibited 'good regeneration', and *B. utilis* and *S. foliolosa* recorded 'fair' and 'poor' regeneration, respectively.
- Satellite imageries and our field observations showed increasing number of seedlings and sapling recruitment and growth of *B. utilis* above the timberline in both sites whereas density of other tree species decreased with increase in altitude. The higher number of seedlings of *B. utilis* was recorded in pure forest (3600-4100 m asl) and ranged between 19.33 to 33.50

seedlings/100m^2 and 7.83 to 30.00 seedlings/100m^2 for north and south aspects of VoF-NP and ND-NP at timberline, respectively.

- The fuelwood consumption ranged between 2.60 to 8.84 kg/capita/day while per capita fodder consumption was found between 8.23 to 31.30 kg/capita/day in the Niti valley, NDBR. The per capita fuelwood consumption of *B. utilis* was recorded 2.52 kg/capita/day at timberline area particularly by the people involved in Kira Jari (*Cordyceps* spp.) collection during the month of May and June.
- The study exhibited that the area of mixed and pure *B. utilis* forest has increased over last 23 year time period. In 1990, the proportion of pure *B. utilis* forest was increased about 761 ha while mixed forest about 883 ha, however, digitized satellite imagery data indicates that the forest area has increased about 1029 and 1107 ha during 2013. A total of about 268 ha and 224 ha area of pure and mixed *B. utilis* forest has increased between 1990 and 2013 in Nanda Devi NP of NDBR, respectively (Fig. 22).

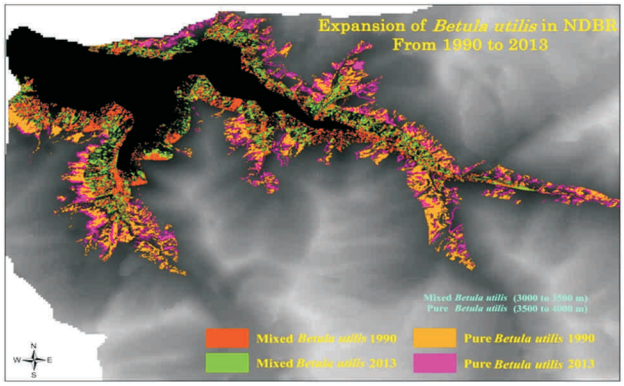


Fig. 22. Distribution and expansion of *Betula utilis* at timberline zone of NDBR.

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 (2013-16, SERB-DST, New Delhi)

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. The Himalayan birch (*Betula utilis*) is multipurpose tree species and considered a keystone species of timberline zone which is sensitive to climate change. It grows in moist cool conditions under complex and unique habitat and also has socio-cultural, religious and spiritual value to people inhabited in the region. Defoliation of central Himalayan birch forests in timberline zone by insect herbivory is obviously the most important disturbance factor in these ecologically sensitive ecosystems. Recently it was reported that *B. utilis* growing in association with *Abies pindrow, Rhododendron campanulatum* and *Taxus baccata* between 3,300 to 3,600 masl were damaged severely by defoliator moths (insects) and this probably due to a decrease in snowfall in the past one decade and a gradual increase in temperature. But yet this kind of herbivory (moth) has not 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. Though enormous research on impact of herbivory on *Betula* species has been carried out elsewhere in the mountain regions of the world, but studies on this aspect particularly on *B. utilis* is almost totally lacking in India. Therefore, the proposed study with the objectives mentioned below was conceptualized and implemented for detail investigation.

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 *B. utilis* caused by herbivory in selected provenance
- To assess the impact of herbivory on population dynamics, regeneration potential and phenophases of *B. utilis*

Achievements

- Identified six insect species viz., *Phylloporia bistrigella*, *Heterarthrus nemoratus*, *Fenusa pussila*, *Eriphyes longisetosus*, *Agrilus anxius*, *Clethrobius commes* defoliating *B. utilis* tree species in timberline landscape of NDBR.
- Based on occurrence of the insects in different parts of *B. utilis*, the identified insects were categorized under four groups including (i) leaf miner comprising three species of the insect (*Phylloporia bistrigella*, *Heterarthrus nemoratus*, *Fenusa pussila),* (ii) gall inducer (*Agrilus anxius*), (iii) birch borer (*Clethrobius commes*), and (iv) birch aphids (*Clethrobius commes*).

- Among different strata, maximum defoliation (ranged between 21.65 - 42.32%) was quantified in trees followed by sapling (ranged between 9.32-21.2%) and seedlings (ranged between 4.95-8.98%) in both sub-sites (Fig. 23).
- The maximum defoliation percent in *B. utilis* was accounted by leaf miner followed by birch borer, birch aphid and gal inducer in both the sub-sites.
- Leaf miner was a major causal organism in *Betula* pure forest in Tolma region which contributed 45% in defoliation. Whereas, Birch aphid was observed to have higher contribution (40%) in *Betula* mixed forest in Valley of Flowers.

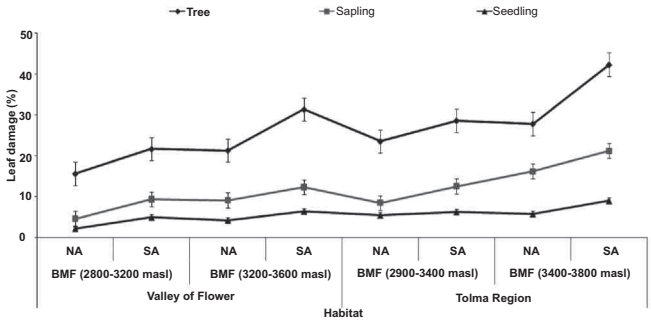


Fig. 23. Quantification of defoliation on *Betula utilis* caused by insect herbivory in timberline landscape of NDBR

Summary of Completed Project

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

The project aimed to quantify the current status of endemic, threatened and high value medicinal plants in Cold Desert region of Uttarakhand through secondary information and ecological assessments. In addition, for awareness building on importance and conservation of these important species training programmes were organized for local people/other stakeholders. Among six Cold Desert regions of Uttarakhand, Byans valley between the altitudinal range of 3250 (Gunji) to 4600 m asl (Parvati Tal) of Pithoragarh district was surveyed in September 2015, and Mana valley (Mana village, 3280 m asl) to Rattakuna (4800 m asl) of Chamoli district were surveyed in August 2015.

Results of two successive year surveys of Byans valley revealed presence of 153 species belonging to 98 genera and 45 families of Angiosperms and Gymnosperms. Rosaceae was the most dominant family in terms of species richness followed by Asteraceae, Ranunculaceae, Poaceae, Brassicaceae, etc. Of the total 153 species 83% were dicot, 11% were monocot and 6% belonged to gymnosperms. Among these 153 species, 36% were Himalayan Endemic and Near Endemic and 18% were Narrow Endemic (Fig. 24). A total of 58 medicinal plants were identified and out of these 20 plants were under different threat categories of endemism. Similarly, 120 species were collected from the Mana valley. The endemic status of the Johar valley cold desert region indicated that of the total 192 recorded plant species 37% were Himalayan Endemic and Near Endemic, and 20% were Narrow Endemic. Meeting-cum-training camps were organized in the project villages (Kuti village in 2015 and Gunji village in 2014), which was attended by 78 participants (33 male, 12 females and 18 researchers).

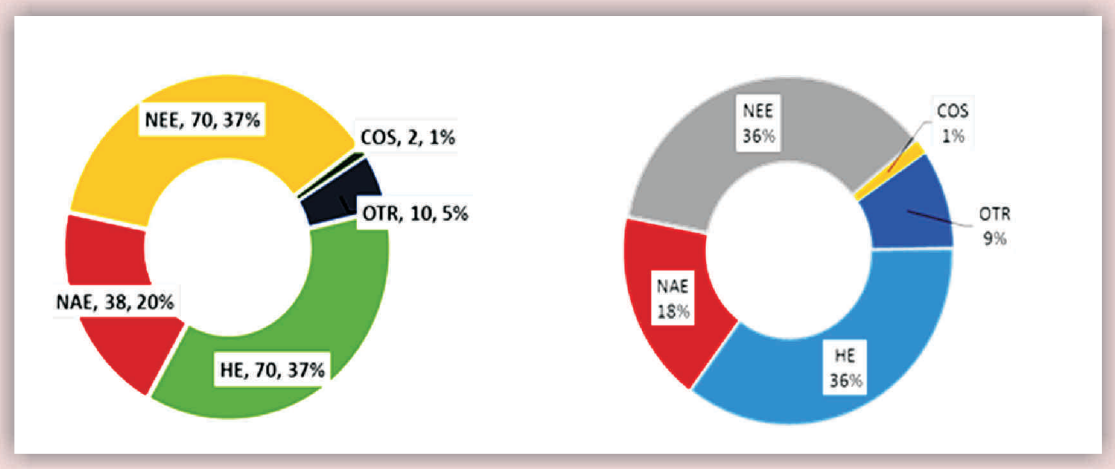


Fig. 24. Status of Endemism in cold desert regions of Johar (Left) and Byans (Right) valley (NEE: Near Endemic; NAE: Narrow Endemic; HE: Himalayan Endemic; OTR: others; COS: Cosmopolitan)

Theme

Climate Change (CC)

Climate is an important environmental influence on ecosystems. Climate changes and the impacts of climate change affect ecosystems in a variety of ways, e.g., warming could force species to migrate to higher elevations for their survival. Climate change not only affects ecosystems and species directly, it also interacts with other human stressors such as development, and cumulative impact may lead to dramatic ecological changes. Thus, climate change poses a threat to social and economic development in the Indian Himalayan Region where natural resource dependency of societies is of high order. As climate variation is complex and wide-ranging mitigation measures fall in "think global-act local" regime. Keeping in view the diverse attributes of the Himalayan ecosystem, this must be appropriately simplified to derive the narrowest possible alternative for reaching site-specific solutions or set of combinations. The theme focuses on (i) identification and prioritization of climate sensitive sectors in the Himalaya, (ii) development of indicators of Climate Change in the Himalaya, (iii) inclusion of Citizen Science Approach in Research, and Adaptation & Mitigation Strategies with reference to Climate Change, and (iv) Practice-Science-Policy connect through integration of community level experiences (acclimatization/adaptation/coping mechanisms) in Policy Framework

Alpine ecosystem dynamics and impact of climate change in Indian Himalaya (2013-17, Space Application Centre, Ahmadabad)

Alpine ecosystems around the globe usually have distinct biological communities and high level of endemism, due to the compression of thermal zones and isolation caused by low-temperature and topography. Many alpine regions in Indian Himalaya are among the remaining most pristine environments on earth, least influenced by anthropogenic activities. Towards understanding the science aspects of climate change and its impact, SAC on its part, through its focused PRogrAmme on Climate change Research In Terrestrial environment (PRACRITI), has been pursuing climate research with specific focus on geospatial modelling to assess climate change impact in critical areas of natural resources. However, we need to take up long-term ecological monitoring studies in this direction for understanding the relationship between vegetation and environment and distinguishing between pathways, causes and mechanisms of changes in alpine ecosystem. This particular work plan deals with alpine ecosystem dynamics and impact of climate change in Indian Himalaya.

Alpine region of the Himalaya comprise of high altitude grasslands or meadows. These meadows in the Indian Central Himalayan region are locally known as *bugyal,* named on a plant species *buggi* (*Trachydeium roylei*) which has been considered as a good fodder by the herders, locally known as *Anwal*. Besides having rich in plant diversity, including endemic and medicinal plants, Himalayan alpines have always been an integral part of the socio-ecological web in the high mountains, and source of inspiration for poets/philosophers/ thinkers. In general, Himalayan landscape has been considered as a sacred entity but is true for Himalayan alpines which has always element of associated spiritual values.

Objectives

- Establishment of HIMADRI Site following GLORIA protocol in the Alpine of Kumaun Himalaya for long term monitoring

Achievements

- Three alpine summits of District Bageshwar (Kumaun region of Uttarakhand State) were brought in the HIMADRI Network in the Indian Himalayan Region. Summits and there details are given in Table 9. Common woody species around the treeline zone were *Rhododendron campanulatus and Rhododendron barbatum,* while treeline was constituted by *Betula utilis, Abies pindrow, and Sorbus acuparia* etc.

Table 9: Details of HIMADRI Long term monitoring Alpine Site - Pakhwa Target Region.

S.N.	Name/ Attribute	HSP Code	Altitude (ma msl)	Geographical Coordinates	
				Latitude	Longitude
Site 1	*Nan-Pakhwa* (Lower Alpine)	NPK	3251	30°07'55.9"N	79°58'44.2"E
Site 2	*Pakhwa* (Upper Alpine)	PKW	3331	30°07'22.2"N	79°58'32.9"E
Site 3	*Kautela* (Sub-Nival)	KTL	3807	30°09'08.6"N	80°01'06.4"E

- Species diversity (total number of vascular plants) was decreasing with an increase in elevation- lower alpine (31 species), upper alpine (28 species), and sub-nival site (15 species). However, species composition of the study area was quite rich, dominance of *Danthonia cachmyriana* was quite visible in lower elevations. With an increasing elevation other species appeared as co- or absolute dominance. For example, Summit 1 area was dominated by Danthonia cashymeriana, while in Summit 2 co-dominance of *Trachydeium roylei* appeared, and at Summit 3 *Danthonia* disappeared and dominated species was *Kobresia duthei*. *Danthonia* appeared as warm site loving species as apparent from its distribution along the elevation and aspects (Fig. 25).

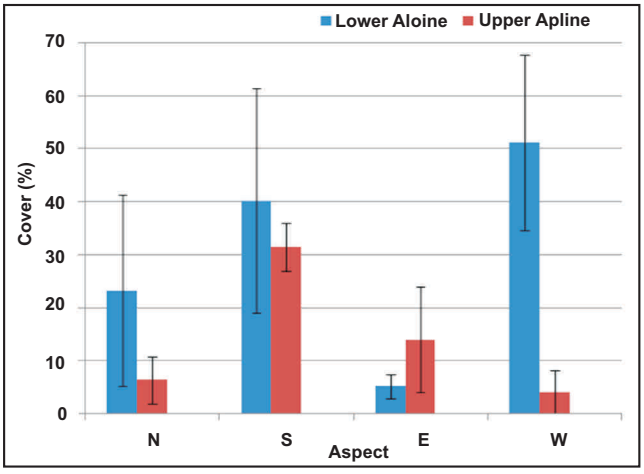


Fig. 25. Per cent cover of *Danthonia cachmyriana* in different aspects. The species is not present in Sub Nival region.

Vulnerability Assessment of Mountain Ecosystems due to Climate Change: Ecosystem Structure and Functioning (2014-19, Indian Institute of Remote Sensing (Department of Space), Dehradun

The Himalayan ecosystems are vulnerable to various risks both anthropogenic and well as natural and with the global climate change causing more impact on the mountain ecosystems, than plains. Various factors makes in the western Himalayan mountain ecosystem makes vulnerable to changes, and these includes (i) potential shifts in the species's bioclimatic envelop thus changes in vegetation assemblages and species migration, (ii) fragmentation in the tree cover due to anthropogenic activities, (iii) impact of geological processes like landslides on the vegetation cover, and (iv) impact of the changes in the socio-economic status in the mountain ecosystems. In view of the significant data requirement on various aspects to understand and forecast various sub-systems of Himalayan ecosystem, it is necessary to establish a few Long Term Ecological Monitoring Stations. These stations will provide data to understand the spatial and temporal variations in the Himalayan ecosystem due to climate change. Thus, Long Term Ecological Research (LTER) sites in differ zones of Uttarakhand, viz., alpine region, mid-altitudinal area and foot-hills will be established to realize the impacts of climate change in different ecosystesm of the mountains. GBPIHED is establishing one of the LTER in high altitude region of the state.

Objectives

- Impact of Climate Change on Himalayan Tree Line Ecotone
- Establishment of Permanent Field Plots for long-term monitoring

Achievements

- Tree line is a dynamic stage of tree vegetation in extremes. In mountains high elevation restricts further movement of growth and establishment of tree seedlings due to adverse & harsh climate.

Occurrence of tree line in Pindari catchment varies between 3048m (Kaphni subwatershed) and 3971m (Pindar sub-watershed) almost an altitudinal variation of about 1 km.

- Observations made in the slopes, leading to termination ridge, of two river valleys having contrast attribute – glaciated valley and non-glaciated valley. In Non-Glaciated slopes of the site *Rhododendron arboreum* alongwith *R. campanulatum* were the species whereas on glaciated slopes the richness was greater *R. barbatum, Abies pindrow, R. arboreum,* and *R. campanulatum,* towards treeline.
- The study conducted in Great Himalayan National Park (GHNP) (31°38'28" N to 31°51'58" N latitudes and 77°20'11" E to 77°45'52" E longitudes) located in Kullu district in Himachal Pradesh. Total 35 sites were surveyed between 2169-3756 m. Maximum sites (21) were represented by Shady Moist habitat, followed by, Riverine (5 sites), Rocky (03), Bouldry (3), Dry (2 site), and 1 Grassland. 10 sites were represented in North aspect, 8 in NW, 7 in NE, 4 in W, 3 in SW, 2 in E and 1 in S aspects. The slope varied from 15°-68°.
- 205 species of vascular plants belonging to 66 families and 142 genera were recorded. Among the identified species, 22 species were trees, 47 species of shrubs, 133 species of herbs and 3 species of ferns. Dominant families were Rosaceae (24 spp.), Asteraceae (21 spp.), Lamiaceae (14 spp.), Ranunculaceae (09spp.), Polygonaceae and Apiaceae (09 spp. each). *Carex, Polygonum, Potentilla, Rubus, Cotoneaster* was the most dominant species rich genera.
- 197 species were economically important, of which 175 species were medicinal, 10 wild edible/food 17 fodder, 16 fuel, 8 religious, 7 timber, 4 fibers, 9 for making agricultural tools, 5 dye yielding and 11 for various other purposes.
- 27 tree communities and (02) shrub communities were identified (Fig. 26 & 27). Maximum sites were represented by *Abies pindrow* community (4 sites), followed by *Picea smithiana, Quercus semecarpifolia, Pinus wallichiana* (02 sites each), the remaining communities were represented by 01 site only.
- The total tree density ranged from 10.00- 490.00 Ind ha^{-1}; total basal area 0.10-75.00 m^2 ha^{-1}; total shrubs density 230.00-3580.00 Ind ha^{-1}; total herbs density 2.92-116.05 Ind m^{-2}; total saplings density 30.00-325.00 Ind ha^{-1} and total seedlings density 20.00-370.00 Ind ha^{-1}. Maximum total tree density was recorded in *Picea smithiana - Abies pindrow* mixed (490.00 Ind ha^{-1}) community, followed by *Quercus semecarpifolia - Abies pindrow* mixed (470.00) community. Total basal area was recorded maximum in *Aesculus indica* (75.00 m^2 ha^{-1}) community. Total shrub density was highest in *Rhododendron anthopogon* (3580.00 Ind ha^{-1}) community, followed by *Betula utilis* (2520.00 Ind ha^{-1}) community.
- Among the sites, pH ranged from 5.39 -7.96, moisture content 15.5 - 49.84%, total nitrogen 0.5-4.52%, total organic carbon 5.04-15.40%, total organic matter 2.62-15.20% and C/N ratio 2.6-60.00. pH was highest for *Betula utilis* community and *Juniperus communis- Rhododendron lepidotum* mixed community.

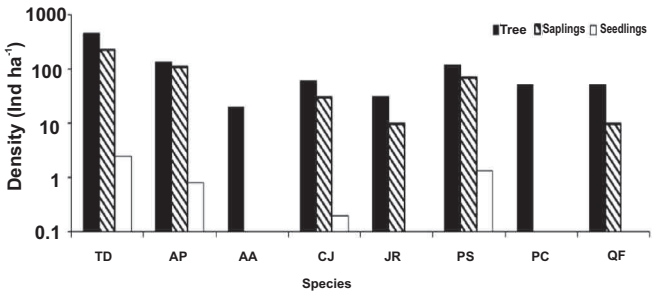


Fig. 26. Population structure of Abies pindrow-Picea smithiana mixed community; TD=Total density; AI= *Abies pindrow, AA=Acer acuminatum,* CJ= *Corylus jacquemontii, JR=Juglans regia, PS=Picea smithiana, PC=Prunus cornuta and QF=Quercus floribunda*

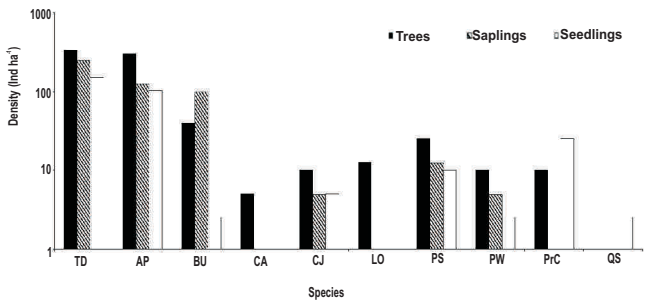


Fig. 27. Population structure of *Abies pindrow* community; TD=Total density; AP= *Abies pindrow*; BU=*Betula utilis*; CA=*Celtis australis*; LO= *Lyonia ovalifolia;* CJ= *Corylus jacquemontii*; LO= *Lyonia ovalifolia;* PS= *Picea smithiana;* PW=*Pinus wallichaiana,* PC= *Prunus cornuta and* QS=*Quercus semecarpifolia*

Theme

Environmental Assessment and Management (EAM) & Environmental Governance and Policy (EGP)

The appalling populations and their ever increasing demands have led over-exploitation of natural resources which together have resulted in scarcity and degradation of existing resources. The degradation of existing resources beyond their carrying capacity therefore leads to a variety of environmental disorders and pollutions. Developmental activities and ever increasing load of pollutions need a fresh re-look in a comprehensive manner for sustainable development. Environmental Assessment and Management and Environmental Governance and Policy (EAM & EGP) themes therefore primarily focus on addressing, monitoring, assessing and analyzing physical, biological and cultural components of environment, related to various types of developmental activities/ interventions/ projects/ policies/ plans in the Indian Himalayan Region (IHR). The theme generate information to assess and analyse impacts, set priorities, identify gaps, develop early mitigating approach and to find new technology and approach to achieve sustainable development of a region. By way of mitigating and minimizing adverse impacts of developmental activities and maximizing their positive impacts would improve ecosystem services and help individuals become more self-reliant. The recent environmental issues like developmental interventions and arising impacts, ambient and columnar aerosols, black carbon aerosols, temperature rise, global warming, climate change and glacier melting have also become the core topics of the theme. The micro level studies specifically on strategic environmental assessment of hydropower projects, impact of climate change on environmental flow in fresh water ecosystem, gaseous pollution in the background sites of the sprawling environment, aerosols climatology, black carbon aerosols over the glaciers, pollution disaster mitigation and participatory approach to investigate vulnerability and adaptive capacity of climate change of the local communities have been covered under the R&D activities of the theme. Given these facts, EAM & EGP themes envisage planning and management options for the sustainable ecological and economic development of the IHR. The objectives of the theme include (i) assessment and monitoring of physical, biological and socio-economic environmental attributes related to various developmental interventions /policies/plans in the Indian Himalayan Region (IHR), and development/ formulation/suggestion of appropriate management plans ensuring ecological and economic sustainability.

Strategic Environmental Assessment (SEA) of Hydropower Projects in the Himalayan Region (2012-17, 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 form 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 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, and
- To suggest measures to promote sustainable HEPs based on SEA.

Achievements

- Vulnerability assessment in the Satluj basin within a selected buffer (10 km) was categorized into three zones, i.e., upper zone (Spiti to Reckong Peo- high value of R_R = 2227 – 6238 asml), middle zone (Reckong-Peo to Rampur- moderate value of R_R=434-6448 asml) and lower zone (Rampur to Kol dam- low value of R_R=468-3639 asml Fig.28).

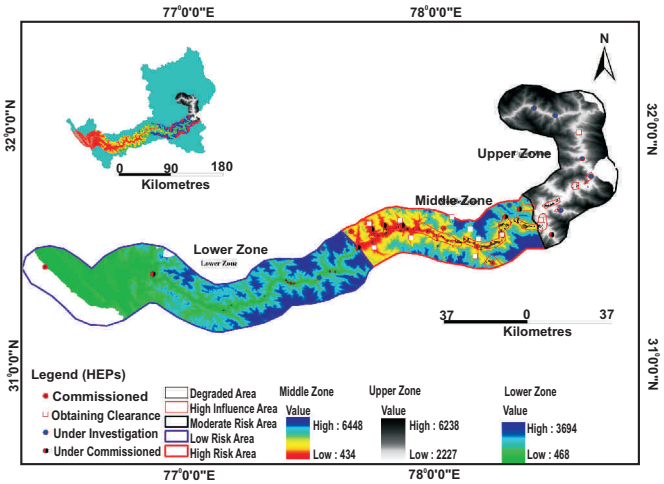


Fig 28. Vulnerability assessment zones in the Sutlej basin, Himachal Pradesh

- Land hazard zonation within a stretch of 582 km^2 from Rampur to Khab identified total 121 landslides, out of which 19 were large and 102small. Area under the influence of landslides has significantly increased from 1.35 km^2 in 1990 to 15.7 km^2 in 2015. Further, 37 km^2 area is vulnerable to landslides. About 3.44 km^2 area under agriculture and settlements was damaged by the landslides from 1989-2015. Out of 118 km length of NH-5 (34 km^2), 28% length was affected by these landslides due to increase in project development activities. It is also observed that area falling under the influence of rain; not only increase the number of landslides, but also increase the soil erosion and sediments load in the River Sutlej.
- Soil pH in the hydropower affected areas in the Sutlej basin was found alkaline in nature. Upslope and downslope regions have been facing more environmental degradations due to excessive construction activities. Soil quality in terms of available nitrogen (N), phosphorus (P) and potassium (K) was low (211±10-224±14 kg ha^{-1}), medium (13.9±1.7-18±2 kg ha^{-1}) and high (283±30-296±31 kg ha^{-1}) respectively. NPK were higher at Khab (2915 m; a pristine site) as compared to other affected areas.
- Among water quality parameters, turbidity of the river water varied from 86.3 NTU to 189.6 NTU with mean value of 121.8±6.9 NTU during post-monsoon. All the analyzed samples were not within desirable limit of 5 NTU (BIS, 1991) and were found not fit for human consumption. Water quality is affected due to debris dumping along the river beds where turbidity (94.8-389.8 NTU) is high.

- Air quality as particulate pollution (PM_{10}) in a majority of samplings crossed (102.2-107.3 $\mu g\ m^{-3}$) the permissible limit (100 $\mu g\ m^{-3}$). While the trace gases (i.e. nitrogen dioxide, sulphur dioxide and ammonia) were under limit
- The consultative meeting of the natives conducted on December 7, 2016 in the Deputy Commissioner Office, Reckong Peo in Kinnaur showed that 87.88% participants suggested that there should be fixed radius of 7 km between the two large projects, 87.88% suggested 5 km fixed radius between two small projects and 81.82% suggested 3 km radius between two mini projects. A brainstorming workshop on 'impacts of HEPs and the role of Environmental Impact Assessment and Strategic Environmental Assessment (EIA&SEA) was organized at Lakhimpur Girls College, Lakhimpur, Assam in the downslope of Ranganandi hydropower project (RHEP). When 48 stakeholders in a questionnaire survey queried during the workshop, 85% of the total respondents said that they have been affected by HEPs, and 58% perceived agriculture sector is mostly affected. But a large number of respondents (69%) perceived that these projects are offering employment opportunity to them.
- In downstream of the RHEP dam site impacts on aquatic life mainly on fish was assessed. Only one fish species *Garra birostris* (family: Cyprinidae) could be captured during the experimental fishing. Only two very small size individual fish were recorded from Ranganadi. There average length and weight was around 4-5 cm and 150 gm respectively. Whereas, in downstream of powerhouse site of River Dikrong, three fish species viz. *Neolissochilus hexagonolepis, Bangana dero* and *Crossocheilus latius* were captured which belong to family Cyprinidae. The size and number of fish species were recorded higher in River Dikrong as compared to River Ranganadi. The average length of *Neolissochilus hexagonolepis* was around 20 cm and average weight was around 500 gm. *Neolissochilus hexagonolepis,* migratory and game fish, has been categorized by IUCN near threatened (NT) category. This prefers to live in deep water especially turning point of Mountain Rivers. This species is facing major threats such as habitat loss due to deforestation and erosion, urbanization, including road construction and over-exploitation. This migratory species is also threatened in parts of its range by recent and planned hydropower developments. Dams and weirs at higher reaches of the River Brahmaputra have affected the spawning run of the fish.

Gaseous air pollution in the background site of sprawling urban Environment of Himachal Pradesh (Long term, 2008- to date; 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 hydroxy 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, natural fires and lightning, and is emitted from combustion processes such as vehicular emissions and fossil fuel power based projects. NO is a short lived gas 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 important concentration of gaseous pollutants such as surface ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) due to anthropogenic sources (such as vehicular congestion, and biomass burning) as well as natural sources (dust storms, etc.) to establish background values in the Himalayan region.
- To observe local meteorological parameters and relate these with gaseous pollutants, and analyze in the background sites of long range transport sources, and
- To suggest some feasible mitigating measures for policy implications.

Achievements

- Observations of trace gases such as surface ozone and its precursors, nitrogen oxides (NO+ NO_2), and carbon monoxide were carried out in the Kullu valley base- Mohal (1154 m amsl) in an Environmental Observatory. The related online analysers and equipments were used. Among the worth mentioning equipments were the UV photometric Ozone Analyzer (Thermo Fischer Model, 49i), NO_x Analyzer (Thermo Fischer, Model 42i), and Carbon Monoxide Analyzer (Thermo Fischer Model, 49i). During a reporting period (April 2015 – March 2016), higher concentration of surface ozone was observed in the months of June, which was maximum as 57.27±9.25 ppb (Fig. 29).

- Diurnal cycle of O_3 concentration at Mohal-Kullu from April 2015 to March 2016 showed unimodal peak during mid of a day at 15:00 hr IST. This is mainly because of strong process of photo-oxidation in presence of sunshine and its precursors. While these values were low in early morning and late evening due to absence of sunlight.
- NO_x shows a bimodal peak. Its precursor showed a maximum concentration of about 20.56±6.22 ppb in December. Diurnal cycle of NO shows maximum 14.25±2.67 ppb in August (Fig. 29).While NO_2 was maximum during 11:00-12:00 IST having 13.91±3.37 ppb in December.
- In summer season (April-June), O_3 was maximum with 57.27±9.25 ppb, NO was 9.10±2.93 ppb in May and NO_2 was 12.29±3.22 ppb in June. NO_X was 15.21±3.34 ppb in June (Fig. 29). The highest values during summer have mainly been because of longer sunshine hours, relatively higher concentration of its precursors due to peak tourist season in the region.
- In rainy season (July-September), O_3 was maximum with 44.41±10.16 ppb in September. NO was highest 14.25±2.67 ppb in August and NO_2 6.94±1.43 ppb. and NO_X was 17.25±3.20 ppb in July. During rainy season, there remains washout effect on the pollutants as a result their concentrations low.
- In autumn/winter season (October-December), O_3 was maximum with 40.95±4.59 ppb in November and minimum with 1.04±1.73 ppb in December. While NO, NO_2 and NO_X in December stood at 8.55±2.19 ppb, 13.91±3.37 ppb and 20.56±6.22 ppb respectively. During autumn in October due to International Kullu Dusshera, sometimes, high pollution is experienced.
- In winter season (January-March), O_3 was maximum with 43.49±7.9 ppb in February and minimum 1.19±2.9 ppb in January. January is the month when NO, NO_2 and NO_X were observed to be 9.17±1.7 ppb, 9.79±2.6 ppb and 18.74±0.95 ppb respectively. During Winter there is minimum tourists' interference except biomass burning and forest fires by the local residents.
- These precursors are mainly considered to be emitted in the present study sites primarily due to anthropogenic emissions such as vehicular emission and biomass burning which are considered to be primary pollutants**.** In addition, the region also has long range transport sources outside the region such as the Indo-Gangetic Plain and Middle East countries and the Indian Thar Desert.

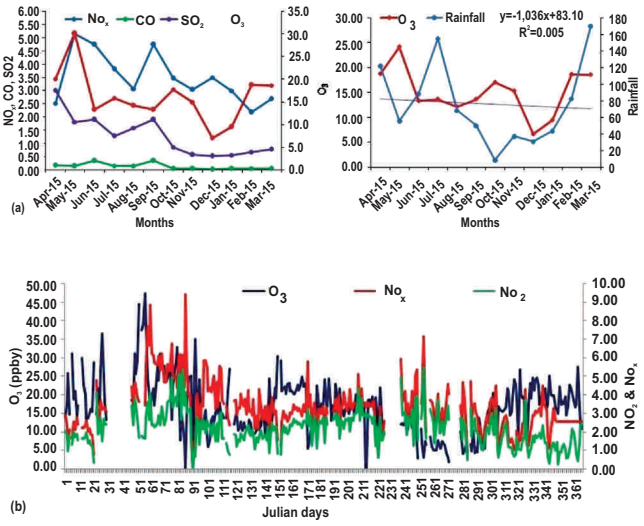


Fig. 29. (a) Monthly variations in surface O_3 concentration with NO_X, CO, SO_2 and rainfall, and (b) variation of O_3 concentration with NO_x and NO_2 during different Julian days

Aerosols climatology over the northwestern Indian Himalayan region, Himachal Pradesh (2005-17, ISRO, SPL, Thiruvanthapuram)

Climate change is one of the most important issue of 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 amount 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 Ångstrom parameters such as Ångstrom exponent 'α' are associated with the fine aerosols whereas turbidity coefficient 'β' is associated with the total aerosol loading. With the increasing concentration of aerosols, there is a decrease in the rainfall. The deposition of the black carbon aerosols on the glaciers increases the light absorption, whereas snow albedo decreases resulting in local temperature increase and the melting of the glaciers. Fossil fuel and biomass burning are the sources of fine size black carbon aerosols which become a cause of impairment in atmospheric visibility 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 atmospheric models.

Achievements

- The mean AOD at the Beas Kund Glacier was 0.20±0.09 at 500_{nm} (Fig. 30a). It ranged from 0.10 to 0.33. The highest daily mean AOD value at 500_{nm} was found to be 0.33 on 14 September 2015 while the same was observed minimum 0.10 on 4 September 2015.
- At Kothi, mean AOD at 500_{nm} was observed to be 0.19±0.05 in 2015. AOD at the same wavelength stood to be as lowest (0.12) and highest (0.26) in August followed by 0.25 in June (Fig.30b).
- Average AOD for the full day at ten wavelengths during the clear sky days from the year 2006 to 2015 was taken into account at Mohal. It was found that AOD values were noticed maximum for the year 2012 and minimum for the year 2007 (Fig. 30c). Due to increase in the anthropogenic activities, 37.96% increase was found in AOD at 500_{nm} from 2007-2015. This increase in AOD at 500_{nm} from FN to AN was 43.0% and overall increase at ten wavelengths from FN to AN was 41.9 %.
- At Mohal, in a majority of the cases (2006 to 2015), the Ångstrom parameters like Ångstrom exponent 'α' shows maximum fine size particles concentration in autumn which was minimum in monsoon season. While turbidity coefficient 'β' shows coarse size particles with maximum concentration in monsoon and minimum in winter and autumn seasons.
- Diurnal variation of BC showed uni-modal peak at Kothi with its highest concentration (5205.8 ng m^{-3}) at 7:00 hrs IST (Fig. 30d). On the other hand, BC shows entirely different pattern at Mohal showing two peaks; during morning hour (10:00 hrs IST) and other in evening hours (20:00 hrs IST). The highest mean value of diurnal BC at Mohal was observed to be 2021.9 ng m^{-3} at 20:00 hrs IST and minimum 676.6 ng m^{-3} at 06:00 hrs IST. While the average concentration of BC at Mohal was 1363.2 ±418.6 ng m^{-3} (Fig.30e).
- In 2015, the instantaneous mean aerosol radiative forcing at Mohal was estimated to be –16.32 ± 7.36 Wm^{-2}, –33.30 ± 13.87 Wm^{-2} and +16.99 ± 7.78 Wm^{-2} on the TOA, surface and atmosphere respectively. Here, mean aerosol radiative forcing for the entire period of 2006-15 was estimated to be –12.99 ± 6.57 Wm^{-2}, –36.10 ± 13.94 Wm^{-2} and +23.11 ± 10.38 Wm^{-2} on top of the atmosphere, surface and atmosphere respectively (Fig.30f) which translates into an average atmospheric heating rate of 0.65 K day^{-1}.
- While noticing relationship of AOD with temperature conditions as correlation coefficient at Mohal, it was found positive (r =0.46) indicating an increase in air temperature with the simultaneous increase in AOD.

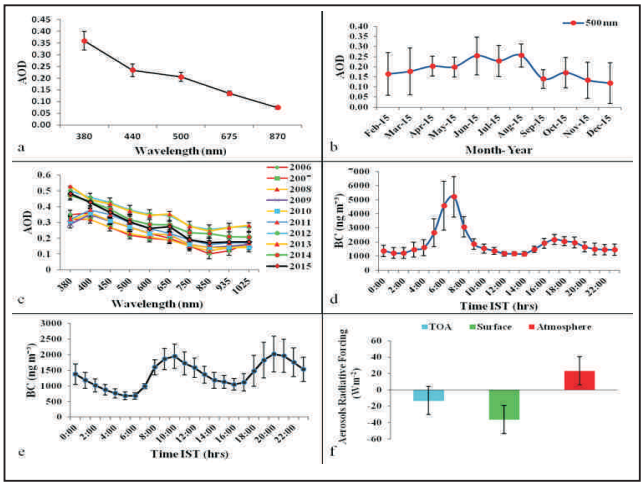


Fig.30. Aerosol optical depth, black carbon and Radiative Forcing in the Kullu valley: **(a)** AOD at Beas Kund Glacier, (b) AOD at Kothi, (c) Annual variations in AOD at Mohal, (d) BC aerosol at Kothi, (e) BC aerosol at Mohal and (f) Aerosol Radiative Forcing (2006-2015) at Mohal.

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 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 part such as glaciers of the mountains. The diurnal variation in the atmospheric boundary layer (ABL) height (1 to 2 km) and its structure indicates an influence over the black carbon (BC) and other aerosol concentrations. The present study therefore focuses on the monitoring of black carbon and other aerosols loading over the Parbati Glacier in Himachal Pradesh. This glacier is located between 31^0 45'- 31^0 49' N and 77^0 45'- 77^0 51' E 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 is 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 under 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. The economic prosperity of the present selected Parbati Glacier, 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 and create imbalance situation on the glaciers.

Objectives

- To observe the role of Black carbon (BC) and other aerosols on the Parbati Glacier environment.
- To analyze snow and ice chemistry of the Parbati Glacier.

Achievements

- The daily average black carbon concentration during August and September in 2015 was 0.41 ± 0.02 µg m^{-3}. While the highest mean value of hourly BC concentration ranged between 0.23 µg m^{-3} at 09:00 IST hrs and 0.51 µg m^{-3} at 20:00 IST hrs. The daily mean BC concentration during August and September was observed to be 0.31±0.02 µg m^{-3} and 0.48 ±0.02 µg m^{-3} respectively (Fig.31a).
- Looking at different source contribution of the total BC, biomass burning- a local source contributed about 13% of the total contribution in the Parbati Glacier. Whereas other source in the region is fossil fuel burning attributable mainly to outside sources with the air masses in the region.
- The mean Aerosol Optical Depth (AOD) at 500 nm was observed to be 0.17±0.02 (Fig.31b). While this value from minimum to maximum ranged from 0.09 to 0.28 respectively. AOD values in 2014 were 0.16 ± 0.01 ranging from 0.08 to 0.25 respectively.
- Snow chemistry of the Parbati Glacier in terms of anions during 2015 were in an order of $Cl^{-}>F^{-}>SO_4^{2-}>NO_3^{-}$(Fig.31c). While that of cations were in an order of $Na^{+} > NH_4^{+} > Mg^{2+} > Li^{+} > K^{+}$. There was single transition metal zinc (Zn^{2+}) with 70 µg L^{-1} concentration which is considered to be due to burning and other activities.
- The radiative forcing due to AOD is estimated for observation period (2014–2015). The ARF estimated at the top of the atmosphere (TOA), surface and atmosphere was - 12.64 ± 1.0 Wm^{-2}, - 3.28 ± 0.33 Wm^{-2} and + 9.37 ± 0.69 Wm^{-2}, respectively (Fig. 31d). The ARF at the TOA, surface and atmosphere varied from - 6.60 to 1.60 Wm^{-2}, - 22.0 to - 6.40 Wm^{-2} and +4.80 to +15.40 Wm^{-2}, respectively. This indicates that atmosphere is going to warm up while the surface is getting cool.

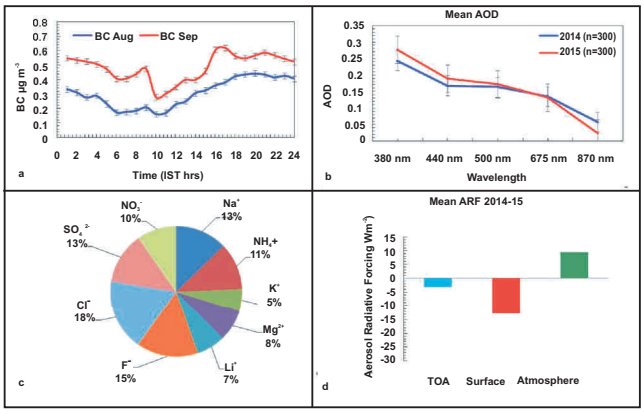


Fig. 31. Parbati Glacier: (a) BC concentration, (b) AOD, (c) ion concentration in the glacier snow, and (d) ARF at Parbati Glacier during 2014-15.

- The fluctuation of the snout of the Parbati Glacier was also monitored using satellite data of different time periods (Fig. 32). Based on the Landsat data, it was found that there is a continuous retreat of the snout of the Parbati Glacier during 53 years between 1962 to 2015. On average, it is found that snout is retreating at an average rate of 0.67 m yr^{-1}. The overall recession in snow area of the Parbati Glacier from 1962 to 2015 stood to be 2150 ± 178 m^2 indicating its recession at the rate of 40.57 m^2 yr^{-1}.

Fig. 32. View of the snout of the Parbati Glacier during October, 2015.

Theme

Socio-Economic Development (SED)

The Indian Himalayan region (IHR) is a unique zone of convergence of diverse ecosystems, cultures and plethora of ethnic communities. Bio-physically, all of the mountain ecosystems are fast approaching many of tis limits and gradually becoming unable to provide enough support to livelihood of the people residing here. The continued population growth and consequential poverty are fast depleting the finite natural resource base and breaking down the indigenously evolved resource use patterns that were socially sanctioned and culturally patterned. Therefore, reduction of poverty in this ecosystem throught ecologically appropriate and socio-culturally acceptable interventions, and promotion of innovative livelihood and skill enhancement of the local communities for their social and economic development are crucial as decrease in poverty can increase environmental protection. With this in view, the Socio Economic Development Theme has focused on prioritized activities, such as improved and sustainable farming systems, promoting ecotourism, providing innovative livelihood options, restoration of ecological balance in the degraded and frazil ecosystem, which have potential to benefit the economically disadvantaged communities of the IHR and reversing the trend of poverty .

Eco-tourism as a potential tool for biodiversity conservation and sustainable livelihood in Indian Himalayan Region (2013-17, In house)

Indian Himalayan Region (IHR) is biologically and culturally one of the richest regions in the country, it 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, etc. The tourism, in turn, has potential for economic development of the ethnic communities and conservation of the rich biodiversity of the region. The present project envisages developing a model, incorporating tourism with ecology, economy, culture and community conserved areas and by using eco-tourism as a potential mechanism to promote livelihoods and conserving 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 Himalayan States of Indian Himalayan Region.

Objectives

- To assess the status of eco-tourism in terms of goals and impacts in select pockets across IHR
- 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, and showcase the knowledge to benefit the tourists and help the community capitalizes 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 potential ecotourism destinations across IHR 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 ecotourism model and many others. In Arunachal Pradesh, the ecotourism model developed at Apatani Plateau was further strengthened by adding a number of cultural items to the model. During the reporting year, for Arunachal, focus was on assessment of positive and adverse impacts of tourism on environment, economy and culture through use of selected variables. As many as 305 respondents (hosts) were assessed in 12 villages in Apatani Plateau, while 100 hosts were assessed in 14 villages of West Kameng District.
- In Sikkim an assessment of tourist flow in Fambhonglho wildlife sanctuary revealed gentle increase during 1996 to 2014, consultative meetings organized with stakeholders (i.e., community, planners & administrators, etc.) for understanding livelihood and conservation issues.
- For Uttarakhand, information on tourist inflow status was updated and survey of 400 tourists, 108 business owners at Kausani and potential scoping for eco-tourism at Jageshwar was carried out. The tourist inflow in Kausani has been static over past 15 years. The tourists' responses to diverse set of services and their percentage ratings, all the services ratings lie above satisfactory level in good category, suggesting a good state of services, hence the consumer satisfaction derived thereof. A comparison of earnings of randomly selected business owners in and around Kausani for Summer Season and Autumn Season vis-à-vis rest of the year depicts a clear cut impact of tourism all across which is maximum for Baijnath area in terms of share of annual income during tourist seasons, which dissipates towards Garud and Someshwar area i.e. with the distance from the place (Fig. 33). The impact of summer season is more pronounced in all places. In Jageshwar area some new hotels and home-stays and restaurant have come-up, which are mainly owned by the local people, and have created employment and income opportunities for the local people. However, inflow volumes at Jageshwar have still remained low. A SWOT analyses of the place reveals the need for diversification of the touristic experience of the place by linking it with shrines, places in scenic settings, and wildlife/ biodiversity viewing at vicinity like Binsar Sanctuary places located at short trekking distances from the place.

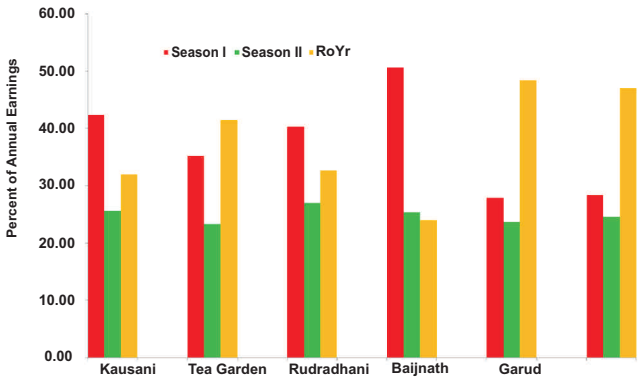


Fig. 33. Tourism's impact on earning of the local business community at selected places in Uttarakhand.

- In Himachal Pradesh an assessment of tourist arrival at the Great Himalayan National Park (GHNP) Fig. 34) and their positive and negative impacts on park and surrounding areas was studied through conversing with 90 respondents. Documentation of good ecotourism practices of Himachal Pradesh, viz., AAMOD, Shogi-Solan, Judges Court, Paragpur-Kangra, Country Cottage, Kangra, Oakwood Hamlet, Solan, ANANDA project, Naggar-Kullu, etc., was also carried out.

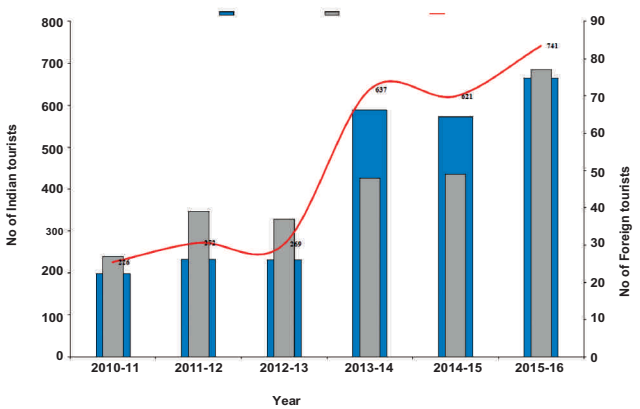


Fig. 34. Yearly tourist arrival in Great Himalayan National Park, Himachal Pradesh

Network programme on Convergence of Traditional Knowledge System for Sustainable Development of Indian Himalaya Region (2015-20, DST - NMSHE Task Force 5)

The National Action Plan on Climate Change (NAPCC) of Govt. of India has given high priority for preserving ecological security of the Himalayan ecosystem in view of its vulnerability to anthropogenic and environmental perturbations. Therefore among eight National Missions, only one location specific 'National Mission for Sustaining Himalayan Ecosystem' (NMSHE) has been launched that aims to take up appropriate measures for sustaining and safeguarding the glaciers and mountain ecosystems. NMSHE has six Task Forces, and Task Force 5 being the 'Network programme on Convergence of Traditional Knowledge System for Sustainable Development of Indian Himalaya Region', which is being coordinated by Jawaharlal Nehru University. GBPNIHESD has been an important partner in the Task Force 5, which is focused to document and analyze traditional knowledge on selected prioritized sectors so as to mainstream it in regional developmental planning process thus help in managing fragile Himalayan ecosystem in the backdrop of climate change.

Objectives

- To document, validate and analyze the traditional knowledge in the Indian Himalayan Region.
- To create a digital library on TKS in the Himalaya.
- To understand the linkages between traditional knowledge and modern science in order to identify promising TKS for improvement and adoption.
- To capacitate the institutions in the Indian Himalayan region to focus on TKS for sustainable development of indigenous communities in the hills.
- To formulate strategic framework for indigenous knowledge management in ecologically fragile mountain ecosystems especially in the face of climate change.

Achievements

- GBPIHED has so far selected four states covering Arunachal Pradesh (7 districts), Sikkim (3 district), Uttarakhand (1 district with different altitudinal gradients), and Himachal Pradesh (3 districts). These sites comprised 15 ethnic communities of IHR (Fig. 35). A detailed questionnaire has been developed to document data across different states. Extensive literature search have also been initiated on the subject.

Fig. 35. A. Apatani plateau In Lower Subansiri District, Arunachal Pradesh; B. Monks performing *Chhamm* dance, Sikkim; C. A view of village settlement in central Himalaya; and D. Lahouli women (Himachal Pradesh) adorn with her traditional costume and jewellery

- While documenting land and soil management practices it was found that tribal communities use locally devised best suited land and water management knowledge, for example Apatani (Arunachal Pradesh) practice efficient rice-fish cultivation and has strong forest management strategy, while Adi community, which practice shifting cultivation (*jhum*), adopt varying approaches by identifying several patches (*Patat* system) of land for crop production. Water and soil management is also explicit for both the region. In shifting agriculture areas logs are used across the slope to control soil erosion (*Panpeng)*. Communities have village level institutions to manage agriculture, forest, and water resources, which is done by implementing customary regulations. *Apatanis* manage forest in four well-defined zones; starting from just above the agricultural fields in the form of bamboo monoculture or bamboo mixed with pine and *Castanopsis* trees, followed by *P. wallichina*, *Castanopsis* and/or mixed vegetation with *Quercus* spp., and lastly the mixed species of *Quercus lanata, Castanopsis, Taxus wallichiana, Cephalotaxus* sp. etc. Though all forest types are important for the community, there is a high dependency on bamboo and *Castanopsis* species.
- In district Bageshwar (Uttarakhand) communities possess huge knowledge on local land races of crops, however considerable loss of local genetic pool was observed. Rice, wheat, *Setaria italica, Eleusine coracana, Linum usitatissimum,*

Echinochloa frumentacea, Sorghum vulgare, Sesamum indicum in agricultural fields in recent times. The community observing a decline is agricultural yield, which is also affected with the wild life menace. Documentation of local land races, traditional agricultural tools, storage items and other implements has been initiated. Communities also have high dependence on forest for fuel, fodder, leaves for animal bedding, medicinal plants, timber for house construction, and other NTFPs. Data collection with regard to these produces is in progress.

- In Himachal Pradesh, documentation of traditional bio-resource use pattern in Lahaul & Spiti, Kullu and Mandi districts have been initiated. Documentation of traditional bamboo basketry art and traditional handicraft items, such as *Mandri* (Carpet made of paddy straw), *Jungda* (made up of *Quercus* sp.) used during ploughing, *Takli* and *Dabotni* (spindle/washing stick made of *Juglans regia*), *Changer*, *Chabadi*, *Tokra*, *Shup*, *Kilta, Tokri/Pataari* etc. made of *ringal (Arundinaria* sp) has been done.
- Use of *Terminalia chebula, Berginia ciliata, Zinziber officinale, Hordium vulgare, Taraxacum officinale, Eupatorium adentophorum* and various other plants in traditional health care system in central Himalaya was also documented. It was recorded that the Herbal healers (Vaidyas) treat wound, cough, cut, burn, hardness and stomach pain, migraine, snake bite, mouth infestion using local plants.

Standardization of post harvest technology for wild rose hips and promotion as sustainable livelihood option among poor self help women groups in Kullu Valley, Himachal Pradesh (2015-18, DST, New Delhi)

Kullu district in Himachal Pradesh comprised over 90% rural population, a literacy rate of 79.40% (male 87.39%, female 70.91%) and a sex ratio of 950 women per 1000 men. 23% of population of the district live below poverty line. Harsh climatic conditions and inaccessibility to basic services impose greater drudgery on poor households in meeting their livelihood needs and there is increasing burden on women in view of their diverse engagements, i.e. collection of fuelwood, fodder, and grass, grazing cattle, fetching water, and various household courses. There is need to increase income of such communities using wild plant materials. Wild Rose, locally called as Rosehip or *Kuja* (*Rosa brunonii* syn *R. moschata*; family Rosaceae), although grows in degraded forest and riverine habitats and used as fodder by goats and sheep, and also an important forage for pollinators, has good potential to be exploited for raising community income by developing some value added products, such as tea, oil and other produces. Considering this a project is being implemented in Kullu district covering selected villages and targeting weaker section, particularly women self help groups.

Objectives

- To estimate composition and oil contents of rosehip and study altitudinal variation in contents;
- To develop post harvest technology for collection and semi processing of rose hip;
- To form women self help groups and develop and test value added products like tea, oils and oil based personal care products;
- To promote sustainable harvesting practices and regeneration of rose in the collection area

Achievements

- The R&D work has been initiated Kullu Valley and after detailed stakeholder consultation eight women Self-help and Credit Groups (WSCGs) were formed in selected villages. These groups have been made aware on the rosehips and its possible potential.
- A one-day workshop cum training programme on "Sustainable harvesting, collection practices and product development of Wild Rosehips" has been

Fig. 36. Wild rose plant and related activities in the project
a) Rosehip flower; b) Rosehip Pods; c) cleaning of harvested fruits; d)Women participants in training

organized; 500 women participated in it who were trained on importance of rosehips, its collection practices, sustainable harvesting techniques, and drying and storage methods (Fig. 36).

- Over 2000 kg of Rosehip fruit was purchased from stakeholders costing @ Rs. 55/- per kg
- Rosehip seed shredder machine was purchased. It is being processed for product development and laboratory testing.

Restoration of ecological balance in the degraded and fragile ecosystem through development of Nanda Van at Almora (2014-18, In house)

All over Himalaya and elsewhere, an increase in wastelands and degradation in land is being observed. Land degradation reduces productivity of land thus impacts food, fuel and fodder supply. Wastelands are formed due to misuse, over utilization and unscientific land management. As over 90 percent rural poor use forest lands for fuel wood collection, animal grazing, and meeting other diverse needs, at various places the land reach to highly degraded status in view of over exploitation of resources. Ecosystem services of such areas are greatly affected putting high impacts on local residents. If land comprised steep slopes and sparse vegetation cover, biotic pressure leads to significant soil erosion during monsoon. Reviving such degraded lands is a huge challenge. As the Institute has been working in close coordination with divers stakeholders and local administration, on the request of Nagar Palika (district municipality), Almora a piece of degraded forest land (1.08 hectare) has been handed over to the Institute to develop it as a model demonstration for forest restoration so that other nearby areas could also be revegetated. The elevation of the target site is 1600 to 1700 m amsl with a slope >60° and low soil depth.

Objectives

- Restoration of ecological balance in the degraded & fragile ecosystem by application of live demonstration of hill specific technology packages.
- Conservation, development and sustainable management of natural resources mainly land, water & forest.
- To study the performance of multipurpose planted tree under the Chir-Pine tree in a degraded mountain site.

Achievements

- So far one thousand saplings of 21 tree species (viz. Banj, Utis, Tajpatta, Ritha, Phalyant, Bottlebrush, Sadabahar, Bamboo, Mulberry, Padam, Deodar, Chinnar, Bedu, etc.) have been planted to improve the degraded land.
- After one year of plantation the survival of plants was recorded as 79% at the highly degraded site whereas it was 84% at the less degraded site.
- Three water harvesting structures have been demonstrated at the site to fulfill the water demand of the plantation.
- Now the women from surrounding areas collected fodder grasses from the site.
- To protect the plantation site from forest fire, dried pine needle regularly removed from the site through voluntary participation by the Institute staff and scholars (Fig. 37).

Fig. 37. Voluntary cleaning and plantation activities at target site and status of planted saplings

Theme

Biotechnological Applications (BTA) & Environmental Physiology (EP)

The thematic area 'Biotechnological Applications and Environmental Physiology' is focusing on 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 microbial diversity is equally important aspect of the theme. 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 mountains. 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 (i) identification and documentation of bioresources of applied value of IHR, (ii) generation of technological knowhow of the process development, (iii) identification of mechanism of plant adaptation, and (iv) human resource development.

Promoting conservation and sustainable utilization of Himalayan Biodiversity elements using biotechnological and physiological approaches (2012-17, 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 the Indian Himalayan Region (IHR) support rich biodiversity including ecologically and economically important plants. While the country ranks 8th in its plant biodiversity, the IHR with 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 in 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

A process for synthetic seed development in *in vitro* grown callus cultures of *Nardostachys jatamansi* has been optimized. *In vitro* grown calli encapsulated in gelled mixture, consisting of ½ MS medium, 3% sodium alginate and stored in a moist environment for 3 months at 25 ± 2°C for germination. After 3 months of storage at 25±2°C, the encapsulated calli were regenerated within 4 weeks of following culture (Fig. 38). The maximum frequency of regeneration i.e. 90% and total shoots number 3±0.45 was found in 3% sodium aliginate beads, which were submerged in calcium chloride after 6 weeks of culture on MS medium containing 1.0 µM & 15.0 µM IAA and TDZ, respectively. Further, optimization for long term storage of encapsulated calli is under progress.

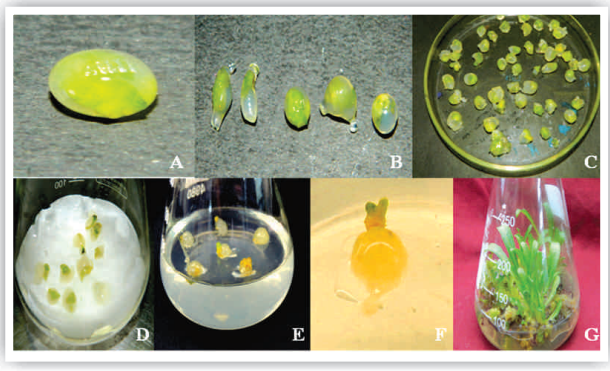


Fig. 38. Different steps of sysnthetic seed production in *Nardostachys jatamansi*; A-C Synthetic seeds, D - Storage of synthetic seeds, E - Germination in synthetic seeds, and F - Fully regenerated plantlets.

- Nutritional, anti-nutritional and anti-mutagenic activities of the fresh and boiled *Paeonia emodi* leaves were analyzed. Significantly higher vitamin A (64.19±0.18 mg/100g), C (160.50±1.85 mg/100g) and E (1.25±0.00 µg/g) were recorded in boiled as compared to fresh and dried juvenile leaves. Similarly, significantly higher protein content (329.63±0.33 mg/100g) was found in boiled budding stage leaves; carbohydrate content (0.353±0.02 and 0.353±0.10 mg/g) in fresh juvenile and mature stage leaves; methionine content (47.75±0.09 mg/g) in dried budding stage leaves and proline content (1.23±0.12 µM/g) in dried mature leaves.

- Anti-nutritional attributes like phytic acid (250.17±0.19 mg/100g; $p<0.05$) and total tannins (48.41±0.09 mg/g) was significantly higher in dried and fresh budding stage leaves, respectively, however, trypsin inhibition activity (91.90±0.34%) in dried juvenile leaves (Table 10). Significantly higher 2, 2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic (ABTS) radical scavenging activity (71.13±0.09 mM AAE/100g) and ferric-reducing antioxidant power (FRAP) activity (3.39±0.01 mM AAE/100g) was recorded higher in dried budding stage leaves. Whereas, 2,2-diphenyl-1-picryylhydrazyl (DPPH) free radical scavenging assay (3.55±0.017 mM AAE/100g)

Table 10. Phytic acid, tannins and trypsin inhibition content in the leaves of *P. emodi* collected during different growth stages. Mean values ± SE (n=3)

Samples	Phytic acid (mg/100g)	Tannin (mg/g)	Trypsin inhibition
Fresh budding leaves	**118.08±0.28^{f}**	**48.41±0.09^{a}**	**59.20±0.28^{g}**
Boiled budding leaves	**113.08±0.14^{g}**	**26.22±0.08^{e}**	**60.95±0.17^{f}**
Dried budding leaves	**250.17±0.19^{a}**	**27.23±0.01^{d}**	**77.05±0.33^{c}**
Fresh juvenile leaves	**156.58±0.16^{c}**	**27.35±0.04^{c}**	**81.05±0.17^{b}**
Boiled juvenile leaves	**103.67±0.20^{h}**	**24.53±0.02^{g}**	**71.75±0.28^{e}**
Dried juvenile leaves	**40.00±0.66^{i}**	**27.32±0.01^{c}**	**91.90±0.34^{a}**
Fresh **mature leaves**	**129.67±0.30^{e}**	**25.21±0.06^{f}**	**58.95±0.28^{g}**
Boiled mature leaves	**153.00±0.12^{d}**	**24.26±0.01^{h}**	**58.60±0.29^{g}**
Dried mature leaves	**158.00±0.17^{b}**	**27.72±0.07^{b}**	**73.00±0.24^{d}**

Different letters in the column showed significant difference using Duncan multiple range test (DMRT) at $p<0.05$ level; No significant variation was recorded in carbohydrates content

and OH ions (1.69±0.01 mM AAE/100g) was significantly higher in boiled juvenile leaves and dried mature leaves, respectively.

- Anti-mutagenic activity of *P. emodi* extract revealed varying level of protection against damaging agents to DNA. The aqueous extract of *P. emodi at* budding stage leaves (500 µg dried) showed comparatively better protective activity as compared to other growth stages. Results of this investigation indicated that the species have nutritional and medicinal value and, therefore, can be a potential source for nutraceutical and pharmaceutical industries.

- Morphological and Physiological study in tissue cultured raised plants of *Valeriana jatamansi* were conducted in two different altitude i.e. Institute nursery (1120 m asl) and Sri Narayan Ashram (2800 m asl). Analysis of morphological parameters reveals that the plant growing at high altitude have more leaf and root number as compared to the plants growing in Institute. However, size of leaf is much larger at 1100 m as compared to plant growing at 3000 m.

Himachal Pradesh

- Studies on *Corylus jacquemontii* (altitude - 2,169 – 3,155m m), *Trillium govanianum* (altitude - 3,000 – 3,732 m) and *Aconitum heterophyllum* (3,363 – 3,869 m) revealed a variation in total tree density (0-466 Ind ha^{-1}), total shrub density (0-1940 Ind ha^{-1}), and total herb density (15.60-106.70 Ind m^{-2}). The relative density of *Corylus jacquemontii was* 12.12-66.67%, *Trillium govanianum* 0.17-49.35%., and *Aconitum heterophyllum* 1.14-3.68 %. Concentration of dominance of trees and shrubs ranged from 0-1, while for the herb it ranged from 0.05-0.17. The species diversity (H') for tree ranged from 0 -1.77, shrubs 0-2.17 and herbs 1.63-3.30. Different soil nutrients such as moisture, pH, total nitrogen, total organic carbon, and C/N ratio varied across the altitude.
- Seed germination experiments in *Pittosporum eriocarpum* collected from the GBPIHED Mohal arboretum showed maximum germination (90%) in KNO_3 (110mM) as compared to control (63.33%). This was followed by GA_3 (15µM), GA_3 (25 µM) and IAA (25µM) (Fig. 39).
- *In vitro* cultures of *T. govanianum* from nodal explants were established on MS medium supplemented with different concentration and combination of growth hormones. Shoot multiplication and rooting experiments are under progress. *In vitro* cultures of *T. govanianum, Lilium polyphyllum* and *Ferula jaeschkeana* from seeds were also established, however, further experiments on shoot multiplication and rooting are under progress.
- One day training programme was organized in collaboration with fruit grower's association, Mahili, Patlikuhl, district- Kullu on "Biodiversity conservation ecosystem services and climate change in Himachal Pradesh". Theme lecture was delivered and demonstrations on participatory rural appraisal exercise and qualitative and quantitative assessment of biodiversity were given. Pre and post training feedbacks were taken. The training programme showed significant improvement in the skills of the participants about biodiversity, ecosystem services and climate change. Total 99 teachers and students participated.

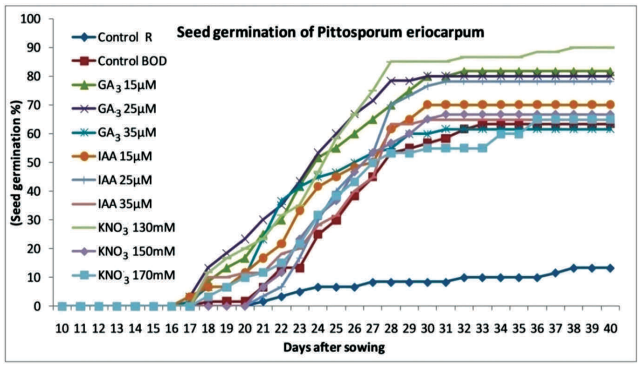


Fig. 39. Seed germination (%) pretreated with different growth regulators

Sikkim Unit

- Up-gradation of arboretum/nurseries carried out. Nursery raised seedlings of *Swertia chirayita*, *Michelia excelsa*, *Spondias axillaris*, and *Rhododendron* spp., etc. were transplanted to

different habitats in semi-natural sites in arboretum and maintained for their survival. About 300 plants of various multipurpose trees were distributed to different stakeholders, including the army personnel. *Ex situ* gene bank was strengthened through propagating *Machilus edulis* plants raised by cuttings.

- Phytochemical investigation of different plant portions of *Aconitum ferox* collected from the two different localities Tsomgo (P1; 3900 m asl) and Yumthang (P2; 4900 m asl), east and north Sikkim, respectively showed the variation in phenolic and antioxidant activity. Tuber extracts showed the highest amount of total phenolic, total flavonoid compounds and maximum antioxidant activity in DPPH and ABTS assays (Fig. 40) as compared to other plant portion. Among populations, Yumthang (P2) samples were found to be better than Tsomgo (P1) samples in terms of antioxidant activity, total phenolic content and total flavonoid content (Fig. 40).

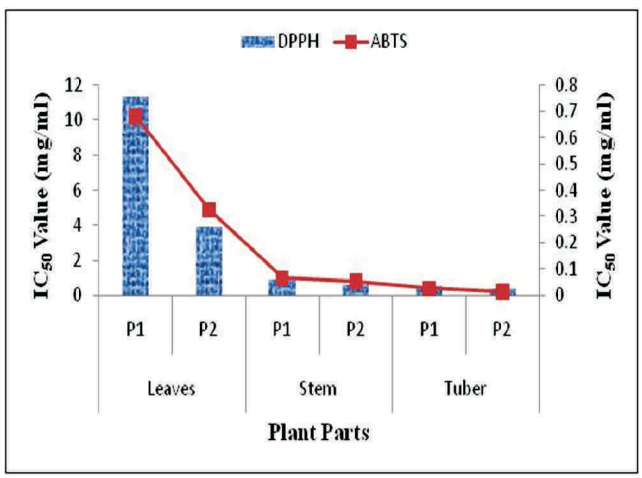


Fig. 40. *In vitro* antioxidant activities of different parts of *A. ferox* populations.

- Investigation on the development of *in vitro* propagation protocol of *Aconitum ferox* was carried out (Fig. 41). Radicle part of the seedling showed profuse callusing in the MS medium supplemented with 2-iP (25 µM) + 2,4-D (5 µM). Indirect shoot organogenesis along with number of shoots and shoot length was achieved in MS + BAP (5 µM) + IAA (5 µM). Rooting of shoots initiated in MS (liquid medium) + IBA (1 µM). Further experiments to improve rooting are underway.
- Micropropagation studies with regards to plant production and maintenance of culture of *R. maddeni, R. griffithianum, R. leptocarpum* and *R. niveum* using existing protocol are continuing.

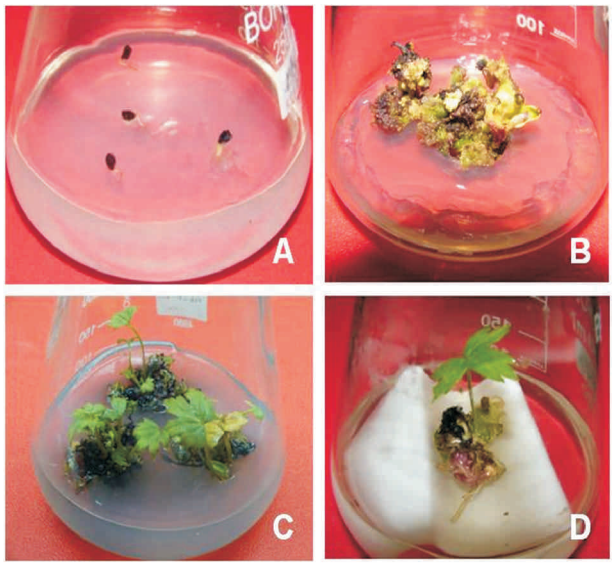


Fig. 41. Tissue culture of *Aconitum ferox.* (a) Radicle emergence from seeds on AM + 2-iP (25 µM) (b) Callusing from radicle on MS + 2-iP (25 µM) + 2,4-D (5 µM) (c) Shoot organogenesis from callus on MS + BAP (5 µM) + IAA (5 µM) (d) Rooting from *in vitro* shoots on MS (liquid medium) + IBA (1 µM).

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 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 was, thus, formulated to address these

issues considering the characterization of extremophiles with particular reference to their biotechnological applications and ecological resilience. Plant biotechnology and plant-microbe interaction based studies with respect to estimation of chemical constituents including bioactive compounds of pharmaceutical as well as neutraceutical relevance were also planned in this project. While important leads have been achieved in case of *Bergenia*, an important medicinal herb of IHR, other medicinally important plants have been selected for documenting their ethno-medicinal value and estimation of the secondary metabolites, antimicrobials and other relevant constituents. Use of PGPRs has been included in *in vitro* plant studies.

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

- In psychrophiles, a psychrotolerant, wide pH tolerant and halotolerant strain of *Pseudomonas chlororaphis* GBPI_507 (MCC2693), isolated from the wheat rhizosphere growing in a mountain location in Indian Himalayan Region, has been investigated for its antimicrobial potential with particular reference to phenazine production and plant growth promoting traits. The polyextremophilic bacterial strain possesses various important characters to consider it as a potential agent for field applications, especially in low temperature environments. GBPI_507 showed phenazine production at the temperatures ranged from 14 to 25 ºC. The benzene extracted compound (Fig. 42) identified as phenazine-1-carboxylic acid (PCA) through GC-MS exhibited antimicrobial properties against Gram positive bacteria and actinomycetes. Molecular studies confirmed production of PCA by the bacterium GBPI_507 through presence of *phzCD* and *phzE*genes in its genome. For thermophilic bacteria, the growth curve studies with respect to amylase production are in progress.

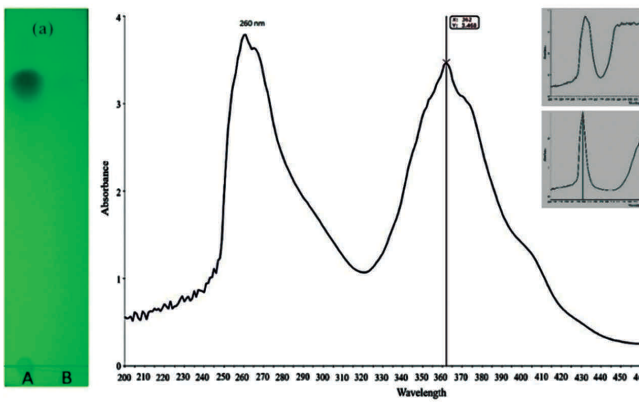


Fig 42. (a) TLC plate showing single spot of metabolite (A) dried extract dissolved in ethyl acetate, (B) crude benzene extract, (b) UV-vis spectrum of dried benzene extract in ethyl acetate. UV-Vis spectrum of standard phenazine (i) and ethyl acetate eluted fraction from column (ii) are shown in inset.

- In order to develop *in vitro* propagation protocol for production of secondary metabolites two species *Bergenia ciliata* and *B. ligulata* have been studied. *In vitro* propagation protocol for *B. ciliata* has been developed using leaf disc explants. Murashige and Skoog (MS) agar-solidified medium supplemented with indole-3-acetic acid (IAA) and 6-benzylaminopurine (BAP) induced direct shoot proliferation from the explants. In *vitro* plants were subjected to biological hardening using *Bacillus subtilis*, with emphasis on standardization of the inoculum size. The bacterial suspension having 1.25 OD was found to be supportive for the growth of *in vitro* propagated *B. ciliata* plants. Chemical investigations revealed the presence of bergenin and gallic acid as

important bioactive components in *B. ligulata*. Protocol for isolation of bergenin as single compound from *B. ligulata* rhizome extract has been developed.

- A preliminary survey was conducted among the *Adi* community of Upper Siang District of Arunachal Pradesh covering 6 villages viz. Gobuk (1201 m), Simong (744 m), Moying (404 m), Gette (612 m), Karko (718 m) and Haleng (411 m) under Yingkiong and Jengngin Circles. The information regarding indigenous ways of plant utilization for medicinal purposes was recorded through interviews with the village head men *(Gaon Burahs),* traditional healers and the local people having substantial knowledge on traditional medicinal practices. During these field surveys notes were taken on the plant species used in traditional medicine and food.
- Four high value medicinal plants of the Sikkim Himalaya viz. *Astilbe rivularis, Eupatorium adenophorum, Artemesia vulgaris* and *Drymaria cordata* were investigated for the total phenolic content, flavanoid content and antioxidant activity using standard protocols (Fig. 43).

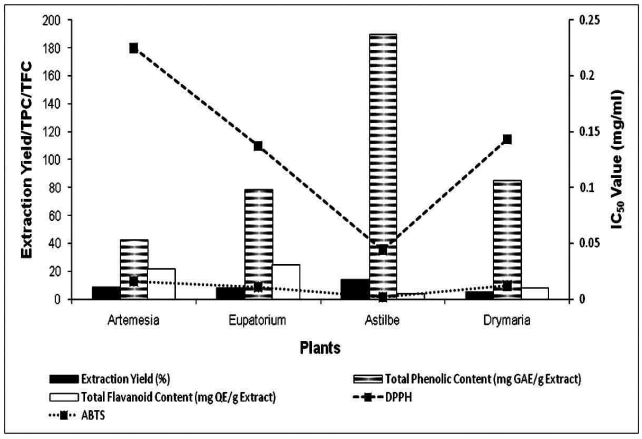


Fig. 43. Total phenolic content (TPC), flavanoid content (TFC) and antioxidant activity of medicinal plants

Nutraceutical potential of wild edible plants of Sikkim Himalaya and their conservation through biotechnological interventions (2014-19, DBT, New Delhi)

The wide range of biodiversity recorded from Sikkim Himalaya is unique and inventories of wild edible plants, which have been consumed by people living in the region, are available. In Sikkim Himalaya a total of 190 species have been screened as wild edible species out of which *Baccaurea sapida* (family: Euphorbiaceae; common name: Kusum), *Diploknema butyracea* (family: Sapotaceae; common name: Chiuree), *Elaeagnus latifolia* (family: Elaeagnaceae; common name: Malindo), *Eriolobus indica* (family: Rosaceae; common name; Mehel), *Machilus edulis* (family: Lauraceae; common name: Pumsi) and *Spondias axillaris* (family: Anacardiaceae; common name: Lupsi) are considered by the local inhabitants as necessity rather than as a supplement, and are eaten frequently. These wild plants make an important contribution to the diet particularly in the rural populations and their dietary contribution is highly appraised as they are available during most seasons, including the periods when the conventional staple crops and vegetables are scarce. Wild edibles of the region are vital, lucrative and inexpensive sources of protein, carbohydrates, fats, vitamins and minerals. This potential coupled with medicinal value of some of these species, can be harnessed for promoting their use as health food supplements.

During recent years, wild edibles have emerged as potential resources for addressing needs and issues of rural development and biodiversity conservation. However, extensive environmental and anthropogenic threats have led to reduction of these species in their natural habitat. It is feared that unless immediate actions are taken, these species could be pushed into threatened category. Considering that wild edibles of Sikkim Himalaya are facing extensive threats and realizing that wild edibles can play a significant role in the food and nutrient security of the local population, the present project proposal has been formulated to investigate the nutraceutical potential of selected wild edible plants of the Sikkim Himalaya and then to develop propagation packages for nutritious wild edible species through biotechnological interventions.

Objectives

- Comprehensive study of wild edibles for nutritive values
- Investigation of wild edibles for antioxidant and anti-quorum sensing activities
- Biochemical analysis for identification and quantification of bioactive compounds
- Development of propagation protocols for wild edibles having high nutraceutical value through conventional and biotechnological methods.

Achievements

- Fruits of *Machilus edulis and Spondias axillaris* were investigated for minerals, total phenolics, total flavanoids and antioxidant activity. The extraction yield varied considerably as a function of solvent nature and ranged from 7.6 to 22.6 % for *M. edulis* and 1.70 to 20.5 % for *S. axillaris* in a descending order of methanol>ethanol>ethyl acetate. In both the fruits, ethanol extract contained higher amount of total phenolic compounds than methanol and ethyl acetate extracts. Very low amount of total flavanoid content was detected in both the fruits. *S. axillaris* contained maximum (8.88±0.14 mg QE/g extract) amount of flavanoid in ethyl acetate extract. In respect to DPPH IC_{50} values, all *M. edulis* extracts IC_{50} values fell within range of 140.64 to 324.25 µg/mL, while *S. axillaris* extracts IC_{50} values were within range of 25.32 to 268.34 µg/mL. The antioxidant activity measured with ABTS assay revealed similar results to that obtained with DPPH scavenging assay. *S. axillaris* ethanol extract exhibited the most potent ABTS radical cation scavenging activity with lowest IC_{50} value i.e. 1.35 µg/mL. The *M. edulis* extracts had IC_{50} values in the range of 6.63 to 30.79 µg/ml, while *S. axillaris* had those ranged from 1.35 to 30.5 µg/mL.
- To obtain rapid, uniform and high seed germination response of *M. edulis and S. axillaris,* different pre-sowing treatments were performed including the pretreatment effect of plant growth regulators on seed germination response of both the fruits. The effects of three plant growth regulators viz. gibberellic acid (GA_3), benzylamino purine (BAP) and indole 3-acetic acid (IAA) at 50, 100, 150 and 200 µM concentrations were tested in a controlled environment system. *M. edulis* seeds germinated without pre-treatment, however, higher germination percentage with low mean germination time was achieved in GA_3 treatment. In *S. axillaris*, growth regulators showed no significant improvement in seed germination response. Reiteration of experiments to confirm the results is in progress.

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

Lignocelluloses are mainly present in the wood cell wall where lignin acts as a barrier against microbes. Lignin is a natural biopolymer which is abundant in nature. Biodegradation of lignin is a crucial step in the global carbon cycle. There are three categories of fungi which can degrade lignin**:** white rot, brown rot and soft rot. Brown rot fungi are basically basidiomycetes which can modify lignin by demethylation and they have preference for coniferous substrates. Biodegradation is a slow process under low temperature environments. The present project was 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 ligninolytic activity
2. Characterization of enzymes involved in lignin degradation
3. Study of molecular diversity of laccase gene in the positive isolates

Achievements

- The project included the diversity of morphological and molecular characterization of the psychrotolerant ligninolytic fungi. These species belonged to the genera *Penicillium, Aspergillus, Cladosporium, Phialophora* and *Eutypella.* These species were studied with respect to their potential to produce lignin degrading enzyme, mainly laccase. The project addressed two major components: the microbial diversity and the biotechnological applications. *Trametes hirsuta* produced laccase of approx 45 kDa by Native PAGE and amplification of laccase gene fragment contained 200 bp. Production of laccase was favoured by high carbon/nitrogen ratio. In case of *Aspergillus niger* and *Penicillium pinophilum*, experiments were conducted with respect to the production of laccase, lignin peroxidase (LiP) and manganese peroxidase (MnP) under different physical (temperature and pH) and nutritional (carbon and nitrogen sources) conditions. 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, *Phialophora 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. One of the remarkable findings was the higher production of laccase at suboptimal growth temperature in several cases.

- The cold adaptive microorganisms have the capability to perform wide variety of activities as they are the principal component of nutrient cycles in the respective environment. Biodegradation is one of the major ecological processes and regulated by the psychrotolerant microorganisms under the low temperature environments. Fungi, in general, are preferred source for biodegradation by virtue of their ability of producing versatile enzymes. While basidiomycetes are the best known degraders, ascomycetes, such as species of *Aspergillus* and *Penicillium*, are getting attention as degraders, mainly in low temperature environments. Characteristics like simultaneous production of laccase at optimum growth temperature and that of LiP and MnP at suboptimal temperature, as in case of *P. pinophillum*, seem to be important ecologically. These characteristics make these fungi more efficient for the degradation under low temperature environments. Further, enhanced enzyme production on addition of some nutritional sources will be important in optimization of the growth conditions for using the fungus for biotechnological applications.

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 representing different climatic conditions have been planned. While the microbiological studies have been planned at three sites (S1- Kosi-Katarmal, Dist Almora, 1345m asl; S2- Kalimati, Dist Chamoli, 1900m asl; and S3- Lata, Dist Chamoli, 2400m asl), representing three sets of climatic conditions with respect to cultivation of local wheat.

Objectives

- 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*)
- To assess the soil microbial diversity vis-a-vis rhizosphere as influenced by climate variables (in wheat).

Achievements

- Under ecophysiological studies, the field experiments for two consecutive growing seasons including winter (*Triticum aestivum*) and summer (*Fagopyrum* spp.) were conducted under Random Block Design. The first experiment was conducted in winter (December 2013). Four varieties (three hybrid and local) of wheat were sown in November using Random Block Design in plots (with three replications of each variety) of 3x3 m with row spacing 20 cm. The hybrid varieties consisted of VL-802, VL-804 and VL-894 obtained from Vivekananda Parvatiya Krishi Anusandhan Sansthan (ICAR), Almora. Local variety was also sown by broadcasting method along with row sowing method. *Fagopyrum* spp. (*F. esculentum* and *F. tataricum*) were sown on July 2014 with row spacing of 30 cm. Meteorological data of the sites are being collected from nearest authorized weather stations. Different physiological parameters, viz, relative water content, net photosynthetic rate, stomatal conductance, intercellular CO_2 concentration, transpiration rate were recorded using portable infra red gas analyzer (LI 6400; Licor, USA; Fig. 44) at regular intervals. The biochemical parameters namely, pigments (chlorophyll & carotenoids), proteins, proline, sugars, enzymes (SOD, peroxidase, catalase & malondialdehyde) have been determined in the leaves using standard protocols at different time periods. The growth parameters were found to be influenced by

increasing altitude and in general yield was less at the highest altitude tested (2000 m). Biochemical parameters (enzymes) could be an indicator of stress which is generally perceived at higher altitudes. Based on yield performance some of the hybrid varieties (VL-892) have the potential for growing at higher altitudes and thus needed to be grown along with local varieties. Further studies will be needed to confirm some of the biochemical aspects of this study.

Fig.44. Field measurements of gas exchange parameters using a portable photosynthesis system (LICOR).

- Among microbial parameters, enzyme activities and the microbial community structure in the soils with respect to wheat rhizosphere was studied at three different altitudes (referred as S1, S2, S3 with increasing altitude). Six soil enzymes including acid and alkaline phosphatase, β-glucosidase, aryl sulfatase, urease and dehydrogenase and microbial populations including bacteria, actinobacteria and fungi (CFU) and colonization by mycorrhiza in roots of wheat plants have been estimated. Dehydrogenase enzyme activity was found to increase with the altitude showing higher microbial activities at the highest altitude (S3). Microbial communities showed maximum bacterial population at S3 site while rest of the two sites did not show any significant difference ($p<0.05$) in their population. Actinobacteria communities showed no such trend with altitude while decreasing fungal population with increasing altitude was observed, however, the difference was not statistically significant ($p<0.05$). Roots of wheat plants at each altitude were found to be colonized with specific microbial structures including mycorrhiza and endophytes. Total root colonization recorded in both the study years was maximum in the roots of S3 site followed by S2 and S1. Such patterned variations, arising due to altitudinal difference, may be considered as indicators for climate manipulations at small scale.
- Soil quality and fertility is governed by its microbial communities and their activities in soils. In the present study, soil enzymes were found to be dependent on the physico-chemical characteristics of the soils and by the altitudinal variation, except the case of dehydrogenase enzyme. The increasing dehydrogenase activity along with the altitude indicated towards the high soil microbial activity in high altitudes and is recommended to be taken in to account for assessing microbial communities with respect to the climatic variations. High soil microbial activity in high altitudinal sites might be due to the presence of microorganisms adapted to harsh environments representing higher number of facultative and micro-aerobes. Root colonization by the organisms like mycorrhizae, endophytes and the dark septate mycelium in extreme conditions, appears to be a topic for advance research in future.

Preventing Extinction and Improving Conservation Status of Threatened Plants Through Application of Biotechnological Tools (2012-17, DST, New Delhi)

Biodiversity is most valuable for the human beings directly, indirectly, aesthetically and ethically. The 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 characteri-zation, 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 reintrod-uction 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

Head Quarters, Almora

- Based on the results of earlier studies (previous year's survey/data and data from secondary sources), field survey was again conducted for collection of propagules i.e., seeds. Quantitative assessment for *Podophyllum hexandrum* was carried out in Kutti village (Byas valley) and for *Angelica glauca* and *Dactylorhiza hatagirea* in Johar and Ralam valley of Pithoragarh district, respectively. The density (Ind/m^2) of *P. hexandrum*, *A. glauca*, and *D. hatagirea* was found to be 1.7, 2.2 and 0.75, respectively.
- A total of 85 distributional records along with Bioclimatic variables were utilized for the prediction of potential areas of occurrence/ distribution of all the 4 target species (*A. glauca*, *D. hatageria*, *Paris polyphylla* and *P. hexandrum*) with the help of Ecological Niche Modelling (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).

- An efficient method to promote seed germination was developed for *A. glauca*. Pre-soaking treatment with various chemicals, namely, IAA (25, 50, 100 and 200 µM), GA_3 (25, 50, 100 and 200 µM), KNO_3 (25, 50, 100 and 200 mM) and $NaHClO_3$ (5% available chlorine; 15, 30 and 45min) were provided and the best response was observed following 100mM KNO_3 treatment (53.33%). The germination percentage (GP), mean germination time (MGT) and survival rate (SR) following various treatments is depicted (Fig. 45).

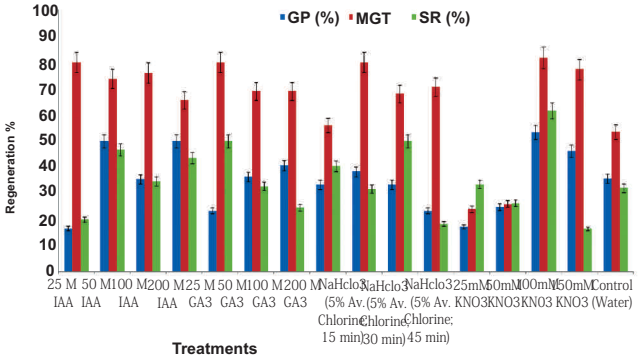


Fig 45. Graph showing the germination percentage (GP%), Mean germination time (MGT) and Survival rate (SR) in above concentration.

- Analysis of rhizomes (senescence phase) extracts of *P. hexandrum* collected from 8 populations of Milam region (2643- 3640m) by HPLC indicated podophyllotoxin content ranging from 0.547% to 1.06% (on dry wt. basis). The maximum podophyllotoxin (1.06%) was found in plants collected from Milam Bugyal (3480m).
- Genetic diversity studies were carried out in 8 populations of *P. hexandrum* collected from Milam region using 7 RAPD primers. A total of 57 reproducible bands were obtained, out of which 43 bands were monomorphic, which corresponds to less diversity within the population.

Himachal Unit

- A total of 55 sites were sampled from the Sangla valley of Kinnaur district, Rohru, Chansal, Dodra, Kawar and Khada Patthar of Shimla district, Churdhar and Sarah forest of Sirmaur district and Tosh nala, Ghanakan and Jhunidhaar (Parvati valley) of Kullu district, Himachal Pradesh. 75 populations were studied and these occurred between 2345-4002 m. These populations

included *Dactylorhiza hatagirea* (8 populations), *Podophyllum hexandrum* (24 populations), *Angelica glauca* (16 populations), *Aconitum heterophyllum* (9 populations), *Picrorhiza kurrooa* (6 populations) and *Rheum australe* (12 populations).

- In general, soil pH ranged from 4.89-8.14, moisture content, 3.32-52%, total nitrogen, 0.05-1.35%, total organic carbon, 0.86-8.85 %, total organic matter, 1.48-15.26% and C/N ratio, 1.02-68.53.
- The above mentioned populations of 6 species were assessed separetely for total herb density, total shrub density, relative density, concentration of dominance of herbs and species diversity for herbs.
- Seeds of *A. heterophyllum*, *A. glauca*, *P. hexandrum* and *R. australe* were collected from the surrounding area of Great Himalayan National Park (GHNP), Kanawar Wildlife Sanctuary, Tosh and Barshaini of Kullu district in Himachal Pradesh. Treatment of *Aconitum heterophyllum* seeds with 25µM GA_3 increased mean germination percentage to 73.33% as compared to 6.67% in control (room temperature) and 26.67% in control BOD condition. High germination percentage was also observed in following treatments with 15µM IAA, 170mM KNO_3 and 15µM GA_3.
- 64 distributional records, Bioclimatic and DEM variables were utilized for the prediction of potential areas of *A. heterophyllum*, *D. hatagirea, P. kurrooa* and *R. australe* with the help of ENM packages. The model test yielded satisfactory results for *A. heterophyllum* (AUC_{train} = 0.988 and AUC_{test}= 0.983±0.031), *D. hatagirea* (AUC_{train} = 0.972 and AUC_{test}= 0.950± 0.061), *P. kurrooa* (AUC_{train} = 0.988 and AUC_{test}= 0.970) ±0.044 (Fig. 46) *and R. australe* (AUC_{train} = 0.984 and AUC_{test}= 0.968 ± 0.109).

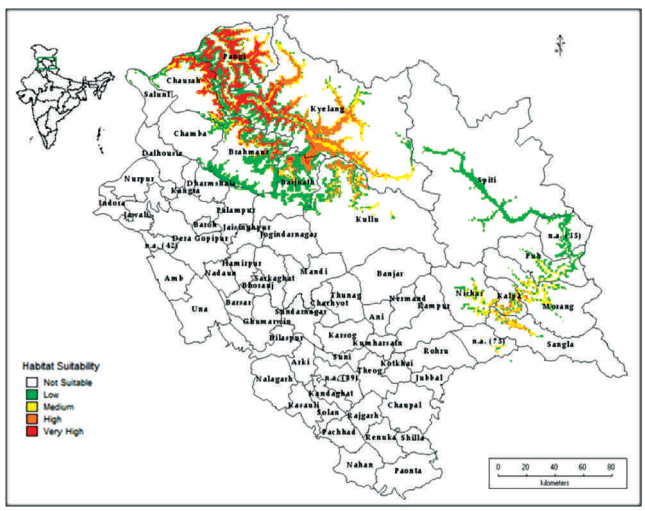


Fig. 46. Habitat suitability and distribution of *Picrorhiza kurrooa* in Himachal Pradesh

Sikkim Unit

- Extensive field trips were conducted for the collection of seeds of *Didiciea cunninghami* (Syn. *Tipularia cunninghami*) and elite germplasm of other species. It seems that in the case of *Didiciea cunninghami*, the species has become wiped out in its type location (Lachen in northern Sikkim).
- *In vitro* propagation protocol for *Rhododendron micromeres* (Syn. *Rhododendron leptocarpum*) has been established. The nodal segments obtained from six weeks old *in vitro* raised seedlings were used as the explants for shoot multiplication. Among various media and growth regulator combinations tested, the frequency of multiple shoot proliferation was highest (78%) in Anderson's Medium (AM) medium supplemented with 2-iP (25 µM) and IAA (0.6 µM) (Fig. 47a).
  - *In vitro* grown shoots were successfully rooted on AM -liquid medium containing 1.0 µM IBA (Fig. 47b). More than two hundred *in vitro* plantlets of *R. micromeres* are currently being maintained in tissue culture lab.
  - Seed germination protocol for the *Phoenix rupicola* was developed in polyhouse as well as in closed poly tunnel condition with various presoaking treatments with plant growth ubstances and systemic fungicide (Bavistin).
  - A large number of seeds (app. 5000) of *Phoenix rupicola* were sown in two net houses in 2013 and 2014 under different sowing and soil conditions, and presently 2700 healthy saplings are available and growing in the net house for field plantation.

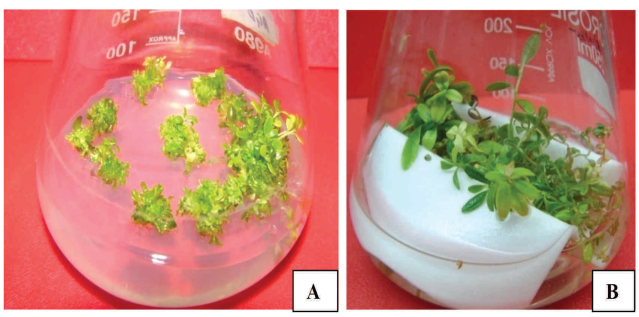


Fig. 47. *In vitro* propagation of *Rhododendron micromeres* (a) Shoots multiplication from nodal segment on AM + 2-iP (25 µM) + IAA (0.6 µM) (b) Rooting of *in vitro* shoots on AM-liquid medium supplemented with 1 µM IBA

Development of Optimum Drying Conditions for Selected Medicinal Plants of Indian Himalayan Region (IHR) (2012-16, NMPB, New Delhi)

Indian Himalayan Region is endowed with vast resources of medicinal and aromatic plants. These plants have been used over the millennia for human welfare in the promotion of health and as drugs and fragrance materials and worldwide use of medicinal plant is expanding. Medicinal plants are traded both as raw herbs or crude drug and processed products. The demand for a wide range of species is increasing with the expansion of market and development of new end uses. So the quality of the medicinal plant plays a very important role. The post-harvesting process of medicinal plants has great importance in the production chain, because of its direct influence on the quality and quantity of the active ingredients in the product sold. Drying is also one of the important steps of post harvest processing. Drying of medicinal plants must meet the following requirements (i) moisture content has to be brought down to be at an equilibrium level that is defined for certain relative air humidity and temperature. This is defined as storage condition by standards, (ii) minimum quality reduction in terms of active ingredients, color, flavor and aroma, and (iii) microbial count must be below the prescribed limits. No chemical additives may be used. Drying of material is a simultaneous coupled heat transfer and multiphase moisture flow process. It helps in quick preservation of medicinal qualities of plants and provides energy efficient operation. Through this process it is easy to understand flow of moisture in a product which could lead to new approaches of drying and to maintain the quality while minimizing cost of the process. Moisture product relationship helps to improve design, operation, and management of drying system.

Objectives

- Collection of selected medicinal plant
- Identification of optimum drying conditions for selected medicinal plants
- Awareness workshop/ training program for Farmers

Achievements

- Rhizomes of cultivated *Inula racemosa* plants were procured Shansha village, Lahul, Himachal Pradesh (Fig. 48). Following drying these rhizomes in a climate chamber under controlled temperature (30-50°C) and humidity (30-80 %) conditions, they were extracted and analyzed for alantolactone (% fw basis) and isoalantolactone [selected as marker compounds] through GC-FID using non-polar capillary column.

Fig. 48. Collection of medicinal plants from cultivation area of Shansha villege, Lahul, Himachal Pradesh

- Significant increase ($p < 0.05$) in alantolactone (ALN) & isoalantolactone (IsoALN) concentration was observed during drying in comparison to fresh material. As energy requirement is low (28.01±5.71 kWh) at 40°C-70% drying condition along with high content of ALN (15.72 ±0.23% fw basis) and IsoALN (11.41 ±0.01% fw basis), this condition can be suggested as best condition for drying of rhizomes of *I. racemosa*.
- Convection drying of biological material /products involves heat and mass transfer properties, and hence is a complex processes. For understanding this phenomenon, different kinetic and isotherm models were tested. Among these Modified Page I was found best for kinetic study (Fig. 49) and Peleg model was found best for isotherm study as these models gave higher values of R^2 and lower values of X^2 and RMSE. Based on drying models from the kinetics and isotherm studies, information will be helpful for modifying the available dryers to obtain good quality dried plant material in a economic way.
- In another study, fresh plants of *Swertia chirayita*, procured *from* State horticulture nursery (in Ravangla, South Sikkim), were dried in climate chamber under controlled temperature and humidity conditions (as mentioned above). Quantification of marker compound, swertiamarin, in the dried plant material is being carried out using RP-HPLC.

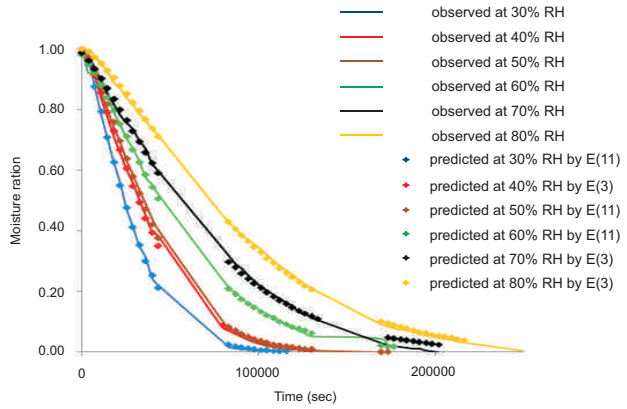


Fig. 49. Influence of % relative humidity of drying air at constant temperature of 40°C on drying curves and simulation of drying curve using Modified Page I drying model for *Inula racemosa*

National Mission on Sustaining the Himalayan Ecosystem (NMSHE) Task Force 3: Forest Resources and Plant Biodiversity (2014-19, DST, New Delhi)

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

- Under the database, list of 474 tree species of Western Himalaya has been prepared. Information on various aspects is being gathered for developing the complete data Of the total tree species inventoried from Western Himalaya, 39% tree species (441 species-381 angiosperms, 60 gymnosperms), 33% tree species (376 species-325angiosperms, 51 gymnosperms) and 28% tree species (314 species- 263 angiosperms, 51 gymnosperms) are listed from three states i.e., Uttarakhand, Himachal Pradesh and Jammu and Kashmir, respectively. A list of 500 orchids belonging to 132 genera and 42 species of Rhododendron from Sikkim has been prepared. Information on family, habit, habitats, distribution, phenology, altitude, etc. being generated for updating the information.
- Representative sites have been identified for intensive long term monitoring in Byans valley of Kali river catchment, Hat Kalika Watershed and East Ramganaga catchment of Pithoragarh district, Uttarakhand (Western Himalaya) (Table

Table 11. Forest Long-Term Ecological Monitoring Sites in Western Himalaya

Locality (Site Code)	Altitude and Geographic Location	Vegetation Zone	Plant Species Richness
Kuti (KUT)	3800 m asl N $30^0$17' 50.6" E $80^0$45' 30.2"	*Betula utilis* dominated forest	Trees- 1, Shrubs-11, Herbs-13
Gunji (GUN)	3300 m asl N $30^0$11' 29.05" E $080^0$50' 58.66"	*Pinus wallichiana* dominated forest	Trees- 1, Shrubs-7, Herbs-23
Hat Kalika (HKW-1)	1967 m asl N 29°38' 14. 8" E 80°02'19.0"	*Quercus leucotrichophora* and *Myrica esculenta* dominated forest	Trees- 5, Shrubs-8, Herbs-8
Hat Kalika (HKW-2)	1520 m asl N 29°40' 34.4" E 80°03' 76.3"	*Pinus roxburghii* forest	Trees- 1, Shrubs-6, Herbs-5
Hat Kalika (HKW-3)	925 m asl N 29°37' 76.4" E 80°06' 00.6"	*Shorea robusta* and *Pinus roxburghii* forest	Trees- 2, Shrubs-5, Herbs-6

11; Fig. 50). The comprehensive study covering all the six aspects has been stated in the selected sites. The sites for pilot studies for revalidation and vulnerability assessment, capacity building and forecasting have also been selected in Central Himalaya (Uttarakhand), Himanchal Pradesh (Western Himalaya), Northeast region (Arunachal Pradesh) and Eastern Himalaya (Sikkim).

Fig. 50. Establishment of Long Term Monitoring Sites under the NMSHE Task Force 3.

- Under modelling aspects, assessment of changes in the summer monsoon rainfall climatology and Intra-seasonal Oscillations (ISO) over the IHR during 2020-2070 for IPCC representative concentration pathways 4.5 and 8.5 (RCP 4.5 and RCP 8.5) is carried out. The rainfall analyses were carried out for a futuristic normal period: NY1 representing the year 2020 to 2040 for investigating changes in the average summer monsoon rainfall over IHR. **A 10 m eddy** covariance flux tower is established at Gangolihat for long term measurement of CO_2 and water vapour exchange between the underneath Oak vegetation and atmosphere. These measurements are carried out at 10 Hz frequency. Also, the indicator tree species (Cedrus *deodara, Pinus roxburghii, Pinus wallichiana, Abies spectabilies, Abies pindrow* and *Betula utilis)* of the region have been identified for dendroclimatic studies under the project.
- Under the monitoring aspect, vegetation sampling was done along an altitudinal gradient (3800-4600 m asl) in the Byans valley of Pithoragarh district, Uttarakhand.A total of 170 plant species belonging to 48 families have been documented from the Byans valley. A total of 39 species of high value medicinal plants belonging to 27 families have been documented from the valley. Similarly, soil sampling at an interval of 200 m along the altitudinal gradient in the Byans valley was done.
- People perception on climate change and climate change impact has been analysed in the Byans valley, Central Himalaya (Uttarakhand), Himanchal Pradesh (Western Himalaya), Northeast region (Arunachal Pradesh) and Eastern Himalaya (Sikkim). The majority of respondents agreed that during recent decades there have been many changes in the climate and they cited various examples.
- Participatory approach was used to investigate vulnerability and adaptive capacity of climate change of the local communities in the Sutlej basin of Kinnaur district and Rampur division of Shimla district in Himachal Pradesh. The approach in carrying out the study included questionnaire survey, group discussion and interview of the communities on climate change. The villages which were considered for survey from higher to lower altitude were: Pangi (3293 m), Kalpa (2980 m), Tangling (2972), Powari (2018), Kwangi (2056 m), Shongtong (2089 m), Tapari (1672 m) in Kinnaur district and Rampur (1180 m), Bayal (828 m), Nogli (899 m), Sainj (890 m), and Luhari (835 m) in Rampur division of Shimla district. After querying upon climate change experience, about 94% respondents were aware of the climate change and its impacts on their surrounding environment. About 88% of the total respondents perceived that weather pattern is changing in terms of rainfall, temperature and moisture, etc.
- Respondents were of the view that rainfall pattern has changed. The variable nature of rain has its adverse impacts on crop and risks to drought by 63% interviewed. About 88% respondents also felt that rainfall has declined in quantity and its normal cycle. They could no longer rely upon timely onset of the monsoon (Fig.51). **T**he villagers also noticed a slow pace of pouring rainfall which for them is useful from percolation view point. However, sometimes it becomes a threat to standing crops in presence of its highest intensity. About 68% respondents from Luhari, Sainj, Nogli and Duttnagar villages of Rampur division of Shimla district perceived that due to less runoff, the water availability has been reduced. But the respondents at Tapari in Kinnaur district realized that the surface runoff has increased in recent decades as compared to previous decades (1990-2001).
- Increased runoff is triggering the incidences of landslides in the villages located at Kinnaur

district. About 76% respondents perceived the events of floods increasing from the last few decades (Fig.51). According to the villagers, snowfall is found to be reduced but precipitation increased which has its direct adverse impacts on apple orchard. During a group discussion with the households of the villages such as Powari, Kwangi and Tapari, about 41 respondents stated that the rainfall was found increased in sub-temperate region of the Sutlej basin. However, the snowfed areas have been under conversion into rainfed areas and barren areas.

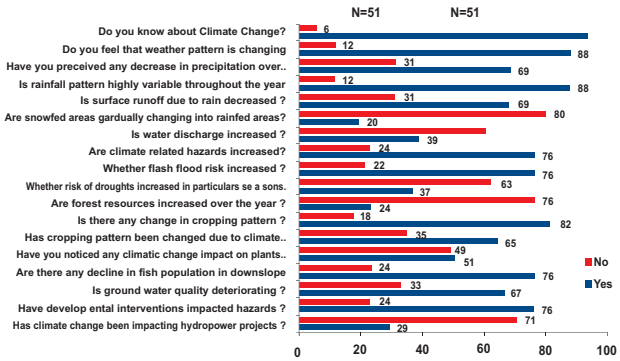


Fig. 51. People perception on the biodiversity and climate change

- The respondents from the Pangi, Kalpa, Khwangi, Shongtong, Powari, Tapari and Barang told that snowfall is reduced. Also, it has been noticed that there has been less snowfall in December-January-February. One senior citizen told, 'I had never seen drying up of traditional water sources throughout the year, but water availability these days has become seasonal'.
- About 64% people responded that their cropping pattern has changed because of the changing rainfall pattern. One of the participant told, 'we hardly saw good yield of crops as it used to be in the past'. Now, the rain does not occur on time as a result they are not willing to grow crops in the field. About 76% respondents perceived that fish production has been reducing in the River Sutlej.
- Respondents from the Tangling, Urni, Tapari, Powari, Sudharang Daku and Khwangi villages have noticed that there is a positive growth in forest cover (see Photograph 5). However, survey conducted in and around of Rampur town reveals that the respondents have observed the negative growth in forest cover. They also indicated that loss of forest cover has adversely impacted traditional water resources, as a result water springs have dried up in summer season. According to secondary data on trees, shrubs, herbs and grasses, they were important from preservation and conservation viewpoints in the region (Table 12).
- Five training programme (one day -1, two day - 2, tree days-2) were organised under different components of the Task force 3. A total of 173 participants were participated.
- Assessment of changes in the summer monsoon rainfall climatology and Intra-seasonal Oscillations (ISO) over the IHR during 2020-2070 for IPCC representative concentration pathways 4.5 and 8.5 (RCP 4.5 and RCP 8.5) is carried out for a futuristic normal period: NY1 representing the year 2020 to 2040. The analysis shows that, when the differences in monsoon rainfall

Table 12: Some common trees, shrubs, herbs and grasses found in the study area (Source:- Rampur Forest Division, 2015)

a. Trees			b. Shrubs and herbs	
Sr. No.	**Botanical name**	**Local Name**	**Botanical name**	**Local name**
1.	*Abies pindrow*	Tosh	*Adhatoda vasica*	Basuti
2.	*Acacia catechu*	Khair	*Agave americana*	Ram ban
3.	*Acer oblongum*	Parang	*Artemisia vulgaris*	Charmer (Khadar)
4.	*Acer pictum*	Rikhandlu	*Bambusa arundinarea*	Bans
5.	*Acer caudatum*	Rikhandlu	*Berberis aristata*	Kasmal
6.	*Aesculus indica*	Khanoor	*Berberis lycium*	Kasmal
7.	*Albizzia lebbek*	Siris	*Carrisa spinarum*	Karonada
8.	*Bauhinia variegata*	Kachnar	*Coriaria neplensis*	Gangara
9.	*Bombax ceiba*	Semal	*Crotalaria albida*	Chhunchhunu
10.	*Butea monosperma*	Dhak	*Cotoneaster bacillaris*	Reuns
11.	*Cassia fistula*	Amaltas	*Cotoneaster microphylla*	Chamrol
12.	*Toona ciliata*	Toon	*Cyathula tomentosa*	Kathla
13.	*Cedrus deodara*	Deodar	*Daphne papyracea*	Kaula
14.	*Celtis australis*	Khirak	*Desmodium tilieaefolium*	Murt
15.	*Cupressus torulosa*	Saru	*Deutzia corymbosa*	Philru
16.	*Corylus colurna*	Banshahri	*Euphorbia royleana*	Shuru
17.	*Cryptomeria japonica*	Japani saru	*Indigofera gerardiana*	Kathi
18.	*Dalbergia sissoo*	Shisham	*Indogofera trifoliate*	Kathi
19.	*Dandrocalamus strictus*	Bans	*Jasminum officinale*	Chameli
20.	*Ficus religiosa*	Pippal	*Juniperus communis*	Guggal
21.	*Grewia oppositifolia*	Biul	*Lonicera orientalis*	Tiknoi
22.	*Ilex dipyrena*	Kandru	*Loranthus vestitus*	Pand
23.	*Jurinea macrocephala*	Dhoop	*Plectranthus coetsa*	Chhichhri
24.	*Kydia calycina*	Pula	*Polygonum chinensis*	Jangli palak
25.	*Juglans regia*	Akhrot	*Prinsepia utilis*	Bhekhal
26.	*Lannea coromandelica*	Jhingan	*Rosa macrophylla*	Gulab
27.	*Litsaea umbrosa*	Chirindi	*Rosa sericea*	Gulab
28.	*Mallotus philippinensis*	Kamela	*Roylea calycina*	Karanoi
29.	*Mangifera indica*	Aam	*Rubus ellipticus*	Hinsar
30.	*Morus alba*	Toot	*Sarcococca saligana*	Tiliari
31.	*Melia azadiarachta*	Drek	*Saussurea lappa*	Kuth
32.	*Olea cuspidata*	Kahu	*Spiraea lindleyana*	Kongtri
33.	*Ougeinia oojeinensis*	Sandan	*Strobilanthus wallichii*	Machin
34.	*Picea smithiana*	Spruce	*Viburnum cotinifolium*	Loe
35.	*Pinus wallichiana*	Kail	*Viburnum cotinifolium*	Loe
36.	*Pinus roxburghii*	Chil		
37.	*Pinus geradiana*	Chilgoza		
38.	*Populus ciliata*	Poplar		
39.	*Prunus armeniaca*	Chulli		
40.	*Prunus cerasus*	Jaman		
41.	*Prunus cornuta*	Jaman/ Jamu/Krun		
42.	*Prunus persica*	Aaroo		
43.	*Pyrus pashia*	Kainth		
44.	*Quercus himalayana*	Mohru		
45.	*Quercus incana*	Ban		
46.	*Quercus semicarpifolia*	Kharshu		
47.	*Rhododendron arborium*	Brass		
48.	*Rhus cotinus*	Tung		
49.	*Robinia pseudoacacia*	Pahari kikar		
50.	*Salix babylonica*	Majnu		
51.	*Salix daphnoides*	Biuns		
52.	*Salix elegans*	Bhashal		

climatology between the evaluation period and RCP 4.5 and RCP 8.5 of NY1 is considered, the foothills of Jammu and Kashmir, central and eastern Himachal Pradesh and most of the Uttarakhand is expected to have an increase in rainfall climatology by > 0.75 mm/day from the evaluation period.

- For the CH region, decline in rainfall by 1 mm/day under RCP 4.5 (Figure 52 a-ii) is expected. However, under RCP 8.5 scenario, the region is expected to have an enhancement of 0.75 mm/day rainfall during NY1 than the evaluation period (Figure 52 b-ii). For the eastern Himalayan region, 1 mm/day of less rainfall is expected during monsoon seasons of NY1 for both the scenario (Figure 52 a, b -iii).

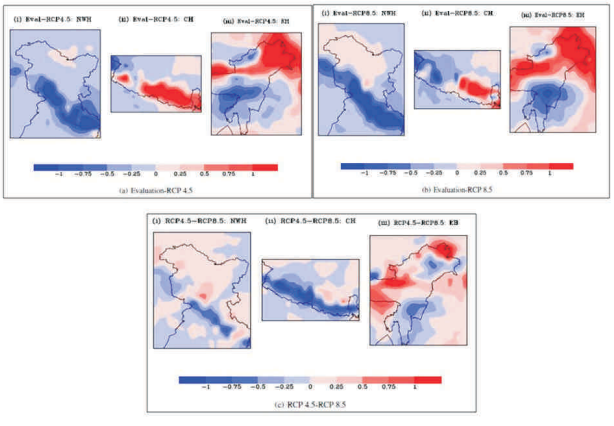


Fig. 52. Ensemble JJAS rainfall climatology different between the evaluationperiod normal run (a) RCP 4.5 of 2020-40 (b) RCP 8.5 of 2020-40, and (C) the ensemble JJAS rainfall climatology different between RCP 4.5 and RCP 8.5 of 2020-40

- Based on literature review and herbarium consultation at BSI, Dehradun, the indicator tree species (*Cedrus deodara, Pinus roxburghii, Pinus wallichiana, Abies spectabilies, Abies pindrow and Betula utilis)* have been identified for dendroclimatic studies and 153 tree ring samples of *Cedrus deodara and Pinus roxburghii* were collected from five forest sites (Table 13).

Table 13: Details of tree ring sampling sites

Site Name	Latitude	Longitude	Altitude (m asl)	Species samples	No. of samples (No. of trees)
Chamunda (Hanera)	29°,39'N	80°,01'E	1770	*Cedrus deodara*	31 (15)
HatKalika	29°,39'N	80°,02'E	1743	*Cedrus deodara*	30 (15)
Patalbhuwneswar	29°,41'N	80°,05'E	1660	*Cedrus deodara*	40 (20)
Chandak	29°,36'N	80°,11'E	1905	*Cedrus deodara*	17 (9)
Digtoli	29°,37'N	80°,08'E	1735	*Pinus roxburghii*	40 (20)

Theme

Knowledge Products and Capacity Building (KCB)

The mountain communities have acquired enormous knowledge of their natural environment. Yet this accumulated knowledge is rapidly disappearing as the traditional communities are steadily becoming more and more culturally and biologically advanced. With greater realization of the value of this knowledge base, it is considered that the knowledge should be an integral part of a holistic and cost-effective approach to sustainable development. The knowledge accumulated, documented, produced/developed over a period of time in any field related to human well being and natural resource management, is required to be transmitted or exchanged through capacity building efforts in empowering all the stakeholders. Knowledge base of the different traditional societies and knowledge developed through science and technology interventions, if successfully adopted/implemented through capacity building programmes, would certainly generate ecologically sound, economically viable, socially acceptable and institutionally enforceable outputs.

Objectives

- 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
- 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;
- Enhance capacities and skill of rural and marginal societies in harnessing the potential of knowledge systems for socio-economic development; and
- 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 (2012-17, In house)

The Indian Himalayan mountains are among the most fragile and complex ecosystem in the world. In these mountains 70% of the total workers and more than 85% of women engaged in land based acitivites, however they are neither able to generate economic surplus nor to find off-farm employment opportunities. Communities live in geographical isolation under ecologically sensitive and economically constrained conditions. As a result people face diverse socio-economic and environmental problems; many migrate to towns and cities to explore economic opportunities. Attaining livelihood security in Himalayan mountains has always been challenging and need special attention. It needs synchronized implementation of strategies for efficient natural resources management as well as sustainable food production. Earlier experiences have revealed that use of low-cost and eco-friendly technologies and capacity building of local communities can play a leading role in livelihood upgradation and environmental management. The present project has been devised with such an approach;

it addresses model demonstration at farmers fields and capacity building for adoption of low-cost technologies with a focus on conservation and sustainable use of natural resources as well as providing opportunity for year round employment generation thus attaining livelihood and environmental security.

Objectives

- To provide 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

- During the reporting period a total of 40 technologies were collected, tested/modified and maintained at different Rural technology Centres (RTCs) at Headquarters, Triyuginarayan (Garhwal Unit), and Pangthang (Sikkim Unit) with a view to replicate and/ or disseminate (Plate-1).
- During the reported period a total of 26 (21 at HQs, 4 at Garhwal Unit and 1 at Sikkim Unit) training and awareness programmes were conducted for different user groups (viz. farmers, officials selected by govt. organizations, non government organizations, institute programme, students, army personnel, etc.) of which 16% training/ awareness programmes were each for NGOs, students and institute programmes, army personnel, 12% for and rest 40% for farmers/ officials selected by Govt. organizations. A total of 1422 persons (Female 628, Male 794) covering 07 districts and 114 villages of Uttarakhand, and 01 district of Sikkim state benefitted (Table 14, Fig. 53).
- Technical guidance and support for demonstration of 10 No. of protected cultivation (Polyhouse, Nethouse, etc.), 14 vegetable cultivation, 7 Vermicomposting model, 2 water harvesting and fish farming tank, 4 biobriquettee frame, Poultry birds, 560 fodder samplings, a number of different vegetable plants and seed were provided for field implementation at different selected sites as well as the selected village cluster (village Babari, Sunari & Pokhari).
- Developed a model nursery in which about 2.75 lakhs plants of *Valleriana wallichii* and *Inula racemosa* were raised at RTC, Triyuginarayan. About seventy five thousand seedlings of *Valleriana wallichii* were distributed to the interested farmers of village Tarsali (district Rudraprayag) and village Pokhri (Pauri district) for large scale domestication and cultivations in the farmers field and facilitated marketing of the final product through Emami Pvt. Ltd.
- The below and above ground biomass (g/dry wt./plant) of *Valleriana wallichii* and *Inula racemosa* under different micro-climatic conditions

Table 14: Training organized for different stake-holders in Uttarakhand (April, 2015- March, 2016)

Stakeholders	Training programs			No. of persons trained		
	One day	3 or more days	Total	Male	Female	Total
Farmers selected by NGOs	05	-	05	62	109	171
Farmers & officials from govt. organizations	05	05	10	357	167	524
Institute programms	-	04	04	189	265	454
Students	04	-	04	47	62	109
Army personnel	01	02	03	139	25	164
Total	**15**	**11**	**26**	**794**	**628**	**1422**

Fig. 53. Photos depicting different training and capacity building programme in Uttarakhand and Sikkim state

(polyhouse, shade-net house and open) was estimated at 2200 m asl (RTC, site). The yield of below ground part was obtained 3 to 6 times higher under polyhouse condition as compared to shade and open conditions because of higher temperature inside the polyhouse.

- During this year an amount of about Rs 4.0 lakhs was generated from the Sponsored Trainings and other activities of the RTC.

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 (2014-16, ICSSR, Govt. of India)

Uttarakhand is known as the 'abode of Gods' due to the famous Hindu shrines Badrinath, Kedarnath, Gangotri and Yamunotri along with the holy Sikh shrine Hemkund Sahib which are visited by pilgrims across the globe besides the nature lovers who visit the beautiful Himalayan landscape. Kedarnath is located in Rudraprayag district at an altitude of 3,583 m asl near the origin of Mandakini river. The heavy rainfall as a form of 'cloud burst' and subsequent crack in the glacial lake above the Kedarnath shrine on June 16th 2013 caused flooding of Saraswati and Mandakini Rivers and damaged everything on the banks of River Mandakini for about 18 km between Kedarnath and Sonprayag. The unprecedented rains 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 a natural calamity but unplanned developmental activities in Kedarnath and downstream was considered a 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 analysing the gaps between environmental policies and human actions and the impact of the above natural disaster in Garhwal Himalaya particularly on the women.

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 the 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 the June 2013disaster and to understand their coping strategies in the absence of the male members.
- To find out the alternative and appropriate techniques that can be devised for empowering the women under present circumstances.

Achievements

- Survey was completed in 40 villages of four village clusters to analyse the status of natural resource, agriculture production system, animal husbandry, and livelihood status.
- Analysing the environmental and other related policies in detail it was found huge gaps exists between all these policies and human actions on the ground in the entire region which increased the magnitude of losses.
- A total of 39.57 percent respondents opined that governmental policies are violated by adopting wrong means, sometimes deliberately, and sometimes unknowingly. About 24.51 percent respondents accepted that the policies are violated by adopting wrong means, while 21.14 percent opined that ignorance leads to the violation of the policies. This shows the reasons behind the gaps between the policies and the human action as carelessness of the agencies towards the proper enforcement of the policies leads to deliberate or unintentional violations.
- Majority of the male respondents particularly from Devli-Bhanigram, Triyuginarayan and Chandrapuri village clusters which ranged between 74.44 to 86.36 percent agreed that diversification of crops and strengthening of agriculture may help to improve women's economic conditions to a large extent. They opined that if cash crops like spices can be produced between two crops of wheat and rice it would fetch good price in the market.
- Majority of the female respondents with maximum representation from Triyuginarayan (75.56%) and minimum from Chandrapuri cluster (38.02%) stressed that interventions and support are needed to develop skill for improving bioresource-based agricultural technology, use of natural resources, livestock and cottage industry would be utmost important for securing livelihood on sustained basis after the disaster.

Ecological Analysis of Indigenous Agroforestry Systems with Reference to Climate Change Adaptation, Mitigation and Coping Strategies in Indian Central Himalaya (2015-18, SERB-DST, New Delhi)

Agro-forestry is a land use system that integrates trees, crops and livestock together and is scientifically sound, ecologically feasible, economically beneficial and socially acceptable to the farmers. Agro-forestry in the Himalayan region is the natural as well as deliberate integration of trees with livestock or crops into intensive land management systems. The system is managed indigenously, with best practices which have been evolved by the farmers through trial and error over the time. In Central Himalayan region of India local communities maintain naturally regenerating tree species, particularly on the edges or margin of rainfed terraced agriculture land without any significant external inputs or manpower. Such indigenous agro-forestry system plays an important role in carbon sequestration, provide option to adaptation to climate change and reducing pressure on natural forests for fodder, fuelwood, and timber extraction. The management of indigenous agro-forestry systems in the Himalaya region while maintaining and managing potential agro-forestry trees, intercropping understory crops, livestock rising and protection of adjacent forests for variety of ecosystem services is an adaptive indigenous practice of the mountain communities.

Objectives

- To identify the key agroforestry species and measure the fodder and fuel wood consumption pattern along an altitudinal gradient.
- To explore the key interventions for enhancing crop yields and carbon sequestration rate of the prominent agroforestry species with reference to climate change adaptation and mitigation.
- To identify the weaknesses or underlying factors behind deterioration of indigenous agroforestry system and design appropriate strategies for conservation and management of ecologically and economically valuable agroforestry tree species along with documentation of their traditional ecological knowledge.

Achievements

- An extensive literature review and a preliminary field survey were carried out for selection of indigenous agro-forestry models in Indian Central Himalaya. Three village clusters e.g. Saknidhar, Jakhand and Dagar in Tehri district along an altitudinal gradient ranged from 800 to 1800 masl were selected for conducting the present study.
- A total of 30 woody agro-forestry species and 31 food crops have been listed and their traditional uses were documented in all three selected village clusters.
- Land use pattern and distribution percentage of agroforestry species in different agroforestry systems was analyzed and categorized based on their occurrence e.g. agriculture land (51%), Barren land (32%), grass land (10%) and kitchen garden (7%).
- Dependency of local people on indigenous agroforestry systems in the study area was carried out and it revealed that the local people depend on different agroforetry produces such as fodder (33.7%), fuelwood (16.5%), food (27.6%), medicine (9.1%), timber (7.5%), fiber (3.3%), and other (2.3%).
- Identified five broad categories of sustainability such as agriculture management, livestock management, forest sustainability, social benefits/needs, and policy inputs along with sixteen criteria and thirty four related indicators to strengthen and provides holistic approach for sustainable management of indigenous agro-forestry systems in Indian central Himalaya.

Experiment to understand the spring low and development of hydrological model (2014-17, ISRO Ahmedabad)

Remoteness, inaccessibility, low population densities and high cost for drilling programme in hilly area hinders the generation of water-table elevation measurements and sub-surface hydraulic data which is very essential for any water resource planning project. Spring and stream hydrograph provides an excellent opportunity to decipher subsurface hydrogeological processes.

Since the catchment area is degrading in rural watershed due to lack of protection and management and urban area is ever expanding, it will be crucial to know & protect the source area for the life sustaining springs & spring-fed-streams. Groundwater protection in fracture media is a pertinent issue in Himalayan region which needs to be addressed through proper multidisciplinary approach. Geological, geohydro-logical, geophysical as well as hydrodrological investigation are required to define the zone of

contribution of springs, spring fed streams or ground water well.

Objectives

- Hydrological experiment for the estimation of aquifer characteristics and spring flow measurement.
- Development of conceptual modeling framework for understanding the spring flow in the Himalayan region.

Achievements

- Generation of long term sound hydrological dataset from small basins
- Geological Mapping of Uregi watershed
- Drilled six shallow well in Hardrock (Dugargad watershed)
- Carried out initial pump test and slug test of hardrock aquifers

R&D HIGHLIGHT OF THE REGIONAL UNITS

GARHWAL UNIT

- Developed the document on potential options for supplementing pilgrimage tourism with other form of tourism (rural tourism, heritage tourism, nature/eco-tourism and community based tourism) for socio-economic development of the disaster affected Kedar rural landscape.
- Developed a model nursery under 4.0 ha of land at Triyuginarayan where about 2.75 lakhs of seedlings of five important species such as *Valeriana wallichi, Inula racimosa,* etc. has been raised for large scale cultivation and about 1.1 lakhs seedlings of *Valeriana wallichi* were provided to the NGOs and four village institutions in districts Rudraprayag and Pauri for large scale cultivation in consultation with HRDI, Gopeshwar.
- Adopted four (4) disaster affected village clusters (each cluster with 2 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.
- The assessment of survival, growth, biomass and productivity of two important medicinal plants such as *Peonia emodi* and *Valleriana wallichii* has been carried out at high altitude (2200 masl) 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.
- Five training programmes (each of two days) were organized between April 2015 to March 2016 on capacity building/ skill development for harnessing the potential of agro and wild bioresources through simple science and technological interventions for livelihood improvement and natural resource management in which about 600 stakeholders actively participated and trained.
- Developed sound hydrological and hydrogeological dataset in small watershed of Pauri Garhwal district using state-of-the-art tools and techniques to assess the long term goal of water resource sustainability.
- Developed package of practices of cultivation and value addition of seven wild herbal spices (*Allium strechyei, Allium humile, Allium rubellium, Angelica glauca and Pleurospermum angelicoides*) and wild fruit resources (*Viburnum mullaha*) for large scale cultivation.
- Generated scientific data on climate change impact, land-use land cover change and anthropogenic activities in *Betula utilis* forest and response of these factors have been evaluated across an elevational gradient between 3200-4400 m asl with regard to population dynamics, seedling recruitment and climate change.
- Satellite imageries and our field observations showed increasing number of seedlings and sapling recruitment and better growth of *Betula utilis* above the timberline in valley of flower National Park (VoF-NP) and Nanda Devi National Park (NDNP) whereas density of other tree species

decreased with increase in altitude. The higher number of seedlings of *Betula utilis* was recorded in pure forest (3600-4100 m asl) at north and south aspects of timberline VoF-NP and ND-NP.

- Identified six insect species viz., *Phylloporia bistrigella*, *Heterarthrus nemoratus*, *Fenusa pussila*, *Eriphyes longisetosus*, *Agrilus anxius*, *Clethrobius commes* defoliating *Betula utilis* tree species in timberline landscape of NDBR. The maximum defoliation was accounted by leaf miner followed by birch borer, birch aphid and gal inducer.
- The action and participatory research work carried out during 2015-16 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 has been incorporated in the action plan of MNREGA, GRAMYA, horticulture mission, district planning, etc.
- Analyzed the environmental and other related policies in relation to Uttarakhand disaster 2013 which highlighted that huge gaps exists between all these policies and human actions on the ground in the entire region which increased the magnitude of losses in demonstration.
- Impact of climate change/variability in farming system were critically analysed while involving 400 households of 20 villages across an elevational gradient between 500 to 3000 masl in Garhwal Himalaya which indicated that farming communities at large adapting with traditional knowledge and their own innovations to fight against climate change impacts.
- The farmer's perceptions and indigenous knowledge related to pests and pest management within a broader perspective of agrobiodiversity and farming system in the central Himalayan region were documented.
- Land use pattern and distribution percentage of agroforestry species in different agroforestry systems in three village clusters was analyzed and categorized based on their occurrence e.g. agriculture land (51%), barren land (32%), grass land (10%) and kitchen garden (7%).
- Identified five broad categories of sustainability (such as agriculture management, livestock management, forest sustainability, social benefits/needs, and policy inputs) along with sixteen criteria and thirty four related indicators to strengthen and provides holistic approach for integrated management of traditional agro-forestry systems in central Himalayan region.

HIMACHAL UNIT

- In Kanawar Wildlife Sanctuary total 19 sites were sampled and 12 forest tree communities identified. 231 species were economically important and used as medicine (90 spp.), wild edible/food (31) spp.), fodder (48 spp.), fuel (31 spp.), timber (5 spp.), religious (05 spp.), fiber (07 spp.), making agricultural tools (06 spp.) and some other purposes (9 spp.). Extraction trend of fuel species in four villages was studied, 28 species (19 trees and 9 shrubs) were collected by the inhabitants. The extraction of fuel species indicated the dependence of inhabitants mainly on *Cedrus deodara, Pinus wallichiana*, *Picea smithiana, Desmodium elegans* and *Abies pindrow.*
- 734 species of vascular plants (363 native, 11 endemic, 119 near endemic, 475 economically important) from Parbati Valley and 637 species (348 native, 11 endemic, 187 near endemic, 415 economically important) from Upper Beas catchment were recorded. From 115 representative sites in Parbati Valley 56 plant communities and from 51 representative sites in Upper Beas catchment 41 plant communities have been identified. Vulnerability assessment of floristic diversity of the Parbati valley identified 05 species as critically Endangered; 11 Endangered, 90 Vulnerable and 188 Near Threatened; and in Upper Beas Catchment, 09 species as Critically Endangered; 14 as Endangered and 47 Vulnerable. The forest communities near to habilitation were more vulnerable than the communities distant from the habilitations. The altitudinal shift of the species such as *Betula utilis, Abies pindrow, Populus ciliata, Aesculus indica, Pinus wallichiana,* etc. and changing patterns of the composition and structure of the forest communities have been observed.
- For mapping community perceptions 791 respondents representing 31 villages and 370 households from Parbati valley and 13 villages and 421 households from Upper Beas Catchment were taken through structured questionnaire. The analysis and synthesis of data revealed impact of climate change on various components of the environment.
- Total 35 sites were surveyed from Great Himalayan National Park. 205 species of vascular plants, 197

species economically important plants, 27 tree communities 02 shrub communities were identified. Soil samples were collected and analyzed for physic chemical properties. 48 sites in Sainj Valley were investigated and 330 species of vascular plants, 236 economically important, 20 tree communities and 145 species of fauna were recorded.

- 42 sites (27 undisturbed and 15 disturbed) sampled for floristic diversity in Bhrighu Rishi, Rupasana Devi, and Jamdagni Rishi Sacred Groves. 240 species of vascular plants and 5 tree communities identified. The disturbed sites showed low species richness and density. Inventory of the fauna of these Sacred Groves was made, carbon sequestration of Rupasana Devi and Jamdagni Rishi Sacred Groves was investigated. Cultural service of the Rupasana Devi, Bhrighu Rishi, Jamdagni Rishi and Kamru Nag were assessed and information gathered
- Two Citizen Science Programmes were organized during April 2015 and October 2015. Information on floristic inventory, community types, insect pollinator's diversity, preferential floral species and phenology of Apple was generated.
- The density and diversity of the pollinators in 9 sites of Upper Beas valley was observed and it was found low. The results after cultivation of Mustard and Coriander in these sites revealed that during March and April maximum density of *Apis cerana*, Drone flies and Syrphids in all the study sites had high visitation rate on the Mustard and Coriander flowers as compared to other flowering plants. 25 Bee boxes of Indian Honey Bee (*Apis cerana*) were distributed to the 22 apple orchardists from 7 villages. Four Awareness cum Training Programmes, one day each on "Biodiversity Conservation, Ecosystem Services and Climate Change with Special Reference to Pollinators in Himachal Pradesh" were organized at Nashala Archhandi and Fruit Growers Association, Mahgili
- Soil properties from the rhizosphere of *Rhododendron campanulatum* and *Betula utilis* were analyzed. The microbial enumeration shown variation from site to site in both *Rhododendron campanulatum – Betula utilis* rhizosphere soil. Various mycorrhizal structures, namely, arbuscules, intra and extra-materical hyphae and vesicles were observed during quantification of root colonization of *Rhododendron campanulatum*. The per cent root colonization ranged between 45±0.70 to 60±0.37 from the root of *Rhododendron campanulatum* and 31±0.45 to 64±1.35 from the roots of *Betula utilis*. Dark septate endophyte was frequently observed in *Rhododendron campanulatum*.
- Total 75 populations, *Dactylorhiza hatagirea* (8 populations), *Podophyllum hexandrum* (24 populations), *Angelica glauca* (16 populations), *Aconitum heterophyllum* (9 populations), *Picrorhiza kurrooa* (6 populations) and *Rheum australe* (12 populations) were studied. These populations were found between 2345-4002 m. 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).
- Seven (7) populations of *Corylus jacquemontii (*2,169 – 3,155m), 12 populations of *Trillium govanianum* (3,000 – 3,732m) and 5 populations of *Aconitum heterophyllum* (3,363 – 3,869m) were assessed. Phenolics and flavonoids content in roots, stems and leaves of *Trillium govanianum* and *Lilium polyphyllum* were investigated. *In-vitro* cultures of *T. govanianum, L. polyphyllum* and *Ferula jaeschkeana* from seeds were established on MS medium containing single and combination of different growth hormones.
- Household survey has been completed for Mohal khad watershed with representative villages. Total 12 villages - 302 families has been surveyed. Villagers felt decrease in water availability; and less investment on development and maintenance of water resources could be the reason of less water availability in recent years. Villagers face maximum water scarcity in May and June. A river gauging station (Digital Water Level Recorder (WLR)) has been established at Mohal khad near institute campus for continuous stream water level monitoring.
- Developmental interventions such as hydropower development and vulnerability assessment in the Satluj basin within a selected buffer (10 km), land hazard zonation within a stretch of 582 km^2 from Rampur to Khab identified 121 landslides, out of which 19 were large and 102 were small. Area under

the influence of landslides has significantly increased from 1.35 km^2 in 1990 to 15.7 km^2 in 2015. Further, 37 km^2 area is vulnerable to landslides. About 3.44 km^2 area under agriculture and settlements was damaged due to landslides from 1989-2015.

- The Aerosol Optical Depth (AOD) study at Mohal showed aerosol radiative forcing to be –16.32 ± 7.36 Wm^{-2}, –33.30 ± 13.87 Wm^{-2} and +16.99 ± 7.78 Wm^{-2} on the top of the atmosphere (TOA), surface and atmosphere respectively. Whereas mean aerosol radiative forcing for the entire period of 2006-15 was estimated to be –12.99 ± 6.57 Wm^{-2}, –36.10 ± 13.94 Wm^{-2} and +23.11 ± 10.38 Wm^{-2} on TOA, surface and atmosphere respectively which translates into an average atmospheric heating rate of 0.65 K day^{-1} in the valley.
- Black carbon concentration monitored during August and September on the Parbati Glacier in 2015 was 0.41 ± 0.02 µg m^{-3}. The AOD at 500 nm was observed 0.17±0.02. Snow chemistry in terms of anions were in an order of $Cl^- > F^- > SO_4^{2-} > NO_3^-$. While cations were in an order of $Na^+ > NH_4^+ > Mg^{2+} > Li^+ > K^+$. Single transition metal zinc (Zn^{2+}) was found in the snow. While BC and other aerosols impact on the glacier was assessed by way of analysing Landsat data, the snout is retreating at an average rate of 0.67 m yr^{-1}. While the overall recession in snow area from 1962 to 2015 stood to be 2150 ± 178 m^2 at the rate of 40.57 m^2 yr^{-1}.
- Questionnaire surveys among tourists (35), all registered home stay owners (20), cottage/camps (4) and different stakeholders were conducted in the Tirthan valley. The result shows all the stakeholders feels there is a lack of tourism infrastructure, lack of communication facilities, solid waste management, etc. They also feel that there is a lack of support from the government agencies. For the development of Wild Rosehips (*Rosa moschata*syn *R. brunonii*) based products 8 Women Self-help and Credit Groups (WSCGs) were formed in different region of the Kullu Valley. The training programme organized mainly focused on the product development with the available resources and its value addition.

SIKKIM UNIT

- First time, a complete transect Yuksom-Black Kabur (1780m-4810 m) in Khangchendzonga Biosphere Reserve (KBR), west Sikkim is investigated for vegetation and pheasants assessment. Total 98 woody species recorded in 15 major sites and IVI based forest communities identified. The regression analysis between woody species richness and altitude of the study sites showed strong relationship (r^2=0.743, $p<0.05$). An important biodiversity element, observations were made on pheasants' availability, abundance, encounter rates and their habitat interaction pattern.
- First time, extensive investigations explored the habitat niches for behavioural and seasonal migration of blood pheasant and Satyr Tragopan in Khangchendzonga Biosphere Reserve (Sikkim) along high altitude zones
- A first time exploration in Sikkim Himalaya, the habitat assessment of 22 populations of threatened taxa, *Swertia chirayita* addressing conservation challenges were made.
- The phytochemical investigation for total phenolics, flavanoids and antioxidant activity on *Aconitum ferox* was performed; the tuber offered highest amount of total phenolic, total flavonoid compounds and maximum antioxidant activity in DPPH and ABTS assays than stems.
- Four high value medicinal plants of the Sikkim Himalaya viz. *Astilbe rivularis*, *Eupatorium adenophorum, Artemesia vulgaris and Drymaria* were investigated for the total phenolic content, flavanoid content and antioxidant activity. *In vitro* propagation protocol for *Bergenia ciliata* successfully established.
- An agreement signed between ICIMOD-Nepal and GBPIHED-India on Khangchendzonga Landscape Conservation & Development Initiative (India) - An Addendum to LoA between ICIMOD-Nepal and GBPIHED-India.

NORTH EAST UNIT

- Under the in-house project entitled 'Ecotourism as a potential tool for biodiversity conservation and sustainable livelihood in the Indian Himalayan Region' selected potential ecotourism destinations across IHR were evaluated for their status in terms of arrival of tourists over a period, impacts on local economy and resources, host attitude towards tourism, functioning of homestays focusing on prospects and constraints and many others.
- The ecotourism model developed at Apatani Plateau in Suluya village was further strengthened.
- Documentation of existing or potential tourist destinations/places across the IHR was carried out

with data on name of the destination, location (lat, long), name of the tourist circuit in which the destination/place is located, and a brief description of the destination/place. Status of state ecotourism/tourism policy and interventions of state government for promotion of tourism in States have been documented.

- During the reporting year, for Arunachal, focus was on assessment of positive and adverse impacts of tourism on environment, economy and culture through use of selected variables. As many as 305 respondents (hosts) were assessed in 12 villages in Apatani Plateau, while 100 hosts were assessed in 14 villages of West Kameng District of Arunachal Pradesh.
- Under the in-house project-3 entitled 'Strategic Environmental Assessment (SEA) of Hydropower Projects in the Indian Himalayan Region', the trend in increase and decease in fish species was determined. During discussion in the field, the local villagers informed that there is a significant decrease in the fish population after construction of the dam.
- In downstream of Ranganadi HEP dam site (in Ranganadi river), only one fish species *Garra birostris* (Family: Cyprinidae) was captured during the experimental fishing using cast net. Only two very small size individual of fishes belonging to *Garra birostris* were recorded from Ranganadi; the average length was around 4-5 cm and weight was around 150 gm. Whereas, in downstream of powerhouse site (in Dikrong river), three fishes species viz. *Neolissochilus hexagonolepis, Bangana dero* and *Crossocheilus latius* were captured.
- Sound level monitoring was carried out in study area at various sampling location. The sampling location included Ranganadi dam site, power house site, and catchment area, downstream of dam site and downstream of powerhouse site in the Ranganadi basin. Sound levels monitored at various locations showed a close range of 52.5 to 70.30 dB(A), which was due to the fact that most of the locations where sound levels were monitored are close to river and habitation.
- Soil samples were collected from upstream and downstream of dam site, powerhouse area and catchment area of Ranganadi basin. Overall in the study sites, the soil moisture content ranged from 25.63% to 43.68%, pH 5.16 to 6.17, total nitrogen 0.14% to 0.31%, sodium 0.04% to 0.13%, potassium 0.79% to 0.99%. Soil of Ranganadi basin is slightly acidic mainly due to the prevalent practice of shifting cultivation (*Jhum* cultivation) in the region.
- Under the In-house project entitled 'Understanding biodiversity patterns and processes under changing resource use and climate scenario in Indian Himalaya – ecological and social implications', use pattern documentation for 20 species belonging to 19 genera and 18 families i.e. Acanthaceae, Acoraceae, Araliaceae, Asteraceae, Begoniaceae, Berberidaceae, Brassicaceae, Cucurbitaceae, Hypoxidaceae, Illiciaceae, Lamiaceae, Liliaceae, Moraceae, Pinaceae, Plantaginaceae, Rubiaceae, Saururaceae and Solanaceae has been carried out in Ziro, Lower Subansiri district, Arunachal Pradesh .
- Under NMSHE Task Force-3 entitled "Forest Resoures & Plant Biodiversity", an extensive literature survey was carried out for compilation of the Rare, Endangered and Threatened (RET) plant species of Arunachal Pradesh, emphasizing more on endemic & vulnerable species to climate change. Currently, 14 villages located in Tato, Mechuka and Rumgong circles in West Siang district, Arunachal Pradesh based on varying altitude, i.e., 500-2500 m are studied for baseline studies in indigenous communities with respect to climate perception and adaptation capabilities and vulnerability indicators of climate change.
- Under NMSHE Task Force-5 entitled "Network Programme on Convergence of Traditional Knowledge System for Sustainable Development in the Indian Himalayan Region" over 150 published literature on different traditional knowledge and practices associated with land, soil and water management, bio-resource utilization and bio-processing including traditional skills in handloom and handicrafts in Arunachal Pradesh have been reviewed. To document, validate and analyze the traditional knowledge, currently, seven districts viz., East Siang, West Siang, Upper Siang, Tawang, West Kameng, Lower Subansiri and Papumpare covering five major tribal communities, Adis, Galos, Nyishis, Monpas and Apatanis have been studied.

MOUNTAIN DIVISION

Achievement

- Towards developing database for the tree species growing in the Indian Himalayan Region, in the first

phase, initiatives for data collection on the tree diversity of Western Himalaya was carried out. Following the published and unblished records, a total of 490 tree species have been inventorized in Wesern Himalaya. This includes 372 species in wild and 118 as cultivated. Uttarakhand represents 454 (92.6%) species [345 (92.7%) wild- Angiosperms-327, Gymnosperms-18; 109 (92.4%) cultivated- Angiosperms- 67, Gymnosperms-42], Himachal Pradesh 390 (79.6%) species [293 (78.80%) wild- Angiosperms-274, Gymnosperms-18; 97 (82.2%) cultivated- Angiosperms-64, Gymnosperms-33] and Jammu & Kashmir 330 (67.3%) species [238 (64%) wild- Angiosperms-220, Gymnosperms-18; 92 (78%) cultivated species- Angiosperms-59, Gymnosperms-33].

- Towards understanding the tree species diversity patterns along the altitudinal range (1000-3000 m asl), West Himalaya exhibits a continuous trend of decline in number from low altitude zone (< 1000m amsl) to highest altitude zone (> 3000m amsl). Of the total (i.e. 372 species), over 66.6% tree species are represented in <1000m altitude zone. Whereas only 4.30% (17 species) are present in zone >3000m altitude. The patterns of proportional tree species distribution across various altitude zones are more or less similar for different Western Himalayan states.
- Tree flora of three Western Himalayan states exhibits high similarity (68.2- 96.2). However, while moving from eastern to western extent of Western Himalaya, the similarity in tree flora declines (Uttarakhand vs J&K- 68.4% wild, 82.2% cultivated).
- As per IUCN (International Union for Conservation of Nature and Natural Recourses), 32 tree species are under threat of various categories indicated towards developing conservation strategies for the same.
- Towards contributing in the goal to end hunger, achieve food security and improved nutrition and promote sustainable agriculture under the sustainable development goal, assessment of nutritional and nutraceutical potential of selected wild edible plant species of Indian Himalayan Region is initiated.
- Details review of literature was done and on the basis of traditional knowledge base a comperhensive list of wild edible species was made. Based on the availability of species in the region (during February - March 2016), *Berberis asiatica* was selected for detail investigation.
- Optimization of extraction procedure for phenolic compounds and their antioxidant activity from *B. asiatica* fruit extract was successfully examined using response surface methodology. Based on the results, it is concluded that the extraction of phenolics were highly depends upon extraction temperature (X_1), sample to solvent ratio (X_3) and solvent concentration (X_5), beside others. These conditions could be opted for harnessing the higher concentration of free radical reducing natural phenolics. The methods can be utilized for further isolation of active fraction/compounds from the *Berberis* fruits and other wild edibles of the region. Further, the fruits of *Berberis* species will be recommended for its commercialization as antioxidant food products to address health issues related to oxidative stress.
- Assessment of floristic diversity and microbial association of the Birch – Rhododendron forests in Himachal Pradesh, North Western Himalaya, was carried out. The soil properties from the rhizosphere of *Rhododendron* and *Betula* were analyzed and varied from site to site. The textural class of soil falls under Loamy sand for Rahla and Naya tipri, sandy loam for Pandurupa. The pH and Electrical Conductivity varied from site to site. The pH ranged between 6.14±0.27 to 7.89±0.06 whereas, the Electrical Conductivity ranged between 171.08±15.74 µS 229.00±11.50 µS. The moisture content (%), organic carbon (%) and organic matter (%) ranged between 59.56±5.04 to 77.54±1.05, 0.83±0.03 to 2.18±0.34 and 1.43±0.03 to 3.76±0.58, respectively. Soil NPK also showed variations at all three sites. Available N, P and K ranged between 574±29.32 to 686±8.08, 0.12±0.01 to 0.15±0.01 and 239.36±48.72 to 433.02±4.03, respectively.
- Various mycorrhizal structures, namely, arbuscules, intra and extra-materical hyphae and vesicles were observed during quantification of root colonization of *Rhododendron campanulatum*. The per cent root colonization was also varied from site to site. The per cent root colonization ranged between 45±0.70 to 60±0.37 from the root of *Rhododendron campanulatum* and 31±0.45 to 64±1.35 from the roots of *Betula utilis*. Dark septate endophyte was frequently observed in *Rhododendron campanulatum*. Spore population study was conducted for only site I. The number of spores per

unit ml of root zone of soil was 2±0.33 for *Rhododendron campanulatum* and 2±0.58 for *Betula utilis*.

- Climatic variables and their impact on environmental flow in the Sutlej river Basin in Himachal Pradesh were carried out. Preliminary data reveals that the water quality for pre and post monsoon results is alkaline in the river Sutlej. Chemical parameters like alkalinity, hardness, chloride and calcium were within desirable limit except EC in some of the samples. EC was beyond its desirable limit and was much higher indicating that the river water was not good for human consumption. Water Quality Index (77.31 and 72.17) indicates that water is very poor in quality and not good for drinking purpose.
- According to the secondary information from Himachal Pradesh State Pollution Control Board (HPSPCB), dissolved oxygen (D.O.) exceeded its limits showing 6 mg/l. T.C. of bacteria as (500 MPN/100ml) shows water is polluted. Overall, it shows increasing trend. As a result, it is likely to affect aquatic life. Total coliform of bacteria was within its limit 500 MPN/100ml. Different sampling sites with different water quality parameters for the winter season in river Sutlej basin shows that biological oxygen demand (B.O.D.) and dissolved oxygen (D.O.) were more than their acceptable limits, i.e., 5mg/l and 3 mg/l respectively.
- Field survey conducted at Tangling village towards understanding the people's perception on river water and its quality. It was found that the local people are still dependant on the spring water for their use, however, dependant on the fishing and irrigation purpose. Respondant (55% of the total villagers) perceived that fishes are disappearing due to construction activities like dams, tunnels, roads, etc.

APPLICATION OF R & D OUTPUTS IN DEMONSTRATION AND DISSEMINATIONS

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

Ministry of Environment and Forests (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. 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

1. A grant-in-aid of Rs. 200 lakhs was received from National Mission on Himalayan Studies (NMHS) to strengthen IERP activities in the IHR.
2. An advertisement requesting for project proposals for funding support from IERP-NMHS was published in national dailies. A total of 58 project proposals were received.
3. The Project Evaluation Committee (i.e., 18th meeting of IERP-PEC) held on 19-20 March 2016 at New Delhi and based on the experts opinion and recommendations the PEC members, a total of 27 new projects were sanctioned for execution in 6 States (namely, Arunachal Pradesh, Himachal Pradesh, J&K, Manipur, Uttarakhand and W.B) of the IHR.
4. At present thirty eight IERP projects are on-going in 8 States (namely; Assam, Arunachal Pradesh, Himachal Pradesh, J&K, Manipur, Sikkim, Uttarakhand and W.B) of the Indian Himalayan region. A total of two projects were completed in the reporting year.

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 then 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 compiled the quantitative and qualitative databases on various aspects of Himalayan Ecology. These include, ENVIS Newsletters Vol. 12(1-4), 2015-16; ENVIS Bulletin Vol. 23, 2015; State at a Glance: Series of Indian Himalayan States [(Arunachal Pradesh Vol. 1(2), 2015; Jammu & Kashmir Vol. 1(3), 2015; Sikkim Vol. 1(4), 2015; Uttarakhand Vol. 1(5), 2015]. In addition, the center has developed educational materials on occasion of Science Express Climate Action Special (SECAS) Activities at Lakuan Station, frequently asked questions (FAQs) on climate change and global warming, and posters (State Symbols of Uttarakhand).
- The coverage and indexing of ENVIS publications have found place in various scientific agencies/libraries/etc. like, ENVIS Newsletter Himalayan Ecology in INDIANScience.in; Academic Resource Index (Research Bib), Japan; Scientific Indexing Services (SIS), USA; AcademicKeys, USA; and ENVIS Bulletin of Himalayan Ecology in Indian Citation Index (ICI); INDIANScience.in; Academic Resource Index (Research Bib), Japan; Open Academic journal Index (OAJI), Russia; Scientific Indexing Services (SIS), USA; and AcademicKeys, USA
- Regular upgradation and maintenance of ENVIS Centre's website (http://gbpihedenvis.nic.in)
- Addition of the new sections in website *viz.:* Web Directory of Indian Himalayan States; News Headlines on Biological Diversity and COP-21, 2015; Frequently Asked Questions (FAQ); Himalayan Popular Lecture Series; E-sections (e-books, reports, etc.); Himalaya in Media- print media coverage on Himalayan environmental, ecological and related issues; and Swachh Bharat Mission
- About 157 queries, related to Himalayan environment and development, were responded to the individuals/institutions, etc. during the year 2015.
- 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 (NGO's and other Government Organization) on payment basis. In the financial year 2015-16, Institute has collected 1.52 lakh rupees as a central laboratory

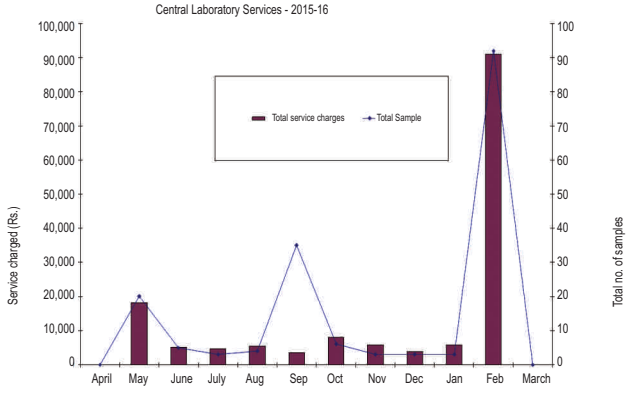


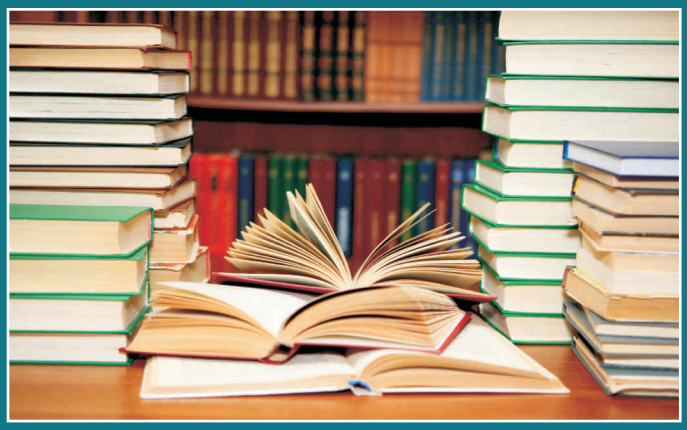
Figure 54. Graphic representation showing total samples 3 analysed under Central Laboratory Services in financial year 2015-16.

service charge from 15 organizations (4 - Govt. Organization, & 11 - NGO's). Apart from this, the Central Lab has also facilitated Institute research work (In-house and external funded projects) in the form of sample analysis using AAS, GC & CHNS. Figure - 54 shows month wise no 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 2015-2016, had 16,614 books. The library is subscribing a total of 77 periodicals (36 Foreign and 41 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, 68 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

(A) NATIONAL

Arya, S.C. and S.S. Samant (2016). Habitat wise Assessment of Alpine vegetation and prioritization of communities for conservation in a part of Nanda Devi Biosphere Reserve of West Himalaya, India-I. *International Journal of Life Sciences* 5 (1): 6-19.

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Participation in Different Events

Events	HQ	Units				Total
		NE	Sikkim	Garhwal	HP	
National						
• Symposia/Conference/Workshop	32	12	17	11	22	94
• Training Courses	37	2		9	5	53
• Meetings	46	8	15	40	12	121
• Participation as a Resources Person	• 56	12	18	22	31	139
•••Any Other	42	3	33		40	118
International	13	2	6	1	3	25

Details of Abroad Visit of Researcher/Scientist in the year of 2015-2016

Sl. No.	Scientist	Researcher	Designation at the time	Country Covered	For Workshop/Semminar	Time Period
1		Mr. Sumit Purohit	Research Fellow	USA	Attend the "2015 InVitro Biology Meeting"	30 May - 3 June 2015
2	Dr. P.P. Dhyani		Director	Switzerland	Attend the 'Short exchange visit to Switzerland in the framework of the Kullu vulnerability framework studies of the Indian Himalayas Climate Adaptation Programme	8 - 14 June 2015
3	Dr. S. S. Samant		Scientist F			1 - 14 June 2015
4		Dr. K.S. Gaira	Field Coordinator (Sikkim Unit)	Bhutan	Attend the "Regional Orientation Training on Participatory Ecosystem based Planning and Management"	5 - 11 August 2015
5		Mr. Johny Lepcha	Field Researcher (Sikkim Unit)			
6		Miss Sheila Sinha	Field Researcher (Sikkim Unit)			
7		Mr. Suman Kumar Sharma Nepal	Field Researcher (Sikkim Unit)			
8		Miss Nongmaithem Rangini	Senior Research Fellow (NE Unit)			
9	Dr. I. D. Bhatt		Scientist D	Paro (Bhutan)	Attend the "Regional Workshop on Tracking options for sustainable management and trade on Yarsagumba"	8 - 13 August 2015
10	Dr. R.S. Rawal		Scientist F	Tokyo (Japan)	Attend the First Authors Meeting of "Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services	17 - 21 August 2015
11	Dr. P.P. Dhyani		Director	Indonesia	Attend the traning course on "Landscape Governance"	24 - 30 August 2015
12	Dr. K. Chandra Sekar		Scientist D	Kathmandu (Nepal)	Attend the "Kailash Sacred Landscape Conservation and Development Initiative - Regional Annual Review and Planning Workshop 2016"	1 -3 September 2015
13		Dr. Ravindra Joshi	Field Coordinator			
14		Mr. Rahul Jain	SRF	Washington DC	Attend the "ASM Conference on Pseudomonas 2015"	8 - 12 September 2015
15	Dr. J. C. Kuniyal		Scientist E	Perth (Scotland) & Bath Spa University (UK)	Attend the "Perth III: Mountains fo Our Future Earth Conference"	2 -17 October 2015
16	Dr. R. K. Maikhuri		Scientist F	Scotland (UK)	Attend the 'Perth III: Mountains of Our Future Earth'	4 - 8 October 2015
17		Mr. Praveen Dhyani	SRF	Kathmandu (Nepal)	Attend the "Asia-Pacific Youth Forum 2015 Towards Sustainable and Climate Resilient Mountain Livelihoods"	5 - 8 October 2015
18	Dr. Paromita Ghosh		Scientist D	Toronto (Canada)	Attend the "Second International Conference on Agriculture & Fisheries 2015"	12 - 13 October 2015
19	Dr. P.P. Dhyani		Director	Kathmandu (Nepal)	Attend the "Himalayan University Consortium Summit of Members Intitutions	28 - 30 October 2015
20	Er. Kireet Kumar		Scientist G	Kathmandu (Nepal)	Attend the Technical Consultative Meeting on Regional Programme Implementation Plan (2016-2020)	3 - 5 December 2015
21	Dr. Hemant Kumar Badola		Scientist F			
22	Dr. J. C. Kuniyal		Scientist E	Chengdu (China)	Attend the Training Course on "Monitoring Greenhouse Gas Fluxes from Natural and Agroecosystems	15 - 31 December 2015
23	Dr. R. S. Rawal		Scientist F	Kathmandu (Nepal)	Attend the "Fourth Programme Steering Committee Meeting for Kailash Sacred Landscape Conservation and Development Initiative	1-Feb-16
24	Dr. Vasudha Agnihotri		Scientist D	Netherlands	Attend the "Eco-Bio 2016 Conference"	06 - 09 March 2016
25	Dr. P. P. Dhyani		Director	Lima (Peru)	Attend the "4th World Congress fo Biosphere Reserves"	14 - 17 March 2016

ANIL SHALINI & ASSOCIATES
CHARTERED ACCOUNTANTS

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INDEPENDENT AUDITOR'S REPORT

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

We have audited the attached Balance Sheet of G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT AND SUSTAINABLE DEVELOPMENT which comprise the Balance Sheet as at March 31, 2016, 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 NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT AND SUSTAINABLE DEVELOPMENT for the year ended March 31, 2016 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 2016.**

(b) In the case of Income and Expenditure Account the Income / expenditure 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: 04.08.2016

Place: Almora

For Anil Shalini & Associates
(Chartered accountants)

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

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
BALANCE SHEET AS ON 31ST MARCH 2016

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
LIABILITIES			
CORPUS / CAPITAL FUND	1	135850950.71	113308796.69
RESERVE AND SURPLUS	2	405080954.23	405545815.49
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	413012327.03	115391097.03
TOTAL		**953944231.97**	**634245709.21**
ASSETS			
FIXED ASSETS	8	405080954.23	405545815.49
INVEST. FROM EARMARKED/ENDOWMENT FUND	9	122648277.71	104227276.69
INVEST. OTHERS	10	0.00	0.00
CURRENT ASSETS , LOANS, ADVANCES ETC.	11	426215000.03	124472617.03
MISCELLANEOUS EXPENDITURE			
TOTAL		**953944231.97**	**634245709.21**
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 : 04.08.2016
PLACE : ALMORA

04/08/2016
(DR. P.P. DHYANI)
DIRECTOR

(DR. ANITA PANDEY)
D.D.O

04/8/16
(SURYA KANT)
FINANCE OFFICER

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
INCOME & EXPENDITURE A/C FOR THE YEAR ENDED 31ST MARCH 2016

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
INCOME			
Income from Sales/Services	12	300163.00	261188.00
Grants/Subsidies(net off exp)	13	218714275.59	173950320.4
Fees/Subscriptions	14	0.00	0.00
Income from Investment	15	0.00	0.00
Income tfr from Fixed Assets fund	-	25236908.15	24156971.55
(to the extent of depreciation & WDV of asset sold)		0.00	0.00
Income from Royalty, Income from Inv. Publication etc.	16	0.00	0.00
Interest Earned	17	15650959.02	11527112.23
Other Income	18	6591032.00	5684047.00
Increase (decrease) in stock of Finished goods and work in progress)	19	0.00	0.00
TOTAL (A)		**266493337.76**	**215579639.19**
EXPENDITURE			
Establishment Expenses: a) Institute	20	80322648.00	88526998.00
b) Projects		18402083.00	13240661.00
c) F.C (Projects)		4781177.00	4596477.00
Administrative Expenses :a) Institute	21	34786153.59	42854225.41
b) Projects (As per Annexure)		44973260.00	12077170.00
c) F.C (Projects)(As per Annexure)		15614243.00	10530716.00
Expenditure on Grants, Subsidies etc.	22	19834711.00	2124073.00
Interest			
Depreciation (Net Total at the year-end-as per Sch. 8)		25236908.15	24156971.55
TOTAL (B)		**243951183.74**	**198107291.96**
Balance being excess of Income over Expenditure (A - B)		**22542154.02**	**17472347.23**
Transfer to special Reserve			**0.00**
Transfer to/ from General Reserve			**0.00**
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Other Income)		**13202673.00**	**9081520.00**
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Corpus Interest Income)		**9339481.02**	**8390827.23**
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 : 04.08.2016
PLACE : ALMORA

04/08/2016
(DR. P.P. DHYANI)
DIRECTOR

(DR. ANITA PANDEY)
D.D.O

4/8/16
(SURYA KANT)
FINANCE OFFICER

G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
RECEIPTS & PAYMENTS A/C FOR THE YEAR ENDED 31ST MARCH 2016

RECEIPTS	CURRENT YEAR	PREVIOUS YEAR	PAYMENTS	CURRENT YEAR	PREVIOUS YEAR
I. Opening Balances			**I. EXPENSES**		
a) Cash in hand	50404.04	38540.53	**a) Establishment Expenses**	84125313.00	76985838.00
			I) Institute		
b) Bank Balances			**b) Administrative expenses**		
			a) Institute	25720446.00	22511088.00
i) In current accounts	0.00	0.00	b) R&D(Rev) expenses	9366753.00	16673195.00
ii) In deposit accounts (Corpus Fund)	29321.71	44204.81	c) Payments for current liabilities(gratuity/leave)	0.00	2815112.00
iii) Savings accounts	71844063.98	47808329.74	**C. Capital expenditure**		
c) Advances & Others	27119163.35	22590993.84	a) Purchase of Fixed Assets	7548754.00	12765018.00
(As per annexure Attached)			b)Expenditure on Capital Work in Progress	0.00	0.00
F.C. ACCOUNT			c) Acquirement of land (Lease money)		
A) Cash in hand	19624.33	930.33	**II Payments made against funds for various proj.**		
b) Cash at bank	3595548.37	16086723.36	**Expenditure State govt. projects**		
c)FC Advances	12870109.82	5459208.67	a) Capital	17036110.00	7421941.00
II. Grants Received			b) Revenue:		
a) From Government of India	126250000.00	130000000.00	Establishment exp	17896975.00	13080104.00
i) Institute & IERP			Administration exp	44981070.00	12063610.00
			Expenditure FC projects		
b) From Other agencies	380026253.00	65896045.00	**a) Capital**	405884.00	1175542.00
c) From other sources [from FC]	24629679.77	11111578.64	**b) Revenue:**		
III. Income on Investments from			Establishment exp	4588871.00	4432282.00
a) Corpus Fund(Received from Institute)	9081520.00	8062276.74	Administration exp	15614243.00	10530716.00
IV. Interest Received			**IERP grant released**	2025610.00	2124073.00
a) On Bank deposits savings a/c	6639530.00	3886763.00	**III Investments and deposits made**		
b)On term deposits a/c	5411765.00	2491452.16	Corpus Fund	19800000.00	23359000.00
c) Loans, Advances etc.	368049.06	370120.00	**IV Refund of Surplus money/Loans**		
			a) To the Government of India	2864858.00	2107044.00
V. Other Income			b)To Others/ security/ caution money)	155674.00	140000.00
(As per annexure Attached)	6891195.00	5945235.00	**V Other payments**		
VI. Amount Borrowed			Other Payment to Instt. FC Proj.	213686.00	829404.00
VII. Any other receipts.			Unspent Balance (FC)	310519.63	34618.48
			Refund of EMD	0.00	0.00
			Fund transfar to Corpus fund	9081520.00	8062276.74
a) Other Receipt FC a/c	0.00	13500.00	**VI Closing balances**		
b) Receipts Current Liabilities	0.00	6577.00	**a) Cash in hand**	130098.50	50404.04
c) IERP grants refunded by grantee Org.			**b) Bank Balance**		
d)Construction Fund			i) In Current account		
e) Corpus Fund FDR'S	26672007.00	12709000.00	ii) In deposit accounts (Corpus Fund)	21602229.71	29321.71
f) Caution Money	4500.00	8500.00	iii) In savings accounts	122457182.15	71844063.98
g) Security Deposit	2000.00				
h) EMD	541250.00	89750.00	**C) Advances and others**	275228785.78	27119163.35
i) Royalty	0.00	0.00	**FC Project**		
j) Sales Tax / VAT	8945.00	6793.00	a) Cash in hand	4305.33	19624.33
k)Service Tax	0.00	12576.00	b) Bank Balance	7967378.44	3595548.37
			c) Advances and others	12928662.89	12870109.82
			Adjustment of previous year closing Advances	0.00	0.00
TOTAL	**702054929.43**	**332639097.82**	**TOTAL**	**702054929.43**	**332639097.82**

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 : 04.08.2016
PLACE : ALMORA

04/08/2016

(Dr. P.P. DHYANI)
DIRECTOR

(Dr. ANITA PANDEY)
D.D.O

(SURYA KANT)
FINANCE OFFICER

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
SCHEDULE FORMING PART OF BALANCE SHEET AS ON 31ST MARCH 2016

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	678170.00	135634.00	0.00	813804.00	3255222.00	3390856.00
2	BUILDING:										
	a) On Freehold Land	214751988.00	0.00	0.00	214751988.00	43686546.41	3500457.40	0.00	47187003.82	167564984.18	171065441.59
3	PLANT MACHINERY & EQUIPMENT										
	a) Scientific Equipments	195213908.11	18232519.00	121990.00	213568417.11	107593611.08	9912187.75	0.00	117505798.82	95691937.17	87620297.03
4	VEHICLES	10124840.30	2350391.00	0.00	12475231.30	9380148.39	992877.83	0.00	10373026.22	2102205.08	744691.91
5	FURNITURE FIXTURES	30035324.40	1356122.00	0.00	31391446.40	21150904.15	1987078.56	0.00	23137982.71	8253463.69	8884420.25
6	OFFICE EQUIPMENT	30974669.35	0.00	0.00	30974669.35	20443766.09	2942593.59	0.00	23386359.68	7588309.67	10530903.26
7	COMPUTER/PHERIPHEARLS	2384957.00	37700.00	0.00	2422657.00	169071.12	115076.21	0.00	284147.33	2138509.67	2215885.88
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	55018.24	2895.70	0.00	57913.94	3048.07	5943.76
9	LIBRARY BOOKS	113469756.50	3044006.00	0.00	116513762.50	54647699.84	5534403.72	0.00	60182103.56	56331658.94	58822056.66
10	TUBE WELLS & W. SUPPLY										
11	OTHER FIXED ASSETS										
	GLASS / NET HOUSE	3911549.00	0.00	0.00	3911549.00	3369295.07	113703.41	0.00	3482998.48	428550.52	542253.93
	TOTAL OF CURRENT YEAR	605072619.89	25020738.00	121990.00	630215347.89	261174230.40	25236908.15	0.00	286411138.55	343433528.23	343898389.50
	PREVIOUS YEAR	583710118.89	21362501.00	0.00	605072619.89	237017258.84	24156971.55	0.00	261174230.40	343898389.49	346692859.61
	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
	TOTAL	666720045.89	25020738.00	121990.00	691862773.89	261174230.40	25236908.15	0.00	286411138.55	405080954.23	405545815.50

G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE 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)	0.00	0.00
Cheque in transit: (G Unit)	0.00	0.00
Cheque in transit: (Sk Unit)	0.00	0.00
Cheque in transit: (N.E. Unit)	0.00	0.00
Advances		
Electrecity Charges Recoverable	4575.00	4575.00
House Building Advance	1154815.00	442673.00
Motor cycle/Car Advance	103975.00	103975.00
Festival Advance	42750.00	40500.00
Computer Advance	0.00	0.00
Income tax deducted at source	191498.00	191498.00
Units of Institute:		
Sikkim Unit	-63012.83	-62552.83
HP Unit	14691.00	7214.00
Garhwal Unit	0.00	57179.50
NE Unit	73083.00	235459.00
FDR (Margin Money/LC A/C)		
Institute	0.00	0.00
DST NMSHE TF 3	878000.00	60078.00
DST SERB JCK H. P. Unit	2687000.00	0.00
SAC S. Trafdar G. Unit	536000.00	0.00
TOTAL:	**5807374.17**	**1264598.67**

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

Brought forward	**5807374.17**	**1264598.67**
Due Staff/ other IC A/c		
Sh. C. M. Sharma (Imprest)	5000.00	0.00
Dr. I. D. Bhatt (L.T.C)	0.00	0.00
STUP Consultant	(7435.00)	(7435.00)
M/S International Trade Links, Mumbai	34328.00	34328.00
LICOR INC USA	0.00	0.00
Tuder Rose UK (Instt.)	88535.00	0.00
S.K. Diesel Sales (Instt.)	66538.00	0.00
Wipro GE Health Care (Instt.)	296534.00	0.00
Adv. a/c of Airport Handling Service (SERB JCK H. P. Unit)	186835.00	18371.00
VPKAS Almora (Instt.)	26560.00	26560.00
Adv. to NIH Roorkee	100000.00	100000.00
Post Master G.P.O Almora	40566.00	0.00
Employment News	48287.00	48287.00
Sigma Aldrich Chemicals	10590.00	10590.00
Siltap Chemicals Ltd (Biotech -III)	408.00	408.00
DST (LMS) ILTP NRSA Hyderabad	48000.00	48000.00
NRSA Hyderabad	35300.00	35300.00
R.K.Nanda & Sons	28517.00	28517.00
NICSI New Delhi	35106.00	35106.00
Security Deposit CET Sikkim Unit	11000.00	11000.00
NRSA Hyderabad (NNRMS Proj.)	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 Hydrabad (DST-KK-I)	7400.00	7400.00
Vankta 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)	62020.00	0.00
EE R.E.S. Almora (MOE&F (BG) RSR	3402000.00	3402000.00
EE R.E.S. Almora Insitute	1571000.00	1571000.00
WWF New Delhi (UNDP-CEF-GOL) NE Unit	-31930.00	-31930.00
Adv. a/c of M/s Mahindra & Mahindra Mumbai	1853206.00	0.00
E E R.E.S. Almora (HRDI I.D.B. Project)	59000.00	59000.00
Adv. a/c of Chief Secretry Nagaland (Mountain Division)	0.00	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	24000.00
Adv. a/c of of FRI Dehradun MoE&F (NNRMS)	626104.00	1465104.00
Adv. a/c of Contrution Division II Pay Jal Nigam (MoE&F Botanical Ga	2493000.00	2493000.00
Adv. a/c of TATA Motors Ltd.	0.00	2836.00
Adv. a/c of Director M. S. Sawaminathan (NNRMS)	0.00	1644000.00
Adv. a/c of Partners NMHS enclose **Annexure 'X'**	0.00	253285620.00
Adv. a/c of Ms. Poonam Mehta	0.00	198.00
FC Advances to Units	(1883148.82)	(2397541.89)
TOTAL	**27119163.35**	**275228785.78**

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	265750.00
XSPUH &F Solan, PDF-B-GEF	150956.00	150956.00
Uttrakhand State Biodiversity Board ICIMOD-RSR (LOA-I)	3327500.00	3202704.00
Adv. a/c of VPKAS PDF B GEF	268410.00	268410.00
Adv. a/c of Dr. R. S. Rawal (ICIMOD RSR KSLCDI	65000.00	0.00
Adv. a/c of Dr. G. C. S. Negi (ICIMOD RSR KSLCDI	50000.00	0.00
Adv. a/c of Uttarakhand Forest Deptt. ICIMOD RSR KSLCDI	4405000.00	3494000.00
Adv. a/c of Himalayan Gram Samiti ICIMOD RSR KSLCDI	1273950.00	982100.00
Adv. a/c of U. SAC Dehradun (Main -New)	0.00	885500.00
Adv. a/c of Himalayan Seva Samiti (Main - New)	0.00	102120.00
FC ADVANCES TO UNIT	1883148.82	2397541.89
	12870109.82	**12928662.89**

INSTITUTE SUPPORTING STAFF

HEAD QUARTERS

Mr. Anil Kumar Yadav	Administrative Officer
Surya Kant Langayan	Finance Officer
L.M.S. Negi	Office Superintendent (Admn.)
Sanjeev Higgins	Technical Gr. – III (3)
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 (2)
Chandra Lal	Driver
K.N.Pathak	Technical Gr. – I (3)
Pan Singh	Group-C
Nathu Ram	Group-C
Ganga Joshi	Group-C
Kanshi Ram	Group-C

GARHWAL UNIT

D.P. Kumeri	L.D.C.
M.P. Nautiyal	Technical Gr. – II (2)
J.M.S. Rawat	Technical Gr. – II (2)
R.C. Nainwal	Field Assistant
R.P. Sati	Group-C

HIMACHAL UNIT

S.P. Maikhuri	Office Superintendent
Daulat Ram	Group-C

SIKKIM UNIT

R.K. Das	L.D.C
Jagnnath Dhakal	Technical Gr. – I(3)
P.K. Tamang	Technical Gr. – I(3)
Musafir Rai	Group-C
Shyambir	Group-C

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-G	Plant Ecology; Rural Ecosystems
Anita Pandey	Scientist-G	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-F	Forest Ecology; Watershed Management; EIA
Subrat Sharma	Scientist-E	Agroecology; Remote Sensing / GIS
Paromita Ghosh	Scientist-E	Plant Science; Soil Science
I.D. Bhatt	Scientist-E	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 (4)	Forest Ecology; Restoration Ecology
Subodh Airi	Tech. Grade IV (3)	Forest Ecology; Biotechnology

HIMACHAL UNIT

S.S. Samant	Scientist-G & In-charge	Plant Taxonomy; Conservation Biology
J.C. Kuniyal	Scientist-F	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 (I)	Zoology

SIKKIM UNIT

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

L.K. Rai	Tech. Grade IV (3)	Plant Taxonomy
Y.K. Rai	Tech. Grade IV (3)	Rural Ecosystems

GARHWAL UNIT

R.K. Maikhuri	Scientist-F & In-charge	Plant Ecology; Rural Ecosystems
A.K. Sahani	Scientist-D	Social Science; Anthropology
S. Tarafdar	Scientist-D	Weather & Climate Change; Glaciology; Hydrology

NORTH-EAST UNIT

P.K. Samal	Scientist-F & In-charge	Social Science; Anthropology
M.S. Lodhi	Scientist-D	Environmental Assessment
S.C. Arya	Scientist-C	High Altitude Ecology
K.S. Kanwal	Scientist-C	Strategic Environmental Assessment
Om Prakash Arya	Tech. Grade IV (1)	Biotechnological Applications

INSTITUTE SUPPORTING STAFF

HEAD QUARTERS

Anil Kumar Yadav	Administrative Officer
Surya Kant Langayan	Finance Officer
L.M.S. Negi	Office Superintendent (Admn.)
Sanjeev Higgins	Technical Gr. – III (3)
Mahesh Chandra Sati	Technical Gr. – IV (4), Lib.
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.
Atul Bisht	L.D.C.
Jagdish Singh Bisht	Technical Gr. – II (2)
Chandra Lal	Driver
K.N.Pathak	Technical Gr. – III (3)
Pan Singh	Group 'Ç'
Nathu Ram	Group 'Ç'
Ganga Joshi	Group 'Ç'
Kanshi Ram	Group 'Ç'
Govind Singh	Driver
Gopal Singh Bisht	Group 'Ç'

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	Group 'Ç'

HIMACHAL UNIT

S.P. Maikhuri	Office Superintendent
Daulat Ram	Group 'Ç'

SIKKIM UNIT

R.K. Das	L.D.C
Jagnnath Dhakal	Technical Gr. – III (3)
P.K. Tamang	Technical Gr. – III (3)
Musafir Rai	Group 'Ç'
Shyambir	Group 'Ç'

NE Unit

Brajesh Kumar	L.D.C.

गोविन्द बल्लभ पंत हिमालय पर्यावरण एवं विकास संस्थान

G.B. Pant Institute of Himalayan Environment & Development

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Government of India
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