# ANNUAL REPORT
## 2013-2014







**G.B. Pant Institute of Himalayan Environment & Development**

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

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

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

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Scientist 'G'/Scientist-in-Charge
IERP, GBPIHED

# CONTENTS



# FOREWORD

In pursuit of consistently striving and achieving the set mandate for the Himalayan environment and development, the Institute has accomplished the substantial journey of 25 years and commemorated "Silver Jubilee Year" during the reporting year 2013-14 all across its presence in the Indian Himalayan Region (IHR). Accomplishing a success milestone brings along with an increased share and sense of responsibilities as well, as here especially in context of taking forward the legacy of the true son of this land Pt G.B. Pant and devising a progressive future path for the premier Institute. To scale up its outreach and stakeholders' involvement, the Institute has started focusing on greater Institutional collaborations with Research and Development-oriented communities within the IHR and at national and international levels.

To bring the mountain welfare agenda at the forefront and support the cause for the Himalayan ecosystems and dependent inhabitants, recently the 5th Unit of the Institute, i.e. "Mountain Division" has also been established this year with the Ministry of Environment, Forests & Climate Change (MoEFCC), New Delhi. To address the societal needs promptly and proactively, the priority research areas and policies are being reviewed time and again by organizing some stimulating deliberations and other thought-provoking sessions for exchange of ideas and mutual learnings across the IHR. Integrating in-built research, development, demonstration and dissemination components, rehabilitation of the degraded land in the region is also one among prime concerns. Recently, rehabilitation of 25 ha common degraded village community land was demonstrated via eco-restoration of a few village clusters in Tehri-Garhwal district of Uttarakhand. This further opens up new scope for replicating such rehabilitation model all over IHR. In refining policies on eco-tourism, community conserved areas and shifting agriculture, the North-east Unit deserves a special mention here, on substantially contributing and influencing Arunachal Pradesh Ecotourism Policy, developed under a GOI-UNDP CCF-II project.

On one hand, to support location-specific eco-developmental needs and activities, the Institute via Integrated Eco-development Research Programme (IERP) section further strengthens its network with regional institutions and agencies in the IHR, recognizing the regional potential and promoting location-specific prospects. On the other hand, the Rural Technology Complex (RTC) of the Institute has ensured widespread dissemination of R&D outcomes to and capacity building of a range of stakeholders in Training-of-Trainers (ToT) mode. Release of grants and funding from the national (DBT, CSIR, DST, UGC, INSA, NEC, Sikkim Govt.) and international (ICIMOD, UNESCO, GOI-UNDP, NORAD, TSB, UNICEF, UNDP/ FAO/ UNIDO, MacArthur Foundation, Indo-Swiss, Indo-Canadian Agencies, etc.) levels are indications of the growing recognition of the Institute and overall endeavours extended by its resources. In addition, increasing pace and presence of the Institute's R&D results in peer-reviewed scientific journals, of national as well as international repute, are examples of conscientious efforts, overall indicating a testimony of its raising standard.

As the Director of this premier Institute, it is my consistent endeavour to strengthen the existing programmes and formulate new ones towards realizing the mandate, thus coming more steps closer to what has been envisaged in the Institute's Vision Document. This is the opportune time to acknowledge valuable support, suggestions and directions provided by the Members of the Apex Body, the Scientific Advisory Committee (SAC), the Governing Body (GB) and the G.B. Pant Society for Himalayan Environment & Development by helping in effective implementation and execution of the Institute programmes. The Institute thanks each concerned stakeholder and, of course, the valuable reader for continued association and rational feedback. I am confident that we all will come together time and again to perform our best roles, responsibilities and duties, acknowledging all great life-supporting services bestowed on us by the majestic and mighty Himalaya!

P.P. Dhyani
Director

# MAJOR ACHIEVEMENTS

- The 5th Unit of the Institute has been established at the Ministry of Environment & Forests (MoEF) as Mountain Division to address specific issues of the mountain ecosystem in an integrated manner within the various divisions of the MoEF, across the relevant key Ministries, and with NGOs and Academia to ensure conservation of mountain ecosystem and sustainable development of the mountain regions.
- Rehabilitation of 25 ha of village common degraded land was successfully done under NAIP project with two restoration models (10 ha), five Horticulture models (13 ha) and one MAPs model (2 ha) in three village clusters of Tehri Garhwal district of Uttarakhand.
- Seasonal water scarcity was investigated with continuous recording of water discharge data through integrated approach of isotope technique, remote sensing and GIS application.
- Background ambient air ($PM_{10}$ 64.1±9.6 μg $m^{-3}$ at Shongtong HEP) and soil quality (N 221, P 19 & K 312 kg $ha^{-1}$) in the project affected areas in the Sutlej basin showed adverse impacts of hydropower projects in the Indian Himalayan region.
- During the reporting year, the North East Unit had substantially contributed to the cause of biodiversity conservation and livelihood development through refining policies on ecotourism, community conserved areas and shifting agriculture. Arunachal Pradesh Ecotourism Policy developed under the GOI-UNDP CCF-II Project entitled "Biodiversity conservation through Community Based natural Resource Management in Arunachal Pradesh" is at the final stage of approval by the Govt. of Arunachal Pradesh.
- The findings, impacts and success stories of the GOI-UNDP CCF-II project published in the book "Biodiversity conservation through Community Based Natural Resource Management : An Approach", are highly appreciated across the board by UNDP, MoEF, Policy Planners, etc.
- Towards addressing the issue of 'Transboundary Landscape' conservation, NE Unit organized two important Consultation Workshops – 1. 'National Consultation for Delineation of Boundary and Preparation of Feasibility Document on BSL-India' on January 03-04, 2014 at Itanagar, Arunachal Pradesh and 'Regional consultation to discuss and develop the basis for transboundary cooperation framework for implementing Brahmaputra-Salween Landscape Conservation and Development Initiative (BSLCDI) on 22-25 January 2014 at Kaziranga, Assam, India. The Regional Consultation was jointly organized by GBPIHED and ICIMOD, Kathmandu and was attended by experts from China, India, Myanmar and Nepal.
- Natural Resources and social database have been developed using latest RS images with a focus on preparing Land use land cover maps under the Monitoring and Inventorization of Biosphere Reserves (Dehang – Debang Biosphere, Arunachal Pradesh) in India using GIS and RS technology. Temporal changes in land use dynamics (at 5 year interval) from the date of notification of the BR were also carried out successfully.

**Publications:**

| | | |
|---|---|---|
| ***1. Peer Reviewed Scientific Journals*** | | |
| **National** | **-** | **26** |
| **International** | **-** | **61** |
| ***2. Chapters in Books/Proceedings*** | **-** | **51** |
| **3. Authored/Edited Books/Booklets/Bulletins/Monographs** | **-** | **06** |
| ***4. Popular Articles*** | **-** | **29** |
| **Award and Honour to GBPIHED Faculty Members** | **-** | **06** |

# EXECUTIVE SUMMARY

The GBPIHED with a strong commitment for sustainable development of the Indian Himalayan Region (IHR) is the only institute of its kind which addresses physical, biological, social and economic issues of the region and its people in an integrated manner. The R&D mandate of the Institute is broad and covers all the facets of environment and development. Towards achieving this, multi-disciplinary approach and integration are the guiding principles. The emphasis on interlinking of natural and social sciences is the major thrust of all the programmes in the Institute. In this effort, special attention is paid on the intricate balance between fragility of mountains, indigenous knowledge and sustainable use of natural resources. Design and implementation of R&D activities on priority environmental problems, development and demonstration of best practices, technology packages and delivery systems for improved livelihood of the people are the core issues covered under most programmes conducted by the Institute. A conscious effort is made to ensure participation of local inhabitants for long-term acceptance and success of various programmes. Therefore, training, education and awareness of a variety of stakeholders are the essential components of all the R&D programmes. A brief summary of R&D activities of the Institute during the reporting year 2013–14 is as follows.

**Watershed Processes and Management (WPM)**

The study on "Ecological, Social and Policy Implications of Changing Water Resource Scenario in the Indian Himalayan Context" was intensified in the Kosi watershed of the Central Himalaya, and generation of different thematic maps and databases *viz.*, watershed and sub-watersheds map, administrative map, drainage map, geology map, soil map, altitudinal zonation map (DEM) were completed. According to the field analysis performed, the average per capita water consumption in Suyal catchment is 20.41 l/day, which is lower than the national norms for rural areas. The average water consumption per livestock is 36.99 l/day. R&D programme on "Farming Systems and Changing Climate Regime: Strengthening Food and Nutritional Security in the Himalaya" reveals that crop productivity has declined in the last 40 years. A similar reduction in productivity is also observed in the government data for paddy, wheat, pea, lentil, soya bean and potato in the past decade, i.e. between 1990 and 2010. The crop sowing time is delayed by 15–25 days as compared to the crop sowing time 40 years earlier for both the winter and rainy season crops. In the recent past, crops were grown mainly for home consumption, but after villages become connected through road link, people wish to harness benefits from the tourism sector. Analyses of the monsoon seasonal rainfall (June to August, JJAS) departures for the entire Himalayan region indicate that the western Himalayan region has a clear decadal oscillating trend of negative and positive rainfall departures. During 1951–1980, the central Himalaya was receiving <20% of the seasonal mean.

GPS studies conducted through permanent stations indicate the precise position and velocity of these sites in ITRF08 reference frame. Preliminary observations show that the velocity of IISC and HYDE is ~52–54 mm/yr, and velocities of GBPIHED's permanent stations GBSK, GBPK, GBNL, GBSN, GBKL and GBZR are ~51, 47, 46, 47, 39 and 44 mm/yr, respectively. Study on "Runoff modeling and simulation of sediment load of Gangotri Glacier system" reveals that the peak discharge of 110.74 $m^3/s$ was in the month of August 2013 whereas the lowest discharge of 39.65 $m^3/s$ was in the month of September. In comparison to previous years, higher discharge was observed during September, which confirms delay in culmination of the ablation season and a consequent delay in the next accumulation season. During the ablation period of 2013, average release of suspended sediment from Gangotri glacier was estimated as 12051.65 tons/day. The snow cover depletion analysis depicts a shift in the duration of ablation and accumulation during the study period (2000–2012) in the basin. The study of glaciers in Gori and Dhauli basin shows different retreat patterns. More number of glaciers were found to be retreating in the Dhauliganga basin (Dhumalia 32.03 m/yr, Jyoling 27.62 m/yr) while

the retreat rate was higher for Milam (49.72 m/yr), the principal glacier of the Goriganga basin. Project on "Responses of some high altitude crops to enhanced UV-B radiation and nutrient fertilization" deals with the response of pea crops grown in Himachal Pradesh to enhance UV-B radiations. Germination and antioxidant activities in methanolic extracts of seeds of eight cultivars of pea (*Pisum sativum*) commonly grown in Kullu valley, Himachal Pradesh have been studied. Total phenolics were also found maximum in Early Giant followed by Saloni, Ruchi, Lincoln, GS-10, CM-Avtar, Prachi and these was found lowest in Anmol. Total flavonoids were recorded highest in Ruchi, followed by Saloni, CM-Avtar, Prachi, Lincoln, GS-10, Anmol and lowest in Early Giant. Economic yields of Lincoln and Early Giant were also found highest among tested cultivars of pea plants.

Programme on "Study of heavy metal transfer from contaminated soil to food chain and their risk to human health in Himachal Pradesh" deals with heavy metal contamination of vegetables grown in Kullu valley. The concentrations of copper (Cu) and zinc (Zn) and non-essential heavy metals such as cadmium (Cd) and lead (Pb) in water and soil collected from production sites of cauliflower, cabbage, radish and tomato during summer were found within the safe limits of Indian and FAO standards. The average concentrations of Cu and Pb in radish and cauliflower collected from production areas during summer 2013 had exceeded safe limits of Indian, FAO/WHO and EU standards. The concentrations of Cd were found above the permissible limits of EU and FAO/WHO standards. Completed R&D project on "Recharge area identification and estimation of mean residence time for springs in one urban and one rural micro-watershed in Pauri Garhwal using isotope technique, remote sensing, and GIS for implementation of artificial recharge structures" reveals that large spatial variability is observed even at small distances, with strong ridge to valley gradient. The isotopic lapse rate ranges between –0.3‰ and 0.4‰ per 100 m ($r^2$ >0.6) matches well with the observation from other parts of the western Himalaya. Observations from the weather station suggest that the regional topographically controlled wind system dominates the smaller watershed also.

**Biodiversity Conservation and Management (BCM)**

In Kanawar Wildlife Sanctuary of Himachal Pradesh, 250 species of vascular plants, 106 economically important species and 10 forest tree communities were identified, and soil samples were analysed for moisture content, pH, organic carbon and nitrogen. In Khanchendzonga Biosphere Reserve, the utilization patterns of fuel and fodder species were studied, and conservation priority index was calculated on the basis of various indicators. In Gangolihat, Watershed utilization pattern of fuel and fodder species by the inhabitants and the lopping intensity of species in different forests were assessed. In West Kameng, utilization pattern of floristic diversity was assessed. In Sainj valley of Himachal Pradesh, 207 species of vascular plants, 20 forest tree communities and 133 economically important species were recorded. Soil samples were collected and analysed for the moisture content, pH, organic carbon and nitrogen. In Upper Beas Valley, 250 species of vascular plants and 4 forest tree communities (i.e. *Pinus wallichiana*, *Cedrus deodara, Alnus nitida* and *Pinus roxburghii*) were recorded. Of the total species, 49 species were bee flora, frequently visited by the bees for forage. Phenological observations were recorded on leaf fall, leaf bud initiation, flower bud initiation and leaf initiation and pink flower bud initiation, flower opening, fruit setting and fruit maturation in the marked Apple, Plum and Pear trees of the six selected orchards. The Participatory Rural Appraisal exercise and questionnaire surveys were conducted in eight villages to generate information on the provisioning of ecosystem services. The people use 39 plants for curing different ailments, 29 as wild edibles, 25 for fuel and 23 for fodder, etc. Total 16 sites representing 3 habitats and 6 aspects were surveyed and sampled between 2000 and 2135 m in Rupasana Devi Sacred Forest (9 sites) and in Bhrighu Rishi Sacred Forest (7 sites). Total 148 species of vascular plants representing trees (13 spp.), shrubs (18spp.) and herbs (117spp.) were recorded. Both the Sacred Forests were dominated by *Cedrus deodara* community. Species were analysed for Species Diversity and Concentration of Dominance. Soil samples were analysed. Soil moisture in Rupasana Devi Sacred Forest ranged from 16.89% to 41.36%, total nitrogen 2.24–2.51% and organic carbon

2.56–2.51%; in Bhrighu Rishi Sacred Forest, soil moisture ranged from 11.38 to 23.57%, total nitrogen 1.87 to 2.45%, and organic carbon 1.64% to 6.17%.

In Cold Desert Biosphere Reserve, 70 sites representing 12 habitats and 08 aspects were sampled. A total of 360 species belonging to 60 families and 270 genera were identified. Among the identified species, 265 species (Angiosperms: 262; Gymnosperms: 02; and Pteridophytes: 01) of economically important plants were recorded. 32 plant communities (shrubs: 19 and herbs: 13) were identified. Species were analysed for Species Diversity (H′) and Concentration of Dominance (Cd). Soil samples were also collected and analysed. Overall in the study sites, the soil moisture content ranged from 0.04% to 31.62%, pH 5.48–8.09, total nitrogen (–) 0.07% to 1.33%, organic carbon 0.20–5.25% and organic matter 0.34–9.05%. In all, 60 populations of *Arnebia euchroma (15* populations*), Dactylorhiza hatagirea (2* populations*), Podophyllum hexandrum (14* populations*), Angelica glauca (12* populations*), Aconitum heterophyllum (3* populations*), Picrorhiza kurrooa (6* populations*)* and *Rheum australe (7* populations*)* were studied between 2,096 and 4,492 m amsl in Himachal Pradesh. Seventy (70) distributional records, Bioclimatic, NDVI, Physiographic, Topographic, Bathymetric and hydrology variables were utilized for the prediction of potential areas of *Arnebia euchroma, Angelica glauca* and *Podophyllum hexandrum* with the help of ecological niche modeling packages. The model test yielded satisfactory results for *Arnebia euchroma* ($AUC_{train}$ = 0.998 ± 0.055 and $AUC_{test}$= 0.978 ± 0.046), *Angelica glauca* ($AUC_{train}$ = 0.998 ± 0.215 and $AUC_{test}$= 0.941 ± 0.129) *and Podophyllum hexandrum* ($AUC_{train}$ = 0.983 ± 0.073 and $AUC_{test}$= 0.959 ± 0.048). The Pollination Deficit Protocols (PDP) were successfully implemented at three STEP sites (Mustard, Apple and Large Cardamom); for three consecutive years (Mustard for 2 years). Based on the results of PDP, the following broad trends were observed; (i) in case of Large Cardamom the bumble-bee (*Bombus* sp.) and honey-bee (*Apis cerana)* were most frequent visitors and the density of pollinators responded positively with flowering phenology of target crop. It was observed that the increasing density of bumble-bee (*Bombus* sp.) resulted in significantly ($p$ <0.03) higher yield of the crop (on an average 21–41 gm/plant); (ii) in case of apple, higher population densities of *Apis cerana, Bombus* sp. and wild bees were recorded in orchards near natural habitats. Higher fruit set and fruit yield were observed in orchards supplemented with bee colonies irrespective of relative location of orchard with respect to natural habitat; (iii) for mustard, although there has been a declining trend for pollinator density in the second year, yet no significant impact was revealed when compared with the yield. Collection of key/native pollinators was made, and so far 70 insect visitors/pollinators were recorded/ photographed from STEP sites. Laminated field guides on insect visitors /pollinators were prepared for distribution amongst farmers and other stakeholders.

The Institute, as Coordinating Institute for India, entered into Agreement with International Center for Integrated Mountain Development (ICIMOD) on October 26, 2013 for implementation of KSLCDI in the Indian part. Agreements for implementation of KSLCDI activities were signed with Uttarakhand State Biodiversity Board (UKSBB) for work component 3 - Access and Benefit Sharing, and Uttarakhand Forest Department (UKFD) for work component 2 - Ecosystem Management, and work component 4 - Implementation of Conservation Strategy and Monitoring Plan. On the basis of existing literature and herbarium records, Uttarakhand Cold Desert comprises of 549 species distributed in 276 genera and 68 families. Of these, 206 species are of medicinal plants and used in different medicinal systems and, 37 species fall under different threatened categories. Mapping of Cold Desert Biosphere Reserve in Himachal Pradesh was completed and GIS database was created. The Land Use Land Cover (LULC) of CDBR classified the total area into 10 classes. Each and every class was identified on the basis of signature and ground truthing. The LULC map shows that in CDBR, vegetation covers only an area of about 247.3 $km^2$ (3.19%) and all non-vegetation classes cover 7522.67 $km^2$ (96.81%) area. Land use/land cover mapping of 1990 and 2005 for Nanda Devi Biosphere Reserve were completed along with GIS layers. Landscape analysis, along the time series of Dibru-Saikhowa island in the Dibru-Saikhowa Biosphere Reserve was done for policy inputs.

**Environmental Assessment and Management (EAM)**

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

The EAM Theme has successfully achieved its targets during 2013–2014. The on-going activities under the theme focused on seven projects, 2 in-house while the remaining 5 externally funded. The project on "Strategic environmental assessment (SEA) of hydropower projects in the Himalayan Region" is being implemented to carry out integrated and cumulative impact assessment of all hydropower projects in Sutlaj (Himachal Pradesh), Alkananda (Uttarakhand) and Ranganagi (Arunachal Pradesh) basins with an aim to develop a broad framework for the installation of hydropower projects in a given river basin. Remote Sensing and Geographic Information System (RS & GIS) are being used along with field verification tools. The project on "Climate change impacts on ecosystem services in the Indian Himalayan Region" aims to investigate four dominant forest types of the Central Himalaya for change in their structure and functioning *vis-à-vis* focus on its impact on ecosystem services. The phenological investigation on dominant species is being made as an early indicator of climate change. Other projects in the theme comprise "Indicators of climate change in context to the Himalayan forest ecosystems along an environmental gradient", "Gaseous air pollution in the background site of sprawling urban environment of Himachal Pradesh", "Aerosol climatology over the northwestern Indian Himalayan region (Himachal Pradesh)", and "Black carbon and other aerosols loading, and their impact on melting of the Parbati glacier in the northwestern Himalaya, India"; these R&D works pertained to aerosols (i.e. gaseous pollutants, columnar aerosol and black carbon aerosol) and their impacts on temperature rise, radiative forcing and climate change.

**Socio-Economic Development (SED)**

During the XI$^{th}$ plan, the Socio Economic Development theme has taken up R&D work on "Eco-tourism as a potential tool for biodiversity conservation and sustainable livelihood in Indian Himalayan Region", "Biodiversity conservation through community based natural resource management", and "Enhancement of livelihood security through sustainable farming systems and related farm enterprises in North-West Himalaya". "Shifting agriculture: issues and options with focus on adaptive interventions to make it ecologically, economically and socially viable", "Indigenous Knowledge: traditional health care practices in rural areas of Uttarakhand", and

"Migration: socioeconomic and cultural implication in Central Himalaya". Also, "Capacity building for entrepreneurship development and self-employment in the Himalayan region" was continued. During the reporting year, the R&D projects and consultancies taken up from the previous year were continued, *viz*. (i) Biodiversity conservation though community based natural resource management in Arunachal Pradesh (NE Unit), (ii) Enhancement of livelihood security through sustainable farming systems and related farm enterprises in north-west Himalaya (HQs), and (iii) Preparation of Wildlife management plan / Biodiversity conservation plan for Trans Arunachal Highways (NE Unit). Besides, one project on "Brahmaputra–Salween Landscape Conservation and Development Initiative (BSLCDI)" (the NE Unit) was also initiated.

The R&D projects of the Theme continued to strengthen/generate database on various aspects of IHR, emphasize on appropriate interventions and skill enhancement of the people to enable them to develop viable, replicable and effective community based natural resource management options to effectively protect and enhance the biodiversity simultaneously improving their economy and quality of life. In principle, through R&D projects and initiatives, the group has tried to promote participation of local communities in sustainable resource management and in alternative and innovative livelihood schemes like ecotourism, agro forestry, and micro enterprises, and pave the information gap for improving policies and knowledge base. *The group created a s*trong and empirically sound database on tourism potential all across the IHR and analysed adoption/adaptation scenario of tested/innovative resource management practices in central Himalaya. It significantly contributed in the conservation of the rich biodiversity of selected proposed heritage sites in Arunachal Pradesh ensuring community participation addressing *c*ritical issues such as hunting, community welfare and alternative livelihood. A strong interface established between state governments and various initiatives of the group is worth mentioning. The group also made visible contribution in developing policies and guidelines that have direct impact on conservation of biodiversity and promotion of livelihood. The important policies/guidelines developed include: (1) Guidelines for Promotion of Homestays in Arunachal Pradesh, (2) Guidelines for promotion and management of Community Conserved Areas (CCA) in Arunachal Pradesh, and (3) Arunachal Pradesh Ecotourism Policy. The group also brought out a well-appreciated volume on biodiversity conservation entitled "Biodiversity Conservation through Community based Natural Resource Management: An approach". At national and state levels, the members of the group also adequately contributed to the processes of conservation, livelihood promotion and climate change adaptation, through duly constituted national- and state-level working groups and committees.

**Biotechnological Applications (BTA)**

The focus of the theme is to document, characterize, conserve and utilize ecologically and economically important Himalayan bioresources using biotechnological approaches. In this context, *Valeriana jatamansi*, *Ginkgo biloba* and *Withania somnifera* were used for estimation of phytochemicals and antioxidant properties. Presence of optimum amount of phytochemicals and antioxidant properties indicates that these species can be promoted as natural antioxidants in addition to their traditional medicinal uses. Characterization of different Podophyllum species using molecular markers has been done, and some podophylotoxin pathway specific genes were identified. Similarly, efforts are being made to develop propagation protocols using conventional and *in vitro* methods for large-scale multiplication and production of quality planting material. *In vitro* propagation was established for *Valeriana jatamansi* and *Rhododendron maddenni*. Preliminary standardization has also been completed for *Gingko biloba*, *Quercus lamellosa*, and *Olea ferruginea*, etc. Conventional propagation of *Hedychium spicatium*, *Pandanus nepalensis, Spondias axillaries, Carpinus viminea* has also been done through seed germination and vegetative propagation techniques. Over 650 seedlings of *R. maddeni* were distributed to different stakeholders for demonstrations in the field conditions. Besides, studies were initiated on ecological niche modelling of some threatened medicinal plants, i.e. *Podophyllum hexandrum*, *Paris polyphylla*, *Angelica glauca*, *Dactylorhiza hatagirea* to

identify possible habitats of their occurrence so that further reintroduction of the species can be done.

Another component of the theme is to characterize microbial diversity of extremophiles, thermophiles and psychrophiles in the Indian Himalayan Region (IHR). A hyperthermophilic bacterium, isolated from autoclaved sediments collected from a hot spring site in District Chamoli of Garhwal Himalaya, has been characterized. The growth curves, drawn at different temperatures, showed clear preference for high temperature for production of cell biomass. Following polyphasic approach, the bacterium was identified as *Geobacillus stearothermophilus*. Elasticity in morphological structures and the production of thermostable enzymes at elevated temperatures by the bacterium are likely to play an important role in conferring resilience to bacterium for survival and multiplication under high temperatures. Twenty five species of cold, pH and salt tolerant *Penicillium*, isolated from soil samples from the high altitudes in IHR, have been characterized. Characters like tolerance for low temperature, wide range of pH, and high salt concentration, and enhancement in sporulation and production of secondary metabolites such as watery exudates at low temperature were attributed to the ecological resilience possessed by these fungi for survival under low temperature environment of the mountain ecosystem.

A project on characterization of pyschrotolerant fungi with particular reference to lignin degradation under mountain ecosystem is underway in an ICMR-funded project. Species of *Aspergillus*, *Penicillium* and *Trametes* are being studied for their ability to produce laccases under different physico-chemical and cultural conditions. Analysis of leaf extracts of *Ginkgo biloba* with reference to antimicrobial phytochemicals has been carried out in a CSIR-funded project. A DST-funded network project is underway on microbiological and eco-physiological parameters along an altitudinal gradient. Importance of psychrotolerant microbial consortium in plant growth promotion under mountain ecosystem was studied under CV Raman International Fellowships for African Researchers (2012–2013). Pure cultures of bacteria, actinomycetes and fungi are being maintained in a Microbial culture collection established in Microbiology Laboratory and regularly being accessioned by various national laboratories and institutes. Under the pond-based integrated farming system, studies are being continued to document Saprolegniasis, a common fungal infection of fishes in lakes and ponds, which will be used to understand fish diseases and formulate integrated management to the farmers in the region. Various training workshops and exposure visits are being carried out throughout the year to sensitize the diverse group of stakeholders towards the sustainable utilization of Himalayan bioresources.

**Knowledge Product and Capacity Building (KCB)**

A detailed document on reconstruction and sustainable development of disaster-affected Kedar valley was developed and submitted to Shri Nitin Bhaduriya, IAS (the-then Disaster Relief Commissioner, Govt of Uttarakhand), who has highly appreciated the efforts made by the Unit in this direction. Project staff working at RTC-Triyuginarayan extended great help during the Uttarakhand Disaster 2013 and provided shelter for 200 pilgrims at RTC-Triyuginarayan during 18–25 June 2013. A total of six training programmes each of two-days on "*Capacity Building and Skill Development of Stakeholders with regard to Management of Bioresources through Eco-friendly Technologies, Ecotourism, Livelihood Enhancement and Entrepreneurship Development*" were organized between January 2013 and March 2014, in which a total of 400 participants were imparted live demonstration and training on the above-mentioned areas. Another successful milestone was rehabilitation of 25 ha of village common degraded land, covering 8 prototypes under NAIP project [two restoration models (10 ha), five Horticulture models (13 ha) and one MAPs (2 ha)] in three village clusters of Tehri Garhwal district of Uttarakhand. A pilot report on Uttarakhand Disaster 2013 with particular reference to Kedar valley was developed and submitted to the Institute HQs. A suitable option for sustainable development of disaster-affected rural landscape/areas of Kedar valley based on locally available resources through simple technological interventions was recommended (*Current Science*, *in press*). Under Fast Track Young Scientist Scheme, DST, New Delhi, an in-depth study was initiated on assessment and quantification of defoliation by insect herbivory and its

impact on population dynamics and regeneration potential of *Betula utilis* a key stone species of the timberline zone of high altitude. The seasonal water scarcity was investigated, and the continuous water discharge data through integrated approach of isotop technique, remote sensing and GIS application was recorded. Bioresources based livelihood enhancement R&D activities and capacity building/skill development programmes in 12 disaster-affected villages of upper Kedar valley for redevelopment/ reconstruction were also initiated.

An in-depth study has been carried out at the timberline zone of the Valley of Flowers National Park (VOFNP) and buffer zone of Nanda Devi Biosphere Reserve (NDBR) to understand the population dynamics (structure & composition), regeneration pattern, anthropogenic pressure and different phenophases of the dominant species including keystone species *Betula utilis*. Land use and land cover (LULC) change studies were carried out to assess the future changes in distribution of *Betula utilis* and other associated species in the timberline zone of Central Himalaya. A medicinal plant nursery was developed on 4 ha land at Triyuginarayan which houses 1.5 lakhs seedlings of *Valeriana jatamansi* and 25,000 of *Inula racimosa*. Besides, a small pilot nursery was developed within the Unit premises (Srinagar Garhwal) in July 2013 where about one lakh seedlings of *Valeriana jatamansi* were raised because the approach road to Kedar valley (Triyuginarayan) was totally washed away due to disaster. A detailed vision document (33 pages) of Garhwal Unit of GBPIHED was developed with particular reference to mission, strategic goal, priorities for action and expected outcomes for the period 2016–2040. Assessment of farmer's perceptions, responses, adaptation and coping strategies to climate change impact/variability with respect to agriculture, forests, animal husbandry, water resources and overall impact on livelihood of the people inhabiting the lower Nayar valley and the upper Nayar valley were carried out. A monograph on "Bioprospecting of wild herbal spices for sustainable entrepreneurship development in rural areas of the central Himalaya (Uttarakhand)" was published. A total of 24 hectare village common degraded land was developed under different rehabilitation models (i.e. MPT models - 10 ha, Horticulture - 13 ha and MAPs - 1.0 ha) and a total of 3900 seedlings of various horticultural crops, i.e. Pear (*Prunus persica*) – 350, Apricot (*Prunus armenica*) – 1100, Walnut (*Juglans regia*) – 800, Apple (*Malus* sp.) – 200 and Peach (*Pyrus communis*) – 400, and Plum (*Prunus domestica*) – 600 were planted in three village clusters. Anthropogenic studies were carried out in 15 villages of two valleys at NDBR *viz*., valley of flowers National Park and Niti valley to assess the impact of tourist movement (for camping and trekking), over-exploitation/ collection of bioresources (fuel, fodder, timber, MAPs and other NTFPs) by local people and grazing pressure by domestic livetock (cow, sheep, goat, mule, etc.) near the timberline and adjoining areas.

# 1. INTRODUCTION

During the year 2013-14, various R&D activities were executed at different locations of the Indian Himalaya through its HQs at Kosi-Katarmal (Almora) and four regional Units, viz., Himachal Unit (Kullu), Garhwal Unit (Srinagar-Garhwal), Sikkim Unit (Pangthang) and NE Unit (Itanagar) by GBPIHED. 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 consultations with the stakeholders across the region, including those of the Scientific Advisory Committee, the Institute developed a perspective plan for the XIIth plan period (2012–2017). The identified thematic categories include the following: (1) Watershed Processes and Management (WPM); (2) Biodiversity Conservation and Management (BCM); (3) Environmental Assessment and Management (EAM); (4) Socio-economic Development (SED); (5) Biotechnological Applications (BTA) and (6) Knowledge Product and Capacity Building (KCB).

During the reporting period, various activities/projects were concluded. Summaries of these are included at appropriate places in the text. In due course of time, relevant detailed documents will be published and made available for the public. The progress made during the year 2013–2014 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

**World Environment Day (WED)**

The World Environment Day was celebrated at GBPIHED-HQs at Kosi-Katarmal, Almora and all the four regional units as "A Day with Students" with a theme "*Think, Eat and Save*" on June 5, 2013. On this occasion, students from different schools of the region were exposed to various laboratories of the Institute to see live demonstrations on different topics like water testing, tissue culture, bio-technology, microbiology and remote sensing and GIS, etc. Besides, various documentaries on nature, space, biodiversity, etc. were shown to the students. Welcoming the participants, the Director of the Institute described the importance of the "World Environment Day" and its objectives.

The Himachal Unit of the Institute also celebrated the Environment Day with the students. Various activities such as Declamation contest; Poster and Slogan Competitions and Cultural programmes related to the environmental conservation were organized. The Sikkim Unit, at its Pangthang campus, also organized the World Environmental Day. The day commenced with a group plantation of multi-purpose trees in tune to strengthen the green mission of the state. Scientists, technicians and staff of the Institute and workers and miscellaneous persons actively participated in the plantation programme.

Similar celebrations were also held at the Garhwal Unit and NE Unit of the Institute to mark the World Environment Day. Open discussion was held among the scientists and participants, covering different issues related to climate change impact, biodiversity loss, land degradation, forest degradation, human integrity, cultural and religious entity and ways to cope with adverse situations in future with respect to environmental conservation so that appropriate strategies could be developed for conserving environment sustainably.

**Annual Day Celebration**

The Institute celebrated the 126$^{th}$ Birth Anniversary of Pt. Govind Ballabh Pant and Annual Day function at its HQs Kosi-Katarmal and all the four Units (Garhwal Unit – Srinagar; HP Unit – Kullu; Sikkim Unit – Pangthang; and NE Unit – Itanagar) on September 10, 2013. Chief Guest Professor H.S. Dhami, Vice-Chancellor, Kumaun University, Nainital delivered the inaugural address. Dr. P.P. Dhyani, Director of the Institute delivered the welcome address and briefly highlighted the Institute's R&D activities conducted through its HQs and four regional Units. The new initiatives in the research including study of Glaciers; Kailash Sacred Landscape, Climate Change, etc. were emphasized. Institute's commitment for promotion and up-scaling of environment-friendly and cost-effective technologies in the region was highlighted.

On this occasion, the 19$^{th}$ Pt. Govind Ballabh Pant Memorial lecture entitled "Sustaining the Himalaya as the Water Tower of Asia – Need for Innovation Policy-Making from India and China" was delivered by Professor Jayanta Bandyopadhyay, Adviser (Water Diplomacy Programme, Fletcher School of Diplomacy, Tufts University, USA and Ecosystem for Life Programme, IUCN, New Delhi) and Former Professor & Head, Centre for Development and Environment Policy, Indian Institute of Management, Kolkata. Presidential address was delivered by Shri Hem Pande, IAS, Additional Secretary, Government of India, MoEF, New Delhi. Remarks were also given by the Former Directors of the Institute (Prof. P.S. Ramakrishnan, Dr. L.M.S. Palni, Dr. Mohinder Pal and Dr. Uppeandra Dhar) on the occasion of the Silver Jubilee Year of the Institute.

Besides, a photo competition-cum-exhibition on different aspects of Himalayan Biodiversity and Ecology was inaugurated by Professor V.K. Gaur. Vote of thanks was proposed by Er. Kireet Kumar, senior most Scientist of the Institute. Over 200 participants representing diverse sections of society participated in the programme.

**Launch of International Project**

Launching of international project, "Khangchendzonga Landscape Conservation an Development Initiative" (India) – a National (inception) consultation organized by GBPIHED, Sikkim Unit (collaboration: ICIMOD, Nepal; Convener: H.K. Badola) in Gangtok during 28–29 January 2014 for delineating proposed Khangchendzonga Landscape (India) including entire Sikkim, Darjeeling and Jalpaiguri districts of West Bengal. In addition to formation of a core group and two working groups for providing inputs for the preparation of Feasibility Assessment report, different

partners and experts were identified. The whole programme on "Khangchendzonga Landscape Conservation and Development Initiative" (India) was apprised at high level meetings in MoEF, Govt of India, New Delhi and in Directorate of Forests, Govt of West Bengal. A stakeholder workshop in West Bengal was organized and various conservation and development issues emerged out for Feasibility Assessment of Khangchendzonga landscape.

**Awareness Programme on Water Resource Management and Conservation**

A one-day "Awareness programme on Water resource management and conservation" was organized by the Garhwal Unit, GBPIHED at Vikas Bhawan, Pauri on February 11, 2014. About 70 participants from various departments of Uttarakhand (i.e. Uttarakhand Jal Sansthan, Public Works Department, SWAJAL, Forest Department, C.M.O., etc. including District Magistrate and Chief Development Officer, Pauri participated in this programme. CDO, Pauri opined that grassroot workers need to be associated with watershed development and water resource management programmes.

**Khangchendzonga Sacred Landscape Yatra**

Khangchendzonga Sacred Landscape Yatra, Sikkim (KSLY), a programme under the aegis of Ministry of Envionment & Forests, Govt of India was oganized by GBPIHED, Sikkim Unit, with the support coming from FEWMD, RMDD, GBPIHED, WWF-India and KCC. The Landscape Yatra with an idea to be able to connect with the land and people in the course of a journey (*Yatra*) through a landscape was launched on 22 February 2014 and it ceremoniously ended on 27 February 2014. A pre-Yatra briefing meeting was organized by GBPIHED, Sikkim and attended by various organizations represented by Dr. Sandeep Tambe, Special Secretary (RMDD), Mr. Pradeep Kumar, CCF (WL), Shri R.P. Gurung from ECOSS, Ms Priya Darshinee from WWF and Dr. H.K. Badola, Scientist In-Charge, GBPIHED, Sikkim Unit. Officials representing on behalf of their respective departments in the Yatra were Dr. B.M.S. Rathore, Joint Secretary (MoEF, New Delhi), Mr. Pradeep Kumar, CCF (WL), Mr. T.P. Bhutia, DFO (WL), Mr. S. Bhutia, DFO (KNP), Ms. P. Shrestha, Dr. P.S. Ghosh (WWF-India), Mr. P.G. Bhutia Asstt. Director (HRDD), Ms. U. Bhutia and Mr. K. Bhutia (KCC), Mr. N.T. Bhutia (RMDD), and from the Institute, Dr. K.K. Singh (Coordinator-KSLY), Drs. R. Semwal, S.C. Joshi, Y.K. Rai and L.K. Rai (GBPIHED).

**Workshop on Climate Change Impact on Traditional Farming System and Promotion of Organic Farming**

A two-day workshop on "Climate change impact on traditional farming systems and people's perception at local level" was organized by the Garhwal Unit of GBPIHED at Shilkakhal village, Tehri Garhwal, Uttarakhand during 24–25 February 2014. The workshop provided an umbrella for sharing experience and ideas among wider stakeholders such as scientists, officials of line departments, villagers, NGOs, and students in the context of climate change impact on the traditional farming system and promotion of organic cultivation to cope with the adverse impact of climate change. Shri Anil Swami and Shri Sundarlal Baloni were the chief guest and guest of honour 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 measurements to cope with the current situation by adopting eco-friendly technologies at local level. About 75 participants from different villages, i.e. Chachkinda, Ulna, Suni and Guni, govt. line agencies and NGOs participated in the programme. The participants were motivated and encouraged to adopt simple eco-friendly technologies for livelihood enhancement. In the concluding session of the programme, an 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 where upon their capacity could be strengthened.

**Training Programme on Ecotourism as a Potential Tool for Biodiversity Conservation and Sustainable Socio-economy in Indian Central Himalaya**

A one-day Training programme on Eco-tourism as a potential tool for bio-diversity conservation and sustainable socio-economy in Indian Central Himalayas was organized by the Garhwal Unit of GBPIHED at village Tiwargoan, Tehri, Uttarakhand on March 15, 2014. The expert, Dr. R.K. Dhodi, Centre for Mountain Tourism & Hospitality Studies, HNB Garhwal University, Srinagar delivered the key note speech on tools on ecotourism and home stay accommodation. The function was presided over by Dr. R.K. Maikhuri, Scientist In-Charge, and he stressed on the need for capacity and skill development towards harnessing the eco-tourism/tourism potential of Tehri dam and adjoining areas. A total of 153 (88 males and

65 female) local stakeholders participated in the interactive session. Various other options related to tourism promotion were discussed, including natural interpretation, rural tourism, bird watching, etc.

**Project Evaluation Committee (PEC) Meeting**

The 16th meeting of the Project Evaluation Committee (PEC) was organized and convened under the Integrated Eco-development Research Programme (IERP) of the Institute at Seminar Hall of the Indian Council of Forestry Research and Education (ICFRE), Van Vigyan Bhawan, Sector-V, R.K. Puram, New Delhi on 24th March 2014, in which 56 project proposals were examined critically by the members of the PEC and a total of 11 projects were recommended for funding. The meeting was held under the chairmanship of Professor R.S. Tripathi. The following seven members attended the meeting; Professor B.D. Joshi, Professor B.K. Tiwari, Professor S.S. Singh, Dr. M.G. Tiwari, Dr. Kishor Kumar, Dr. K.S. Kapoor and Mr. C.M. Sharma. Dr. P.P. Dhyani, the Director of the Institute, extended his hearty welcome to the PEC Chairman and members, and then gave a detailed power-point presentation about the Institute (GBPIHED) and its various R&D activities. He also presented details of IERP in the Himalayan region, highlighting its mandate, objectives and financial targets. The Director - GBPIHED also highlighted the crucial role of IERP in building scientific credibility of the Institute, in strengthening infrastructure for environmental research in the Himalayan region, and in achieving the second objective of the Institute which pertains to the identification and strengthening of local knowledge of the environment towards strengthening researches of regional relevance in the scientific institutions/ universities, etc.

**Workshop on Managing Natural Resources through Simple Technologies for Livelihood Improvement**

A two-day workshop on managing natural resources by simple technologies for livelihood improvement was organized by the Garhwal Unit of GBPIHED during 27–28 March 2014 at RTC-Triyuginarayan, Rudraprayag. Shri Deenmani Gairola and Parushram Gairola were the Chief guest and Guest of honour while Shri Mukundi Satkari presided over the programme. The workshop played a great role in developing an interaction between different stakeholders and scientists, to address the issues covering different sectors of livelihood; affected due to the natural disaster in Kedar valley and the possible strategies in the context of re-construction and improvement of the livelihood options for the local people by wise utilization of natural resources and their management through introduction of simple technologies. Scientist In-Charge emphasized on management of natural resources through simple technological interventions for livelihood improvement *via* powerpoint presentation and motivated participants to adopt these technologies for improving sources of income. Through live demonstration, the participants were imparted trainings on protected cultivation, organic composting, MAPs cultivation, water harvesting technologies, value-addition of wild edible fruits, ecotourism etc. for livelihood diversification.

# 3. RESEARCH AND DEVELOPMENT PROGRAMMES

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

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

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

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

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

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

Theme

# WATERSHED PROCESSES & MANAGEMENT (WPM)

Himalayan watersheds support varieties of managed and natural land use types such as terraced farming, agroforestry and orchards in north west and central to *jhum* farming in the north-east Himalayan regions. Besides these, natural forests, pastures, degraded lands, glacier and snowbound regions are other important land uses that regulate watershed processes. The UN Millennium Development Goals are targeted to reduce the proportion of people without sustainable access to safe drinking water by half and reduce hunger. The R & D activities of the theme, during the 12$^{th}$ Plan, include problem identification, assessment and quantification of watershed processes through synthesis of research findings and development of practices/packages for implementation with the involvement of beneficiaries. The theme focuses to work on watershed services and management, land and water use policy, consequences of climatic change, improvement of Himalayan farming systems and relevant Indigenous knowledge systems, etc. The main objectives of the theme are: i) Study the dynamics of the watershed processes and evaluation of ecosystem components on watershed scale; ii) Develop ways and means of optimal uses of watershed services for improved economic and ecological viability; and iii) Evolve strategies for efficient utilization of resources through integrated watershed management.

**Ecological, Social and Policy Implications of Changing Water Resource Scenario in the Indian Himalayan Context *(2012-2017, In-house)***

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

**Objectives**

- To identify, analyse and assess potential indicators depicting changes in water resource scenario under changing climate regime and their interaction with consumptive and non-consumptive uses at watershed scale.

- To investigate the implications of changing surface water regime and delineate the critical ecosystem components susceptible to change.
- Analyses of the consequences of the changing water resources on society and adaptation measures employed at local and policy level.
- To develop policy options and adaptive water management action plans for addressing the challenges identified above in the context of Himalayan mountains.

**Achievements**

- Generation of different thematic maps and databases viz. watershed and sub-watershed map (Fig. 1), administrative maps, drainage maps, geology maps, soil maps, altitudinal zonation maps (DEM) has been completed using GIS for baseline studies, geo-database and further modeling and analysis.
- An extensive field study and household surveys has been conducted in Suyal catchment, a sub-watershed of the Kosi watershed. 142 water springs have been identified, positioned and mapped. According to the field analysis performed, the average per capita water consumption in Suyal catchment is 20.41 l/day which is lower than the national norms for rural areas. The average water consumption per livestock is 36.99 l/day.
- On Jan 10, 2014, a participatory meeting was organized at Jalna (Suyal sub-watershed) in collaboration with CHEA Nainital and 75 people

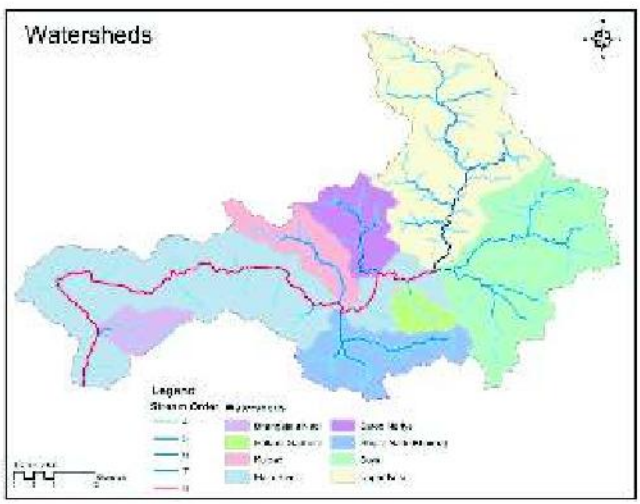


Fig. 1: Sub-Watershed with stream ordering in Kosi watershed (Almora–Nainital districts, Uttarakhand).

Fig. 2: Stakeholders' consultation meeting in Kosi watershed.

from 25 villages attended the meeting (Fig. 2). Issues and views regarding water, land and agriculture, livelihood and employment, environment etc. were gathered through a rapid PRA approach. The main issues analysed were; (i) severe water scarcity (30% people expressed this), (ii) devastation of agricultural fields and of crops by wild animals viz. monkeys, pigs etc. and birds (73% of people had reported this situation), (iii) deforestation (32% of people opined this problem) and (iv) Unemployment (41% of the people raised this issue).

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

The Indian Himalayan Region (IHR) is a distinct and eco-sensitive geographical region where about 70% of the population is rural and dependent mainly on rainfed agriculture, horticulture and animal husbandry. Here farming systems are complex; crop husbandry, animal husbandry and forests constitute interlinked production systems. Farming systems of the region are increasingly influenced by technological innovations, market economy and off-farm economic avenues. Climate and agriculture are interlinked and climate change is one of several factors affecting food production systems. Pheno-phases of the food crops are also affected by climate change. Any variation in crop phases affects agriculture by influencing the timing of planting, maturity, harvest and pest activity. In IHR, farmers have developed locally suitable practices to cope with the harsh environment of the hills. These

practices are continuously upgraded to meet new demands posed by the changing local environment. New crop varieties are being introduced into the system. This study examines the changes in the farming system, soil nutrient status and climatic changes in Kosi watershed. Since, monsoon rainfall is a regional scale phenomenon and the localized trend analysis of rainfall is inadequate to represent the trend of the entire Himalayan region, this study uses a high resolution climatological rainfall data of the entire Indian Himalayan region to indentify spatio-temporal changes in the summer monsoon rainfall patterns.

**Objectives**

- To study changes in mountain farming systems due to socioeconomic factors.
- To study changes in mountain farming systems due to ecological factors including climate change.
- To develop future farming scenario based on the above two objectives.
- To develop appropriate strategies and action plans for sustainability of mountain farming systems.

**Achievements**

- Three villages of Kosi catchment namely, Kantli (1865 m: High hill), Dhaniyakote (1127m: Mid hills) and Dabra Saural (700–880 m: Sub mountain Low hills) have been selected on the basis of agro-climatic zones to investigate impacts of climate change on the faming system; the villages have both rain fed and irrigated land and forest patches (Fig. 3A–D). Similar studies have also been initiated in the Garhwal region (Nayar valley and Guptkasi region) of Uttarakhand and in Kullu district of Himachal Pradesh.
- In Kantli ~85% households were farmers and the remaining 15% were landless. About 85% respondents of the village said that the crop productivity has declined in the last 40 years. A similar reduction in productivity is also observed in the data of Sankhyakeeya Patrika, Arth Evam Sankhyadhikari, Almora for paddy, wheat, pea, lentil, soya bean and potato between 1990 to 2010. Crop sowing time has been delayed by 15–25 days as compared to the crop sowing time 40 years earlier for both the winter and rainy crops, according to 28% farmers.
- During consultation meetings at Kantli and Dhaniyakote, the farmers emphasized on the shortage of irrigation water and crop damages by wild animals as the main causes of reduced crop productivity resulting in the abandoning of hill farms. In Himachal Pradesh, people wanted stress tolerant new food crop varieties to cope with climate changes. In Garhwal region of Uttarakhand farmers feel organic farming is one of the ways to minimize impact of climate change.
- The yearly analyses of rainfall for the Kosi-catchment of Uttarakhand show that precipitation has increased by 5% during pre-monsoon season, while a decline of 3% during winter and 6% in monsoon season has been observed during the last century (Table 1). It is observed that, minimum temperature during winter season has increased at a rate of 1.3 $^{0}$C/100 yrs whereas maximum temperature during winters is increasing at the rate of 1.1 $^{0}$C/100 years (Fig. 4A,B). The pattern of change in precipitation and temperature shows large variation in decadal change rates.

**Table 1: Trends of variation in precipitation**

| Season | Trend Analysis for average precipitation | | Rate of change (in % / 100 yr) |
|---|---|---|---|
| | Mann-Kendall Method | Linear Regression Method | |
| Winter | (–)* | (–)* | 3 |
| Pre-Monsoon | (+)* | (+)* | 5 |
| Monsoon | (–)* | (–)* | 6 |

*(+): Increasing Trend, ( ):-Decreasing Trend, *Significant at 95 % level of confidence,*


Fig. 3: Farming in Upper Kosi Valley. In insets, **A:** Irrigation channel in valley area, **B:** cropping of pulses during kharif side by side to paddy, **C:** cropping of Colocasia, locally called gadaeri as cash crop, and **D:** cropping of beans along the edges of crop field.

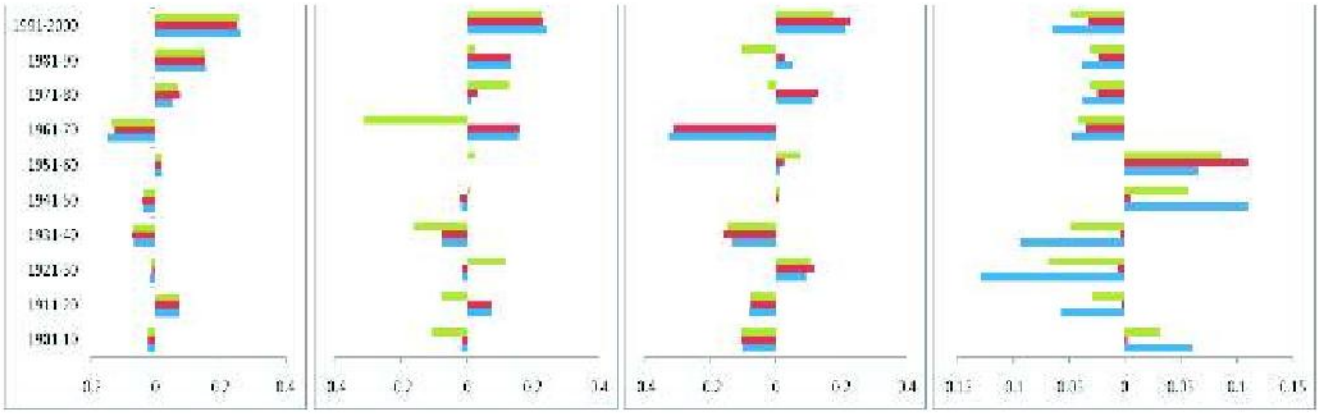

Fig. 4A: Decadal rate of change in (a) Pre-monsoon, (b) Monsoon, (c) Winter, and (d) Annual average precipitation.

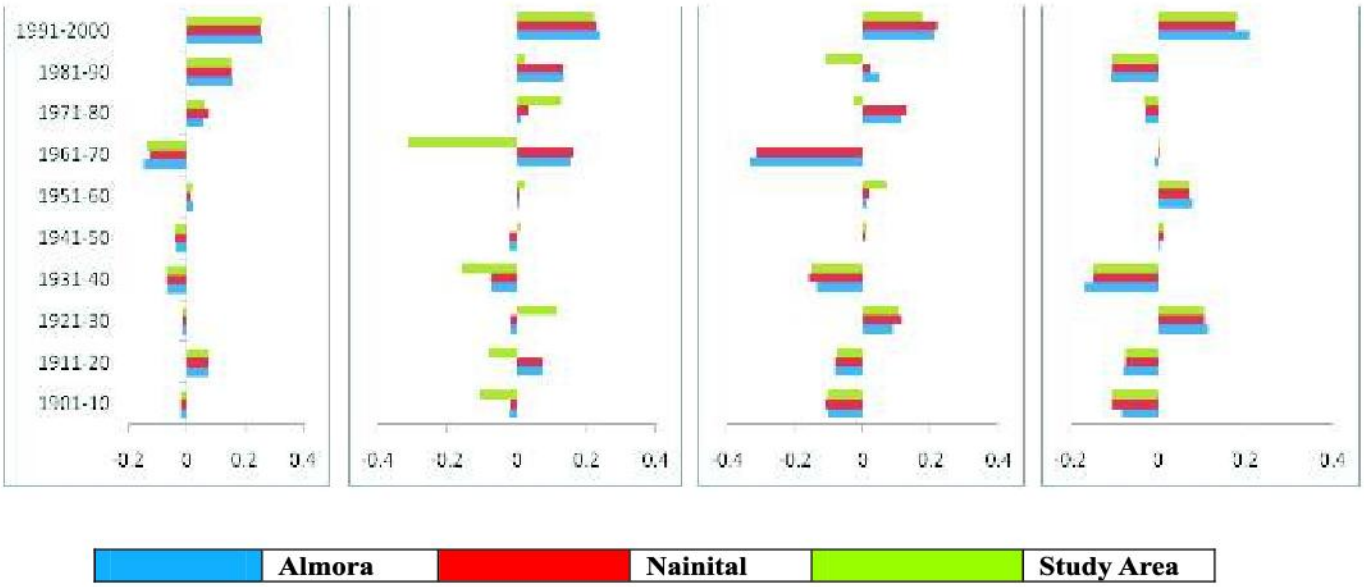


Fig. 4B: Decadal change rate in (a) Winter minimum, (b) Winter maximum, (c) Monsoon minimum, and (d) Monsoon maximum temperature.

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

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

**Objectives**

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

**Achievements**

- Regular upkeep & maintenance of the system and data processing of permanent station at Almora (GBPK), Nainital (GBNL), Srinagar (GBSN), Kullu (GBKL), Pangthang (GBSK) and Zero (GBZR) for reference to other campaign sites is being done. Field work GPS campaign from 10 sites along Gori valley and 10 sites along Kali valley in Kumaun Himalaya is completed and data is processed using GAMIT/GLOBK software. Coordinates and baseline of all campaign sites are determined with millimetre accuracy.
- 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 ~52–54 mm/yr, and velocities of GBPIHED's permanent stations GBSK, GBPK, GBNL, GBSN, GBKL and GBZR are ~51 mm/yr, 47 mm/yr, 46 mm/yr, 47 mm/yr, 39 mm/yr and 44 mm/yr, respectively (Fig. 5).
- There is convergence of 13.8mm/yr, 16.32 mm/yr and 9.66 mm/yr between GBPK_KIT3, GBNL_KIT3 and GBSN_KIT3 respectively and 28.34 mm/yr, 32.81 mm/yr and 26.44 mm/yr between GBPK_POL2, GBNL_POL2 and GBSN_POL2 respectively and 30.37 mm/yr, 35.43 mm/yr and 28.34 mm/yr between GBPK_SELE, GBNL_SELE and GBSN_SELE, respectively (Table 2).

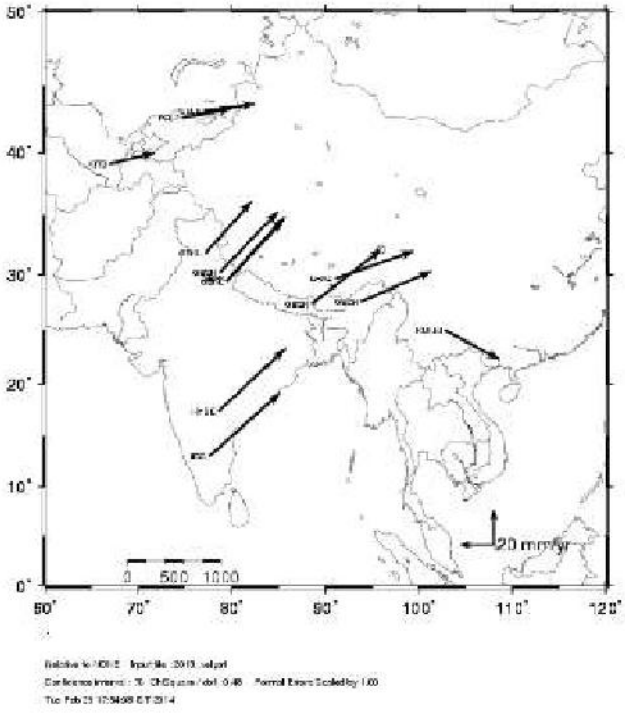


Fig. 5: Velocity of permanent stations (2010–2013) and reference IGS stations in ITRF08.

**Table 2: Baseline changes for the year 2012–2013**

| Station | Baseline 2012 (m) | Baseline 2013(m) | Baseline change 2012–2013(m) |
|---|---|---|---|
| GBPK_IISC | 1845790.057 | 1845790.058 | 0.0008 |
| GBPK_KIT3 | 1568521.453 | 1568521.439 | –0.0138 |
| GBPK_POL2 | 1509568.886 | 1509568.858 | –0.0283 |
| GBPK_LHAZ | 1110483.231 | 1110483.240 | 0.0091 |
| GBPK_HYDE | 1355461.275 | 1355461.276 | 0.0005 |
| GBPK_SELE | 1517100.515 | 1517100.485 | –0.0304 |
| GBNL_IISC | 1817190.034 | 1817190.032 | –0.0027 |
| GBNL_KIT3 | 1576439.572 | 1576439.556 | –0.0163 |
| GBNL_POL2 | 1531364.185 | 1531364.152 | –0.0328 |
| GBNL_LHAZ | 1128991.477 | 1128991.478 | 0.0004 |
| GBNL_HYDE | 1327243.259 | 1327243.257 | –0.0018 |
| GBNL_SELE | 1541727.110 | 1541727.075 | –0.0354 |
| GBSN_IISC | 1898824.080 | 1898824.081 | 0.0012 |
| GBSN_KIT3 | 1463504.258 | 1463504.248 | –0.0097 |
| GBSN_POL2 | 1427962.708 | 1427962.682 | –0.0264 |
| GBSN_LHAZ | 1196110.747 | 1196110.752 | 0.0054 |
| GBSN_HYDE | 1412954.603 | 1412954.603 | 0.0004 |
| GBSN_SELE | 1445492.005 | 1445491.976 | –0.0288 |

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

Glaciers, an important component of earth system, control the river hydrology of the mountainous and the areas downstream. Himalayan glaciers are showing a decrease in snow cover and extensive glacial retreat.

Gangotri glacier which was earlier receding at a rate of 26 m/year between 1935 and 1971 has shown a gradual decline of 17 m/year between 1971 and 2004 and lastly showed a recession rate of 12 m/year during 2004–2005. The rapid recession and overall decrease in the volume of glacier is adding to the total area of erosion every year. It generates large amount of suspended sediment load, which is carried from the glacierized basin. Suspended sediment forms a part of glacier erosion. Estimates of sediment yield are required in a wide spectrum of problems such as design of reservoirs & dams, transport of sediment and pollutants in rivers, lakes, design of stable channels, dams and debris basins, protection of fish and wildlife habitats, determination of the effects of watershed management, and environmental impact assessment which are considered essential for land and water management. The magnitude of sediment transported by rivers has become a serious concern for the planning projects of water resources. Therefore, correct estimation and prediction of sediment load carried by a river is very important. Further, the runoff generated by snow and glacier melt processes causes sediment transportation from the high altitude basins of the Himalayan region, especially from the middle and greater Himalayan ranges. Due to lack of information on hydrological processes of snow/glacier regime and availability of melt water, water resources management policies at the lower reaches of the glacier-fed rivers are often formulated without considering the impact of snow and glacier on river hydrology.

**Objectives**

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

**Achievements**

- The peak discharge for 2013 was observed in the month of August (110.74 $m^3/s$) whereas lowest discharge was observed in the month of September (39.65 $m^3/s$) during the study period (Table 3). The average discharge values for the months of June, July, August and September were observed as 75.8, 60.56, 75.07 and 49.78 $m^3/s$, respectively.
- In comparison to previous years, higher discharge was observed during September (Fig. 6) which confirms delay in end of ablation season and consequently delays in next accumulation season. Further, events related to high flow mostly occurred in the months of July and August confirming that these events were caused by opening up drainage network and excessive melting of snow and ice on account of rising temperature.
- During the ablation period of 2013, average release of suspended sediment from Gangotri glacier was estimated as 12051.65 tones/day. Maximum concentration in a day was observed in May (9.36 g/l on JD:147) followed by in June (8.22 g/l on JD:171) while minimum is observed in the month of September (0.02 g/l on JD: 269) followed by in October (0.03 g/l on JD: 277).
- The snow cover depletion analysis depicts a shift in the duration of ablation and accumulation during the study period (2000–2012) in the basin. The data analysed indicated significant increase in SCA in the middle elevation zones (4000–5500 m) and decline in SCA in the lower elevation zones (3000–4000 m) during autumn at varying rates.

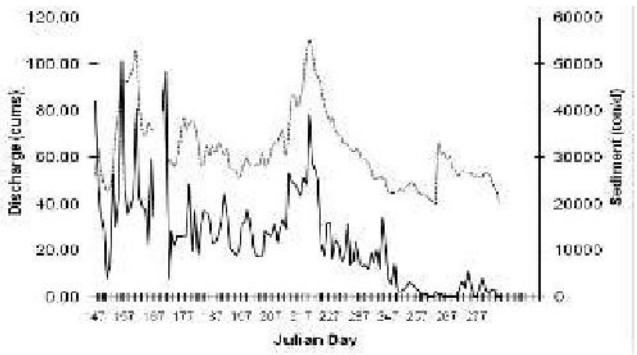


Fig. 6: Variation in daily discharge and sediment concentration observed during ablation season.

**Table 3: Patterns of discharge observed during ablation season of 2013**

| Month | No. of days/ observations | Discharge (in $m^3/s$) | | | | |
|---|---|---|---|---|---|---|
| | | Average | Maximum | Minimum | Total | SD |
| May | 6 | 51.8 | 63.7 | 45.5 | 310.56 | 6.6 |
| June | 30 | 75.79 | 104.60 | 55.76 | 2122.27 | 13.3 |
| July | 31 | 60.56 | 72.12 | 50.96 | 1877.38 | 5.3 |
| August | 31 | 75.07 | 110.64 | 50.64 | 2580.65 | 17.1 |
| September | 30 | 9.78 | 65.72 | 39.65 | 1493.44 | 6.7 |
| October | 12 | 49.84 | 53.16 | 39.89 | 548.21 | 4.1 |

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

Glaciers play a critical and vital role in the complex interaction of geological, cryospheric, atmospheric, hydrological and environmental processes that bear special significance for sustaining earth's biodiversity, climate and water cycle which directly or indirectly influences human life. They constitute 17% by area of the Himalaya and impact the regional climate, hydrology and environment of the Indian subcontinent. Permanent snow fields and glaciers located in high altitude Himalayan mountain chains are also very important natural sources of fresh water imperative to nation's planning policies, development and growth. Unfortunately, most glaciers in the Himalayan region are retreating due to accelerated global warming during the last century causing long-term loss of natural freshwater storage. Hence, in view of the conservation of this crucial resource, monitoring, measurement and mapping of the glacier dynamics has been focused upon in the Kumaun Himalayan region in this project using both satellite images and field studies. The study area spans over the Goriganga, Dhauliganga and Kaliganaga basins wherein glacier identification, snout retreat/advancement, terminus verification mass balance, surface velocity, meltwater sediment load discharge assessment, morphological and hypsometric studies are being undertaken.

**Objectives**

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

**Achievements**

- Correlation of various glacier morphometric parameters such as Glacier length, perimeter, snout width, altitude, glacier relief, slope, aspect etc. with reference to glacier area change and shift in snout position revealed that while the morphometric parameters exerted a substantial control over area changes in glaciers, they do not have much control over linear retreat/ advancement of the snout of the glaciers. Also, it was found out that the snout of the glaciers which possess low relief witnessed more retreat while percentage area loss was higher in smaller glaciers indicating their sensitivity to climate change.
- Assessment of area- altitude distribution of glaciers in Goriganga and Dhauliganga revealed that most of the area of the glaciers occurred between an elevations of 4500–6000 m. over steep to very steep slopes (Fig. 7). Majority of area lies in the accumulation zone of the glaciers in both the basins.
- Retreat rates were found to be different in both the basins. The lowest altitude of the snout of the Dhauliganga glacier was 3352 m asl, while the lowest snout altitude in the Goriganga Basin was 3400 m asl. More number of glaciers were found to be retreating in the Dhauliganga basin (Dhumalia 32.03 m/yr, Jyoling 27.62 m/yr) while the retreat rate was higher for Milam (49.72 m/yr), the principal glacier of the Goriganga basin.

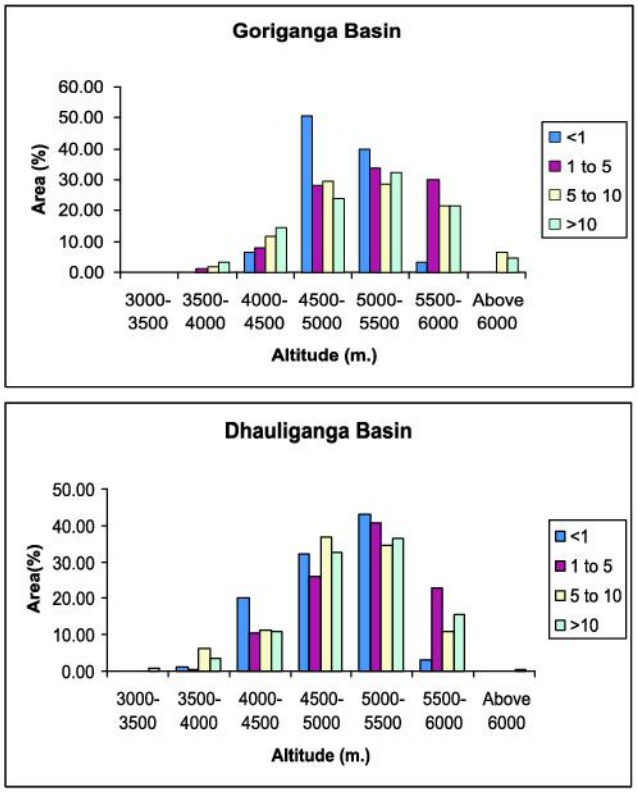


Fig. 7: Area–Altitude distribution in Goriganga and Dhauliganga Basins.

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

The Himalayan glaciers are retreating rapidly. The recession and overall decrease in the volume of glaciers is adding to the total area of erosion every year. It generates large amount of suspended sediment load, which is carried from the glacierized basins. The geodynamic changes in Glacier basins are responsible for multidimensional changes in glacier ecology. This proposal stems from the effort made by the Institute to understand the ecosystem of Gangotri, Thelu and Raktvarna valleys under the completed DST projects. The base line data was collected on different bio-physical elements of the glacier valley. The present proposal envisages analyzing long term dynamics of Gangotri glacier system and its impact on bio-physical and chemical components of glacial environment. The underlying hypothesis is whether or not the present dynamics of glacier (to be measured by precise snout monitoring using GPS) significantly affects the physical environment (i.e. geo-hydrology and micro-climate), and glacier chemistry. The results of this study are expected to yield helpful information for understanding the role of glacier dynamics in present context of climate change and the development of water management plan for downstream usages such as hydropower and irrigation.

**Objectives**

- To assess impacts on geo-hydrological features by monitoring of snout and glacier surface using precision surveys for retreat/ flow assessment.
- Investigate hydrology and quantification of suspended sediments of the meltwater stream of tributary glaciers/ streams to evolve the erosion rates and its possible relation with glacier dynamics.
- To assess the Glacier Chemistry and $CO_2$ levels through the study of temporal and spatial solute dynamics of glacier.
- To explore the relationship between solute dynamics and glacier dynamics.

**Achievements**

- The site for field survey was explored in the initial period of the project (Fig. 8). Survey of campaign sites selection for field data collection in proposed study area will be done in next ablation season.
- The geomorphology of the glacier valley has changed significantly in recent years indicating excessive melting in the northern side of the glacier snout (Fig. 9). The earlier study has shown that the northern portion of the snout has been retreating at a significantly higher rate in comparison to its southern part.
- The variable rate of recession of the snout of Gangotri glacier is possibly due to excessive forcing of meltwater from the tributary glaciers (Raktverna and Chaturangi). Further studies in the upper part of the glacier valley will be necessary to confirm the recession pattern of Gangotri.

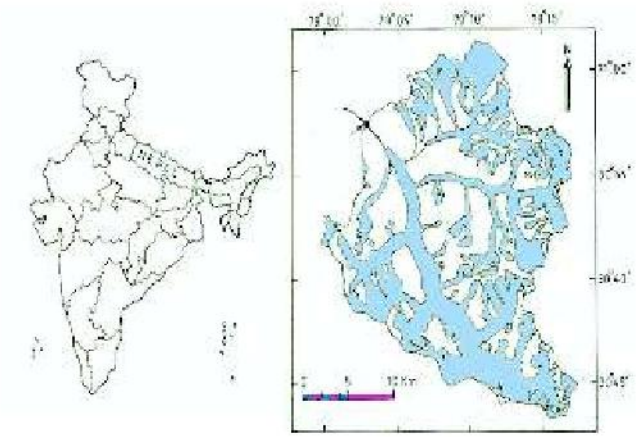


Fig. 8: Map of study area (Gangotri glacier, Uttarkashi district, Uttarakhand).

Fig. 9: Signs of excessive melting and erosion in northern portion of Gangotri Glacier.

**Responses of Some High Altitude Crops to Enhanced UV-B Radiation and Nutrient Fertilization *(2013–2016, DST, New Delhi – Women Scientist-A)***

Enhanced ultraviolet-B (UV-B) radiations due to depletion of stratospheric ozone layer affect agriculture crops in many ways either directly or indirectly. In the Indian Himalayan region, UV-B radiation is increasing due to increased deforestation, forest fires and transportation.The levels of ambient UV-B radiation in tropics are already high and any further enhancement in UV-B could be of considerable importance. Increased UV-B radiation may significantly alter plant ecosystems by reducing productivity of several economically and ecologically important plants. Very few reports on the effects of enhanced UV-B radiations on agricultural crops of Himachal Pradesh are available. Therefore, the present study on the response of some agricultural crops of Himachal Pradesh to enhanced UV-B radiations and nutrient fertilization is being carried out with the following objectives

**Objectives**

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

**Achievements**

- Total phenolics in pea (*Pisum sativum*) seeds, commonly grown in Kullu valley, were maximum in Early Giant followed by Saloni, Ruchi, Lincoln, GS-10, CM-Avtar, Prachi and minimum in Anmol. Total flavonoids were recorded highest in Ruchi followed by Saloni, CM-Avtar, Prachi, Lincoln, GS-10, Anmol and lowest in Early Giant. DPPH inhibition was shown highest by seeds of Early Giant followed by Lincoln, CM-Avtar, Ruchi, GS-10, Saloni, Anmol, Prachi and lowest in Anmol.
- Growth, biochemical and physiological performance of different cultivars of pea plants grown under field conditions of Kullu valley of Himachal Pradesh were studied. The cultivars such as Lincoln and Early Giant showed maximum length, dry matter yield, total phenolics and chlorophyll contents as compared to other tested cultivars of pea plants. Similarly economic yield of Lincoln and Early Giant were also found highest among tested cultivars of pea plants (Table 4).
- An experiment to study the responses of two cultivars of French beans (*Phaseolus vulgaris* L. Cv. Pusa Himlata and Pusa Parvati) to enhanced and ambient UV-B radiation is initiated.

Table 4: Growth performance, total phenolics and total chlorophyll contents in leaf tissues of different cultivars of Pea (*P. sativum*) plants

| Cultivars | Growth performance | | | Total phenolics (mg $g^{-1}$ fw) | Total chlorophyll (mg $g^{-1}$ dw) | Economic Yield (g $plant^{-1}$) |
|---|---|---|---|---|---|---|
| | Total length (cm $plant^{-1}$) | Total plant dw (g $plant^{-1}$) | Root shoot ratio | | | |
| Lincoln | $31.65^{b} \pm 0.54$ | $0.744^{b} \pm 0.02$ | $0.35^{e} \pm 0.16$ | $666.40^{b} \pm 30.58$ | $55.52^{b} \pm 0.65$ | $6.00^{b} \pm 0.32$ |
| Early Giant | $56.94^{a} \pm 0.67$ | $0.946^{a} \pm 0.04$ | $0.28^{f} \pm 0.19$ | $1060.41^{a} \pm 37.22$ | $68.65^{a} \pm 0.89$ | $9.00^{a} \pm 0.55$ |
| GS-10 | $27.69^{cd} \pm 0.44$ | $0.517^{d} \pm 0.07$ | $0.44^{c} \pm 0.11$ | $445.20^{d} \pm 20.65$ | $33.74^{ef} \pm 0.61$ | $3.40^{e} \pm 0.24$ |
| Saloni | $28.96^{cd} \pm 0.63$ | $0.542^{d} \pm 0.02$ | $0.36^{e} \pm 0.14$ | $571.27^{c} \pm 11.65$ | $41.69^{c} \pm 0.44$ | $3.60^{e} \pm 0.24$ |
| Ruchi | $20.61^{g} \pm 0.24$ | $0.486^{d} \pm 0.06$ | $0.55^{b} \pm 0.20$ | $374.33^{f} \pm 21.44$ | $30.67^{fg} \pm 0.74$ | $2.60^{e} \pm 0.24$ |
| CM- Avtar | $19.67^{g} \pm 0.60$ | $0.567^{d} \pm 0.08$ | $0.40^{d} \pm 0.11$ | $442.20^{d} \pm 24.59$ | $37.61^{d} \pm 0.91$ | $3.20^{e} \pm 0.37$ |
| Prachi | $24.64^{e} \pm 0.57$ | $0.593^{c} \pm 0.06$ | $0.70^{a} \pm 0.17$ | $251.61^{h} \pm 15.26$ | $42.40^{c} \pm 0.74$ | $3.20^{e} \pm 0.20$ |
| Anmol | $21.69^{f} \pm 0.46$ | $0.565^{d} \pm 0.07$ | $0.34^{e} \pm 0.23$ | $332.45^{g} \pm 24.67$ | $33.37^{ef} \pm 0.85$ | $5.20^{b} \pm 0.73$ |

*Values are mean ± SE of five replicates for growth parameters and three replicates for total phenolics and chlorophyll contents. Values in each column followed by different letters are significantly different at $p<0.05$ (Duncan Multiple Range Test)*

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

Human concerns on heavy metal contamination of vegetables are growing due to their ill-health or health-threat causing effects and non-biodegradable nature. Increasing urbanization, industrialization as well as heavy use of pesticides, contaminated irrigation water, chemical fertilizers, infected solid waste composts are contaminating them with essential heavy metals like copper (Cu) and zinc (Zn) and non essential heavy metals like cadmium (Cd) and lead (Pb). The consumption of such contaminated vegetables can pose health threats to tourists and local population of

Himachal Pradesh which has more than 0.4 million population (Census 2011). There is scarcity of information on heavy metal contamination of vegetables and their risk to local population, therefore the present study is aimed at studying the effect of the transfer of heavy metals from contaminated soil to food the chain and their risk to health of the general public of Himachal Pradesh.

**Objectives**

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

**Achievements**

- Samples of cauliflower (*Brassica oleracea* L. var. *capitata*), cabbage, (*Brassica oleracea* L. var. *botrytis*), radish (*Raphanus sativus* L.) and tomato (*Lycopersicon esculentum* L.) were collected from production and market sites in Kullu valley during summer, rainy and winter seasons of 2013-2014. The samples were analysed for Cu, Zn, Cd and Pb using an Atomic Absorption Spectrophotometer.
- The concentrations of Cu, Zn, Cd and Pb in water and soil collected from production sites during summer were found within the safe limits of Indian and FAO standards.
- The average concentrations of Cu and Pb in radish and cauliflower collected from production areas during summer 2013 had exceeded safe limits of Indian, FAO/WHO and EU standards (Table 5). The concentrations of Cd were found above the permissible limits of EU and FAO/WHO standards.
- Vegetables such as spinach (*palak*) and French bean were grown on soil amended with locally produced municipal solid waste composts (0–60%). Transfer of heavy metals from soil to edible parts of these vegetables was studied (Fig. 10). Transfer factor of Zn, Cd and Pb exceeded its unit value in French beans, however, the same was found less by a unit in spinach.

Table 5: Minimum, maximum and average concentrations of heavy metals in water, soil and vegetables collected from production areas of Kullu, Himachal Pradesh during summer 2013

| Samples | | Heavy metals | | | |
|---|---|---|---|---|---|
| | | Cu | Zn | Cd | Pb |
| **Water (mg/L)** | Min | 0.004 | 0.076 | 0.001 | 0.016 |
| (n=4) | Max | 0.006 | 0.107 | 0.002 | 0.019 |
| | Average | 0.005 | 0.09 | 0.001 | 0.018 |
| | Indian Standards [a] | 0.05 | 5 | 0.01 | 0.10 |
| | FAO Standards [b] | 0.20 | 2 | 0.01 | 5.00 |
| **Soil (mg/kg d.w.)** | | | | | |
| (n=8) | Min | 33.50 | 12.10 | 6.40 | 1.40 |
| | Max | 82.10 | 76.60 | 7.50 | 34.30 |
| | Average | 55.63 | 34.14 | 6.84 | 14.41 |
| | Indian Standards [a] | 135–270 | 300–600 | 3–6 | 250–500 |
| | EU Standards [c] | 140 | 300 | 3 | 300 |
| **Vegetables (mg/kg d.w.)** | | | | | |
| Cauliflower | Min | 43.30 | 32.25 | 0.66 | 0.95 |
| (n=4) | Max | 72.10 | 71.60 | 1.37 | 3.75 |
| | Average | 53.54 | 46.60 | 0.92 | 2.30 |
| Radish | Min | 39.90 | 11.45 | 0.52 | 0.75 |
| (n=4) | Max | 45.65 | 13.80 | 1.14 | 2.68 |
| | Average | 42.72 | 12.83 | 0.79 | 1.80 |
| | Indian Standard [a] | 30 | 50 | 1.5 | 2.5 |
| | EU Standards [d] | – | – | 0.2 | 0.3 |
| | WHO/FAO Standards [e] | 40 | 60 | 0.3 | – |

*n= Total number of samples collected and analysed in triplicates.*
*[a]Awashthi (2000) [b]FAO (1985) [c]EU (2002) [d]EU (2006); WHO/FAO (2007)*

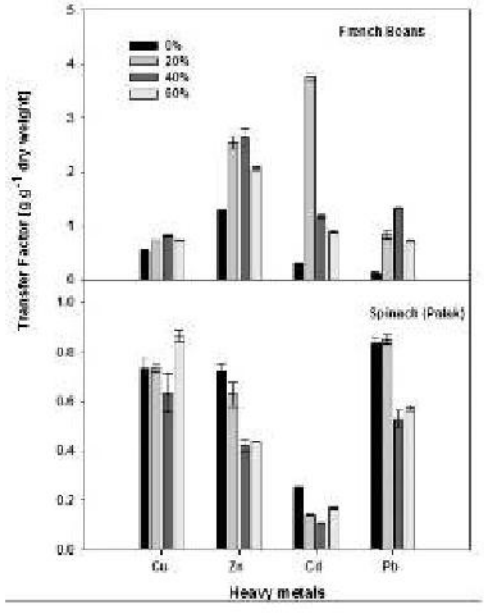



Fig. 10: Transfer of heavy metals from contaminated soil to edible parts of French beans and spinach. Bars are mean ± SE of three replicates.

*Summary of Completed Project / Activity*

**Recharge Area Identification and Estimation Mean Residence Time for Springs in one Urban and one Rural Microwastershed in Pauri Garhwal Using Isotope Technique, Remote Sensing and GIS for Implementation of Artificial Recharge Structures**

- Large spatial variability is observed even at small distances, with strong ridge to valley gradient being reported. Profound influence of topography in spatial distribution of rainfall is observed.
- The study also highlights that in studies of Himalaya basin or microwatersheds, no or sparse distribution of rain gauges might inadequately represent the spatial variability of rain.
- The meteorological data is being investigated for the month of June through September to understand the synoptic as well as local climatological systems. The site specific lapse rate for the microwatershed matches close to the observed temperature lapse report from Himalaya during the monsoon period (Fig.11). The day and night time monthly lapse rate of -0.6°C (100m-1) is reported for the study site.
- The isotopic lapse rate ranges between -0.3‰ to 0.4‰ per 100m (r2 >0.6) matches well with the observation from other parts of western Himalaya.
- The observations from the weather station suggest regional topographically controlled wind system dominates in the smaller watershed also.


Fig. 11: Spring Hydrograph of two Moulthi Spring (Mouthi 1 and Moulthi 2).

Fig. 12: Springs at Moulthi village which are monitored daily through volumetric assessment.

Theme

# BIODIVERSITY CONSERVATION AND MANAGEMENT (BCM)

The characterization of biodiversity critically depends on taxonomical, genetic and ecological investigation. The robust data sets, thus generated, play an important role in developing appropriate short and long term conservation and management plans. The long-term research sites and programmes provide appropriate information on how biodiversity changes with time and this information is important in distinguishing anthropogenic and natural changes. Among the mountain landscapes of the world, the Indian Himalayan Region (IHR) is considered one amongst the most vulnerable due to its geology and various anthropogenic activities coupled with the changing environmental conditions. Therefore, the region requires immediate actions towards: (i) assessing status, changing patterns and processes of biodiversity components, as well as their conservation and socio-economic values; (ii) evaluating and comparing ecological integrity, stability and resilience of ecosystems and their components; and (iii) analyzing impacts of climate and resource use changes on the biodiversity components and assessing their socio-economic consequences. In addition, development of packages of practices for maintenance and optimal use of sensitive biodiversity components and improving bio-resource based livelihood options for native communities, establishment of demonstration models, development of dissemination packages on cultivation and establishment of *ex situ* gene banks of elite planting materials; and creation of awareness among the stakeholders about the potential benefits and benefit sharing mechanism of biodiversity are essentially required. Besides these, establishment of Himalayan Biodiversity and Climate Change Knowledge Network (HBCC-KN) to build on existing knowledge and enhance information generation through robust globally accepted protocols, and development of management and sustainable use plans with policy briefs are urgently needed. During the plan period studies have been initiated on these lines, so that the above issues could be addressed and appropriate management plans for biodiversity could be prepared and implemented through different organizations.

Realizing the above and considering the importance of biodiversity for sustainable development and environmental conservation, the Biodiversity Conservation and Management (BCM) Theme envisages the following objectives: (i) To generate robust datasets on status, changing patterns and processes of biodiversity components, as well as their conservation and socio-economic values on the Indian Himalayan landscapes; (ii) To evaluate and compare ecological integrity, stability and resilience of ecosystems and their components in the Indian Himalayan landscapes; (iii) To analyse impacts of climate and resource use changes on the biodiversity components, and assess their socio-economic consequences; (iv) To develop packages of practices for maintenance and optimal use of sensitive biodiversity components and improvement of bio-resource based livelihood options for indigenous communities; (v) To

establish demonstration models, develop dissemination packages on cultivation/plantation and establish *ex situ* gene banks of elite planting materials; (vi) To inculcate awareness among the diverse stakeholders about the potential benefits and benefit sharing mechanisms of biodiversity; and (vii) To establish Himalayan Biodiversity and Climate Change Knowledge Network (HBCC-KN) to build on existing knowledge and enhance information generation through robust globally accepted protocols, and develop management plans.

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

The biodiversity of Indian Himalayan ecosystems is depleting fast due to habitat degradation caused by various anthropogenic activities coupled with the changing environmental conditions and also by the various anthropogenic activities. All these factors make the Indian Himalayan Region most vulnerable amongst the mountain landscapes of the world. Therefore, it calls for immediate actions towards assessing status, changing patterns and processes of biodiversity components of the temperate, sub-alpine and alpine landscapes and their conservation and socio-economic values; evaluating and comparing ecological integrity, stability and resilience of representative ecosystems and their components; analysing impacts of climate and resource use changes on the biodiversity components, and assessing their socio-economic consequences so as to draw realistic and widely accepted action agenda for the conservation and sustainable use of its biological diversity under changing climate and land use. Keeping in view the importance of biodiversity of the temperate, sub-alpine and alpine regions and its vulnerability to global climate change, the study has been initiated in the temperate, subalpine and alpine landscapes of Himachal Pradesh in the North Western Himalayan biogeography province. Establishment of long term monitoring sites to ensure uninterrupted flow of information, identification of most resilient habitat and formulation of Himalayan biodiversity and climate change network (HBCC-KN) are among the 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 analyse impacts of climate and resource use changes on the biodiversity components, and assess their socio-economic consequences.
- To establish Himalayan Biodiversity and Climate Change Knowledge Network (HBCC-KN) to build on existing knowledge and enhance information generation through robust globally accepted protocols, and develop management and sustainable use plans with policy briefs.

**Achievements**

**Headquarters, Uttarakhand**

- Four forest types namely Banj-Oak, Banj-Oak mixed, Pine, and Pine–Oak mixed Forests were selected at different elevations in Hat-Kalika (Gangolihat) watershed, and nearby villages were surveyed to understand their level of dependence on the forests.
- Fuel and fodder resources utilization patterns and extraction trends revealed that *Pyrus pashia, Myrica esculenta, Pinus roxburghii, Rhododendron arboreum*, *Berberis asiatica, Pyracantha crenulata, Quercus leucotrichophora, Celtis australis and Lyonia ovalifolia* were the major fuel species. The most preferred fuel wood species were *Quercus leucotrichophora* and *Pinus roxburghii*. The daily consumption of fuel wood in small (> 4 members), medium (4–8 members) and large fimaly (< 8 members) families was 11.40 kg/day, 18.50 kg/day & 25.40 kg/day, respectively. The inhabitants store fuel wood for utilization during the year (Fig. 13a).
- Among the fodder species, *Grewia oppositifolia, Bauhinia variegata, Celtis australis, Ougeinia oojeinensis, Quercus glauca*, *Q. leucotrichophora,*

*Ficus palmata* and *F. roxburghii* were the major species collected by the inhabitants to feed their cattle. The daily consumption in small category (1–2 cattle) was 12.40 kg/day, medium (2–4 cattle) 20.50 kg/day and large category (< 4 cattle) 28.40 kg/day. The most preferred fodder species was *Grewia oppositifolia.* The inhabitants store grass and fodder for utilization during the winter season (Fig. 13b).

- The lopping intensity varied considerably across forests and the level of protection in Pine–Oak mixed protected forests showed 48.7 %, and 5 year old Oak-mixed protected forest showed 59.7% lopping. The unprotected Oak – mixed forest showed heavy lopping (71.7%) (Fig. 14).

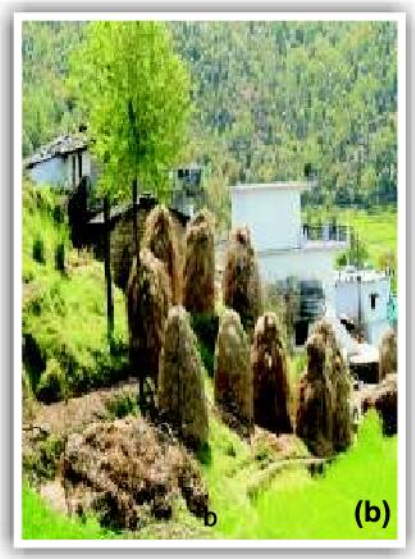




Fig. 13: (a) Traditional practices of fuel wood and (b) dry fodder storage by the inhabitants.

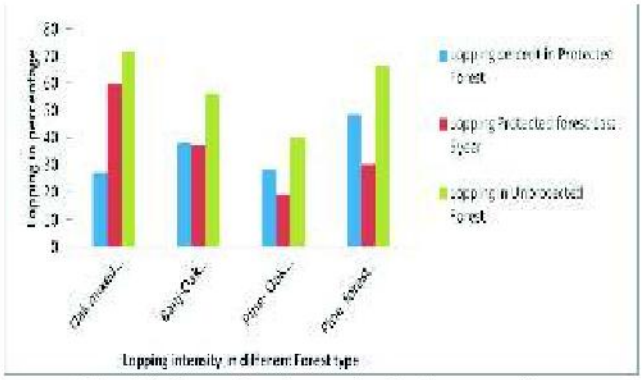


Fig. 14: Lopping intensity in forests of Haat-Kalika watershed.

**Kanawar Wildlife Sanctuary, Himachal Pradesh**

- Rapid sampling for floristic diversity resulted in identification of 257 species of vascular plants (i.e., Angiosperms -243), Gymnosperms7) and Pteridophytes 7 species) Amongst angiosperm families, Asteraceae (26 spp.); Rosaceae (15 spp.) and Ranunculaceae (11 spp.), were species rich. Of the total, 106 species (Angiosperms: 98; Gymnosperms: 06; and Pteridophytes: 02) were economically important and used as medicine (65), wild edible/food (33), fodder (30), fuel (26), timber (06), religious (07), fiber (04), agricultural tools (06) and other purposes (8 spp.).
- Sampling of 23 sites representing different habitats and aspects (between 1,830–4,137m and latitudes 31°52'02"–31°59'10"N and longitudes 077°19'43"–077°23'14"E) helped in identification of forest communities which represented evergreen coniferous (i.e., *Cedrus deodara, Abies pindrow* and *Picea smithiana*); broad leaved evergreen (i.e., *Quercus semecarpifolia* and *Buxus wallichiana*); evergreen coniferous mixed (i.e., *Abies pindrow –Taxus baccata* subsp. *wallichiana* mixed); broad-leaved deciduous mixed (i.e., *Carpinus viminea–Betula alnoides* mixed) forests.
- Across forests, total tree density ranged from 240.0–700.0 Ind ha,$^{-1}$ total basal area from 3.464–145.8 $m^2ha^{-1}$, shrub density from 100.0–2920.0 Ind $ha^{-1}$ and herb density from 27.10–83.45 Ind. $m^{-2}$, respectively Species Diversity Index (H') for trees ranged from 0.26–1.53, saplings, 0.0–1.74, seedlings, 0.0–1.39, shrubs, 0.0–2.84 and herbs, 1.31–3.47.

- Soil samples collected from 23 sites, showed soil moisture ranges between, 16.58–65.49%, pH, 6–6.94, total nitrogen, 0.093–1.0783% and organic carbon, 1.794–8.619%.
- Towards enhancing the knowledge of Teachers and Students on Biodiversity Conservation and Management and on Climate Change, a One Day Training Programme was organized at Government Senior Secondary School, Namhol, Distt. Bilaspur, Himachal Pradesh. The Event included Theme lecture, demonstration of Participatory Rural Appraisal exercise; and qualitative and quantitative assessment of biodiversity. Pre- and post-training feedbacks showed significant improvement in the understading of the participants (Fig. 15).

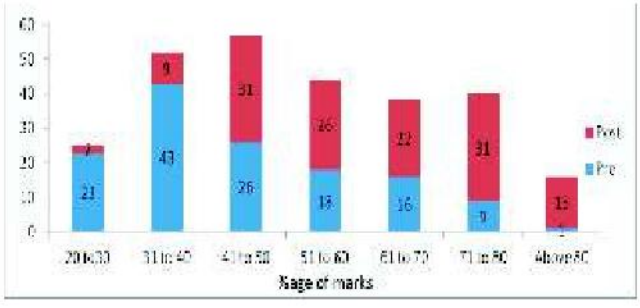



Fig. 15: Pre- and post-evaluation of participants of the Training Programme.

**Kanchendzonga Biosphere Reserve, Sikkim**

- Land use, economic resources and resource use practices were assessed in five more villages of the Transition zone (western and northern part).
- Surveyed household demography of all the villages recorded a higher proportion of female population. Fuel wood use was high in the western part averaging 90% users, compared to the north zone averaging 50% users. Over 18 prioritized woody taxa for fuel use were recorded; *Alnus nepalensis* and *Terminalia myriocarpa* emerged at top, followed by *Castonopsis tribuloides* and *Symplocos theafolia*.
- Amongst unconventional economic resources, tourism emerged at the top. The average tourist visits/ day during the active tourist months were higher in Lachen (V5) with 28.8 and Yuksom (V1) with 19.4 on an average, followed by Khecheopalri (V4) 11.4 and Chojo (V3) 10.4.
- 36 locally identified indicators for biodiversity conservation and sustainability were established under six major groups, viz. (i) Biodiversity conservation (6 indicators), (ii) Bioresources (7 indicators), (iii) Soil improvement (4 indicators), (iv) Economy, farm based (6 indicators), (v) Economy, other resource based (4 indicators); (vi) Resource management (5 indicators); and (vii) Nature/area management (4 indictors).
- Priority index based on inhabitants responses were calculated for different individual indicators for each study village. For biodiversity conservation, on average, forested area (76%), followed by native trees (62%) appeared at the top (Fig. 16). Species diversity and wildlife secured 56% priority index. In resource management, the community control (80%), followed by Joint Forest Management (65%) emerged at the top.

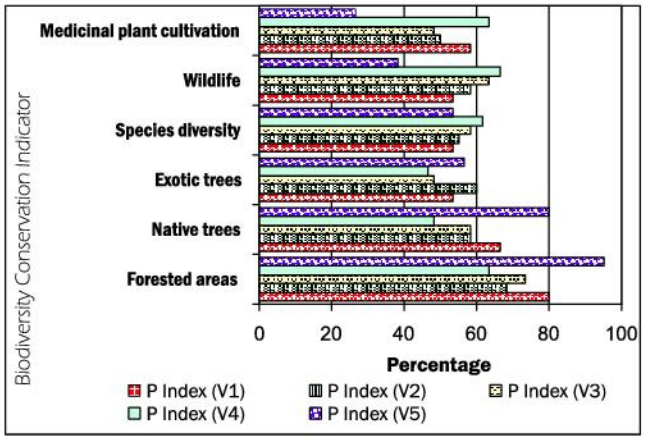



Fig. 16: Biodiversity conservation indicators prioritized by villagers in five villages in Khangchendzonga Biosphere Reserve (west Sikkim).

**West Kameng, Arunachal Pradesh**

- Field survey was conducted in Old Ziro, Hapoli, Pine Groove, Lampia Basti, Hari village & Gandhi Market of Ziro valley of Lower Subansiri district; 18 wild edibles namely, *Michelia champaca, Clerodendrum colebrookianum, Hydrocotyle sibthorpioides, Houttuynia cordata, Plantago erosa, Phyllostachys bambusoides, Chimnobambusa callosa, Bambusa* sp., *Cephalostachyum capitatum, Euphorbia hirta, Solanum indicum, Myrica esculenta, Spondias pinnata, etc. (Fig. 17);* 8 medicinal and aromatic

plants (i.e., *Mesua ferrea, Mentha arvensis, Ocimum sanctum, Michelia champaca, Pinus roxburghii, Acorus calamus, Zanthoxylum armatum and Cymbopogon nardus);* and 34 medicinal plants i.e., *Syzigium cumini, Acorus calamus, Andrographis paniculata, Argeria nervosa, Berberis aristata, Callicarpa arborea, Canarium strictum, Centella asiatica, Cinnammom tamala, Clerodendrum colebrookianum, Costus speciosus, Dioscorea alata, Drymaria cordata, Garcinia pedunculata, Gmelina arborea, Gynocardia odorata, Houttuynia cordata, Illicium griffithii, Litsea cubeba, Piper mullesua, Rhododendron arboreum, Taxus baccata* subsp. *wallichiana, etc.* were recorded.

- Survey of the markets in the study revealed that 11 wild edible, 3 aromatic, and 9 medicinal plant species are supporting the livelihood of the tribes (Table 6).

**Table 6. Commercially potential species of the study area**

| Use Category | Species | Area/ Market | Price in Rs. |
|---|---|---|---|
| Wild edibles | *Michelia champaca* | Hapoli | 50/- kg |
| | *Zanthoxylum armatum* | Hapoli | 60/- kg |
| | *Litsea cubeba* | Hapoli | 10/-bunch |
| | *Myrica esculenta* | Hapoli | 20/- kg |
| | *Spondias pinnata* | Hapoli | 20/- per kg |
| | *Houttuynia cordata* | Hapoli | 05/- for 3 bunches |
| | *Diplazium esculentum* | Hapoli | 05/- for 3 bunches |
| | *Oenanthe javanica* | Hapoli | 05/- for 3 bunches |
| | *Piper pedicellatum* | Hapoli | 05/- for 1 bunch |
| | *Bamboo* sp. | Hapoli | 10/-for 3 pic |
| | *Juglans regia* | Hapoli | 60/- kg. |
| Aromatic | *Cinnamomum tamala* | Old Ziro | 05/- for 1 bunch |
| | *Mentha arvensis* | Old Ziro | 10/- for 3 bunches |
| | *Zanthoxylum armatum* | Old Ziro | 60/-kg |
| Medicinal | *Swertia chirayita* | Old Ziro | 10/- for 1 bunch |
| | *Houttuynia cordata* | Old Ziro | 05/- for 3 bunches |
| | *Centella asiatica* | Old Ziro | 10/- for 1 bunch |
| | *Clerodendrum glandulosum* | Old Ziro | 10/- for 1 bunch |
| | *Spilanthes paniculata* | Old Ziro | 10/- for 1 bunch |
| | *Oroxylum indicum* | Yachuli | 05/- for 1 bunch |
| | *Zingiber* sp. | Yachuli | 80/- kg |
| | *Azardirachta indica* | Yachuli | 05/- for 1 bunch |
| | *Leucas aspera* | Yachuli | 05/- for 1 bunch |

Fig. 17: *Berberis wallichiana*-a wild edible plant.

Fig. 18: *Rubia cordifolia*- a medicinal plant.

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

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 caused a tremendous pressure on the biodiversity in the Indian Himalayan Region. This has resulted in the decreased population of many ecologically and economically important species. A large number of Hydro-Electric Projects have been constructed,are under construction and are proposed for construction on the rivers originating from the Himalaya. The Sainj Hydro-Electric Project (100 MW), a run of the river development on river Sainj, a tributary of river Beas in Kullu district is under construction and located at Neuly in Sainj Valley. It is located in the

periphery of the Great Himalayan National Park (GHNP). The adjacent areas towards the GHNP of the Sainj Hydro-Electric Project are very rich in flora and fauna. Therefore, study on the impact of Sainj Hydro-Electric Project on the Great Himalayan National Park (GHNP) in particular and the flora and fauna of the local area in general is urgently required.

**Objectives**

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

**Achievements**

- Rapid sampling of the floristic diversity in Sainj Valley (Fig. 19) revealed occurrence of 207 species of vascular plants (84families and 170 genera) representing herbs (142), shrubs (42), trees (30) and ferns (13). Families, Asteraceae (22 spp.), Lamiaceae (14 spp.), Rosaceae (12 spp.), Poaceae (07 spp.) and Urticaceae (05 spp.) were species rich, and *Polygonum* (04 ), *Anaphalis, Cornus, Jasminum Rhamnus, Rubus Asplenium* and *Pteris* (03 each), represented the species rich genera.
- Among the recorded species, 133 species of medicinal plants use, 65 species of fodder, 50 species of wild edibles/foods, 44 species of fuel, 11 species of religious, 5 species of fibre, 7 species for making agricultural tools, 7 species of wood timber, 5 species for making of dyes and 9 species for miscellaneous uses were identified.
- Assessment of vegetation in 25 sites representing different aspects and habitats (2,150– 2,815 m and 31,45'17"N to 31,46',54"N latitudes and 77, 20' 54"E to 77,24',50" E longitudes) resulted in identification of 20 forest communities The Maximum number of sites (02) were represented by *Picea smithiana, Pinus wallichiana–Rhododendron arboreum* mixed, *Taxus baccata* subsp. *wallichiana* communities.
- The total tree density ranged from 250–690 Ind $ha^{-1}$ and total basal area from 4.24–143.30 $m^2$ $ha^{-1}$. Maximum total tree density was recorded in *Cedrus deodara–Quercus leucotrichophora* mixed (690 Ind $ha^{-1}$) community, followed by *Rhododendron arboreum–Pinus wallichiana* mixed (670.00 Ind $ha^{-1}$). Total basal area was recorded maximum in *Cedrus deodara– Taxus baccata* subsp. *wallichiana* mixed (143.30 $m^2$ $ha^{-1}$) community, followed by *Picea smithiana* (71.30 $m^2$ $ha^{-1}$). Maximum saplings and seedlings density i.e., 580 Ind $ha^{-1}$ and 640 Ind $ha^{-1}$, respectively were recorded for *Aesculus indica–Celtis tetrandra* mixed community. Population structures of *Cedrus deodara– Quercus leucotrichophora* mixed and *Cedrus deodara–Taxus baccata subsp. wallichiana mixed* communities are presented in Figs. 20 and 21, respectively.
- Species richness (74 spp.) was maximum in *Picea smithiana* community, followed by *Pinus wallichiana–Rhododendron arboreum* mixed (67 spp.) community. The richness of trees was highest (11 spp., each) in *Pinus wallichiana–Rhododendron arboreum* mixed and *Aesculus indica–Celtis tetrandra* mixed communities, followed by *Picea smithiana, Juglans regia – Aseculus indica* mixed and *Pinus wallichiana – Picea smithiana–Lyonia ovalifolia* mixed (8 spp., each) communities.

Fig. 19: An overview of the study area.

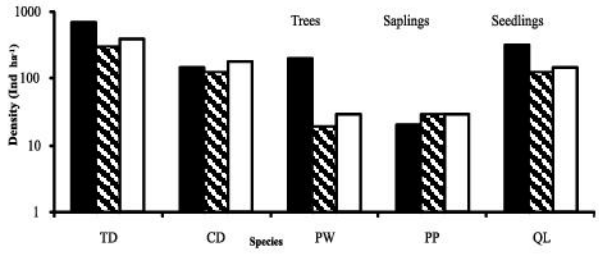



Fig. 20: Population structure of *Cedrus deodara–Quercus leucotrichophora* mixed community. Abbreviations: TD=Total density; CD= *Cedrus deodara*; PW= *Pinus wallichiana;* PP =*Pyrus pashia; and* QL= *Quercus leuchotrichophora.*

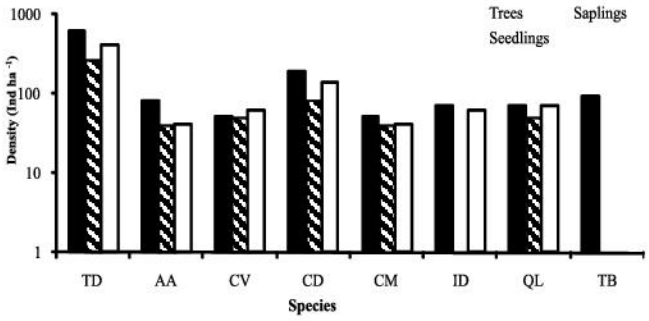



Fig. 21: Population structure of *Cedrus deodara– Taxus baccata* subsp *wallichiana* mixed community. Abbreviations: TD=Total density; AA= *Acer acuminatum;* CV= *Carpinus viminea;* CD= *Cedrus deodara;* CM= *Cornus macrophylla;* ID= *Ilex dipyrena;* QL= *Quercus leucotrichophora;* TB= *Taxus baccata* subsp. *wallichiana*

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

The Himalayan region is one of the 34 Global Biodiversity hotspots. The Indian Himalayan Region (IHR) forms a major part of this hotspot. The region represents tropical, sub-tropical, temperate, sub-alpine, alpine and Tundra ecosystems/biomes. These ecosystems provide provisioning (e.g., fresh water, NTFPs and timber), cultural (e.g., recreation and spiritual), regulating (e.g., carbon sequestration, hydrological) and supporting (e.g., biodiversity, nutrient cycling, pollination) services to the mankind. In the rural areas of the IHR, the mainstay of rural communities is cultivation of agricultural and horticultural crops, including vegetables for their sustenance. Farming practices are largely dependent on various ecosystem services (ES) provided by the forests interspersed in the agricultural landscape. However, changing environmental conditions are causing decline in such ecosystem services (ES). For instance, decline in pollinator services has now been identified as an important issue worldwide. It applies equally for the agro-ecosystems of IHR, which calls for a systematic study on pollinators and other forest ecosystem services in the region.

**Objectives**

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

**Achievements**

- The Study was conducted in the Upper Beas Valley ($32^0$ 05' 51"– $32^0$ 06' 43.8" N and $077^0$ 08' 08.5" – $77^0$ 09' 56.9" E, altitudinal range, 1200–2500m) of Kullu district, Himachal Pradesh. Three volunteer programmes were organized jointly with Earthwatch Institute India, one each in June, August & October 2013.
- Qualitative assessment of the vegetation was carried out in 12 different locations in upper Beas Valley and bee flora in the selected orchards and surrounding areas was identified. (49 species) (Table 7).
- Assessment in 25 sites/plots resulted in identification of four communities *(Pinus wallichiana* 1 site), *Cedrus deodara* 11 sites), *Alnus nitida* 6 sites) and *Pinus roxburghii* 7 sites) (06 sites).
- Across communities, total tree density ranged from 5.32–8.88 Ind 100 $m^{-2}$ and total basal area, 30.12–47.47 $m^2$ $ha^{-1}$. *Alnus nitida* community had maximum tree density (8.88 Ind 100 $m^{-2}$) and

*Cedrus deodara community* showed maximum total basal area *(49.67 $m^2$ $ha^{-1}$)*. Among the communities, total shrub density ranged from 634.0–2460.0 *Ind* $ha^{-1}$ and total herb density, 31.38–66.49 Ind $m^{-2}$.

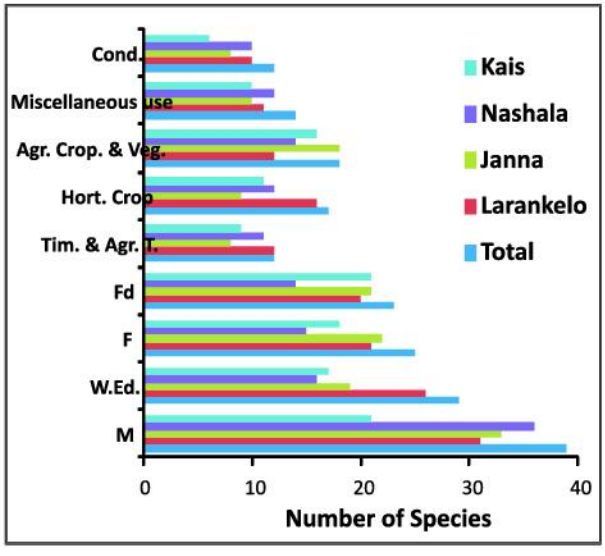
- Phenological observations in Apple, Plum and Pear trees of the six selected orchards of the upper Beas Valley revealed that flowering initiated on 27th March, 2013 (Hirni) and completed on 16th April, 2013 (Raugi); while fruit setting initiated on 20th April, 2013 (Nashala) and completed on 19th May, 2013 (Bashkola). Fruit dropping was observed between May 12– June 08, 2013 and it was minimum at Bashkola (19%) and maximum at Nashala (35%). Leaf fall initiated in the 2nd week of October and culminated in the 4th week of December, 2013.

Table 7: Diversity of insect pollinators in different orchard sites during the month of October, 2013

| Types of Insect | D | N | B | M | R | K | H |
|---|---|---|---|---|---|---|---|
| Indian Honey Bee | + | + | + | + | + | + | + |
| European Honey Bee | + | – | – | – | – | + | – |
| Butterfly | + | + | + | + | + | + | + |
| Bumble Bee | + | + | + | + | + | – | – |
| Hobber Fly | + | + | + | | + | + | + |
| Solitary bee | + | + | + | + | + | + | + |
| Wasp | + | + | + | + | + | + | + |
| House Fly | + | – | + | – | + | + | – |
| Blue Bottle Fly | – | – | + | + | – | – | – |
| Grass Hopper | + | + | + | + | + | + | + |
| Dragon Fly | – | + | | + | – | – | + |
| Drone | – | – | + | + | – | – | – |
| Bee Flora | 10 | 7 | 9 | 7 | 9 | 4 | 8 |

Abbreviations: D=Dhamadhar, N=Nashala, B=Bashkola, M=Mehliseri, R=Raugi, K=Kradsu and H=Hirni

- Participatory Rural Appraisal exercises and questionnaire surveys were conducted in eight villages for assessing Provising ecosystem services (Fig 22). The people use 39 plants for curing different ailments, 29 as wild edibles, 25 for fuel and 23 for fodder, etc. The notable medicinal plants were *Acorus calamus, Angelica glauca, Picrorhiza kurrooa, Viola canescens, Rhododendron campanulatum, Rheum australe, Trillidium govanianum, Podophyllum hexandrum, Taxus baccata subsp. wallichiana, etc.* The notable fuel wood plants are *Quercus leucotrichophora, Cedrus deodara, Pinus wallichiana, Picea smithiana*, etc.



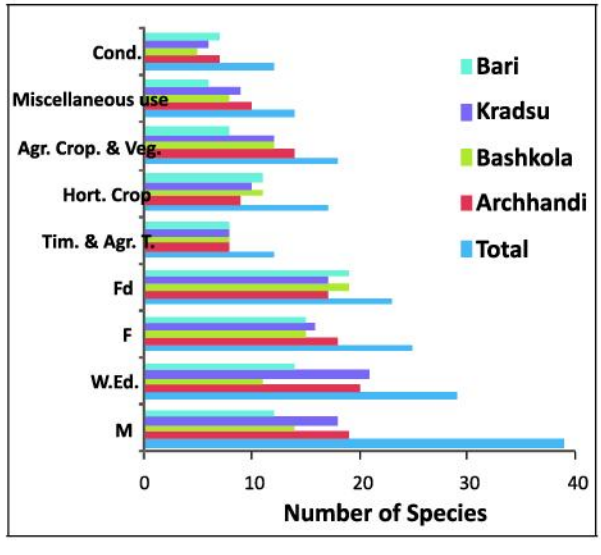




Fig. 22: Various services provided by the agro-ecosystem to the inhabitants of different villages in the Upper Beas Valley.

Abbreviations: M=Medicinal, W.Ed.=Wild Edibles, F= Fuel, Fd.=Fodder, Tim. & Agr.T.=Timber and Agricultural Tools, Hort. Crop=Horticultural Crops, Agr. Crop=Agricultural crops, Veg.=Vegetables, Misc.=Miscellaneous and Cond.=Condiments

- For the promotion of Citizen Science Programme three Volunteer Programmes were organized jointly with Earthwatch Institute, India and volunteers were involved in the collection of data on the different objectives of the project. Initially the volunteers were made aware about the project as a whole and the methodologies to be applied through an LCD presentation. They were then trained practically in the field. The programmes were organized in four different modules; Module 1: Introduction of Participants, Organizations and Programme briefing; Module 2: Deliberations/ Training; Module 3: Learning Sessions and Module 4: Field Surveys and Data Generation. The volunteers assisted the project research team in the collection of data on qualitative and quantitative assessment of vegetation, Assessment of insect/ pollinators diversity and density, phenological observation of the apple and associated crops; and different ecosystem services flowing from forest and agro-ecosystem to the inhabitants (Fig. 23).

Fig. 23: Volunteers involved in different project activities for data collection.

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

The Indian Himalayan Region (IHR) forms the major part of Himalaya The major population of IHR lives in the rural areas and the inhabitants are largely dependent on various services provided by these ecosystems. In view of the rapid depletion of biodiversity, a Protected Area Network in the form of National Parks and Wildlife Sanctuaries has been established across the IHR. In addition, the native communities of the region practice an age old tradition of conserving trees and forests near their settlements and alpine meadows as part of their culture and religious belief. These are known as Sacred Groves. People 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 in the sacred groves. Traditional Sacred Groves (Forests) and Temple Groves are usually found in the region. Of the 13,270 sacred groves documented from India, 5,627 sacred groves fall in the IHR. The Himachal Pradesh state, also known as "Deobhumi" supports about 5,000 Sacred Groves. But, these Sacred Groves have not been explored for the various ecosystem services they provide. The present study has, therefore, been initiated on these lines.

**Objectives**

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

**Achievements**

- A total of 16 sites (Rupasana Devi-9) Bhrighu Rishi -7) were surveyed and sampled between 2000–2135m.148 species of vascular plants representing trees (13), shrubs (18) and herbs (117) were recorded.
- The Rupasana Devi Sacred Forest (Fig. 24), is dominated by *Cedrus deodara* Forest (Fig. 25).

The total tree density ranged from 250 – 500 Ind ha$^{-1}$ and Total Basal Area 32.05 – 124.30 m$^2$ ha$^{-1}$. The total shrub density ranged from 300 – 830 Ind ha$^{-1}$; and total herb density from 13.55 – 35.90 Ind m$^{-2}$ Species diversity (H') ranged from 0.00–0.46 and Concentration of Dominance (Cd) 0.83 – 1.00.

- Bhrighu Rishi Sacred Forest is dominated by *Cedrus deodara* Forest (Fig. 26). The total tree density ranged from 270 – 530 Ind ha$^{-1}$ and Total Basal Area 44.33 – 136.27 m$^2$ ha$^{-1}$. The total shrub density ranged from 670 – 1000 Ind ha$^{-1}$ and herb density from 9.90 – 23.70 Ind m$^{-2}$ Shannon-Wiener diversity (H') ranged from 0.13 – 0.68 and Concentration of Dominance (Cd) 0.71 – 0.94.
- Soil analysis revealed that soil moisture in Rupasana Devi Sacred Forest ranged from 16.89 – 41.36%, total nitrogen, 2.24 – 2.51%; and organic carbon, 2.56 –2.51% and in Bhrighu Rishi Sacred Forest, the soil moisture ranged from 11.38 – 23.57%, total nitrogen 1.87 – 2.45%, and organic carbon, 1.64 –6.17%.

Fig. 24: General view of Rupasana Devi Sacred Forest.

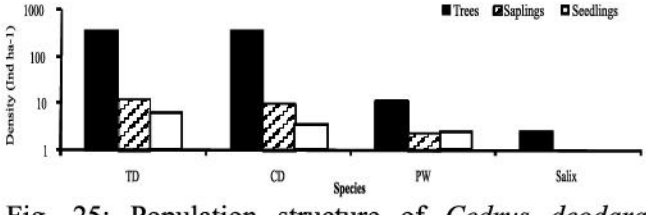



Fig. 25: Population structure of *Cedrus deodara* community in Rupasana Devi Sacred Forest. Abbreviations: TD=Total density; CD=*Cedrus deodara;* PW= *Pinus wallichiana*; and Salix = *Salix daphnoides*

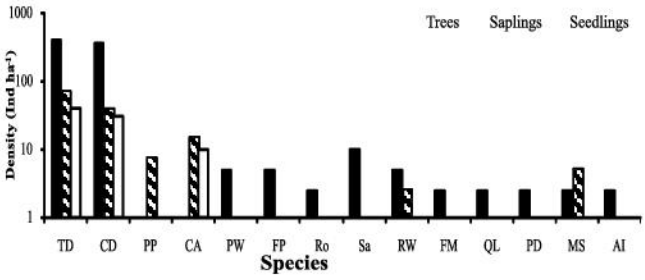



Fig. 26: Population structure of *Cedrus deodara* community in Bhrigu Rishi Sacred Forest.
Abbreviations: TD=Total density; CD=*Cedrus deodara*; PW= *Pinus wallichiana*; PP=*Pyrus pashia*; QF=*Quercus floribunda;* QL=*Quercus leucotrichophora*; Ro=*Robinia pseudoacasia;* PD=*Persea duthiei;* AI=*Aesculus indica;* MS=*Morus serrata;* FP=*Ficus palmata;* Sa=*Salix daphnoides;* RW=*Rhus wallichii;* FM=*Fraxinus micrantha and* CA=*Celtis australis*

**Ecological Evaluation, Mapping and Conservation Prioritization of Floristic Diversity of the Spiti Valley in a Proposed Cold Desert Biosphere Reserve in Trans Himalaya *(2011–2014, Ministry of Environment & Forest, New Delhi)***

Biosphere Reserves (BRs) have been established throughout the globe to conserve the representative ecosystems. The Cold Desert Biosphere Reserve (CDBR) covering the parts of Lahaul valley and whole area of Spiti valley in Himachal Pradesh is one of the Biosphere Reserves of Indian Himalayan Region. It represents a potential area for the conservation of Trans Himalayan ecosystems. Three protected areas namely Pin Valley National Park, Kibber Wildlife Sanctuary and Chander Tal Wilderness form the core zones of the CDBR. All these three areas are well known for Trans Himalayan biodiversity. The Spiti Valley of CDBR is inhabited by a number of tribal villages and supports representative, unique, natural and ecologically and economically important species of Trans- Himalaya. This rich biodiversity is utilized in various forms by tribal communities for their sustenance. This unique and rich biodiversity requires proper conservation and management plans for their long lasting existence. The available information on floristic diversity of the area is fragmentary and inadequate for developing any management plan. The present study envis ages to provide a comprehensive database for developing an

appropriate management plan for the CDBR in particular and Cold Desert region of Trans Himalaya in general.

**Objectives**

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

**Achievements**

- 70 sites representing 12 habitats and 08 aspects between 3,290– 4,533m and $32^0$ 01.360 N – $32^0$28.801 N and $77^0$36.463'E – $78^0$46.340'E were sampled.A total of 360 species (60 families and 270 genera) were identified. Among the identified species 7 species were trees, 30 shrubs and 323 herbs. Among the genera, *Astragalus* (17 spp.), *Potentilla* (13 spp.), *Artemisia* and *Potentilla* (13 spp.), *Poa* (spp.), *Polygonum* (9 spp.), *Nepeta* and *Pedicularis* (7 spp.) and *Allium*, *Chenopodium* and *Sassurea* (5 spp., each) were dominant. These species were recorded from different habitats (Fig. 27).
- A total of 265 species (Angiosperms: 262; Gymnosperms: 02; and Pteridophytes: 01) of economically important plants were recorded. The utilization pattern of the species is presented in Fig.28.
- Thirty two plant communities were identified of which 19 were represented by shrubs and 13 by herbs. In the plant communities, shrub density ranged from 40– 2230 Ind $ha^{-1}$ and herb density from 4.15– 70.4 Ind $m^{-2}$.
- Species Diversity (H′) for shrubs ranged from 0.00– 1.56 and for herbs, 1.12–2.48. The highest H' (1.56) of shrubs was recorded for *Astragalus strobiliferus –Rosa webbiana* mixed community and lowest (0.00) each for *Cotoneaster gilgitensis – Potentilla arbuscula* communities. The highest H' (2.48) of herbs was recorded for *Krachenkovia lanata– Myricaria germanica– Hippophae rhamnoides* subsp. *turkestanica* mixed community and lowest (1.12) for *Bistorta affinis–Potentilla arbuscula– Poa lahulensis* mixed community.
- Concentration of Dominance (Cd) of shrubs ranged from 0.24–01 and herbs, 0.09–0.43. The highest Cd (01) of shrubs was recorded for *Cotoneaster gilgitensis* as well as for *Potentilla arbuscula* communities and lowest (0.24) for *Astragalus stobileiferus – Rosa webbiana* mixed community. The highest Cd (0.43) of herbs was recorded for *Bistorta affinis – Potentilla argyrophylla – Poa lahulensis* mixed community (Table 8).
- Overall in the study sites, the soil moisture content ranged from 0.04–31.62%, pH, 5.48–8.09, total nitrogen 0.07–1.33%, organic carbon 0.20–5.25% and organic matter, 0.34–9.05%.

Fig. 27: Representative habitats in Cold Desert Biosphere Reserve.

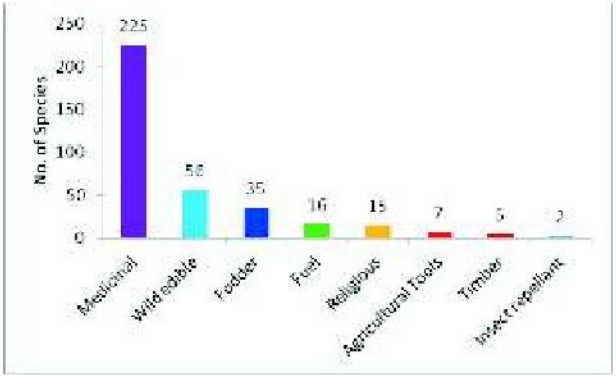



Fig. 28: Utilization pattern of floristic diversity in Spiti Valley of CDBR.

Table 8: Community wise Density, Concentration of Dominance (Cd) and Species Diversity Index (H`) in the Spiti Valley of Proposed CDBR

| Community type | Shrubs | | | Herbs | | |
|---|---|---|---|---|---|---|
| **Shrub Communities** | **Density Ind ha$^{-1}$** | **Cd** | **H'** | **Density Ind m$^{-2}$)** | **Cd** | **H'** |
| *Astragalus strobiliferus* | 380 | 0.85 | 0.28 | 8.45 | 0.18 | 1.82 |
| *Caragana versicolor* | 237 | 0.98 | 0.27 | 25.91 | 0.17 | 1.72 |
| *Cotoneaster gilgitensis* | 40 | 1 | 0 | 22.5 | 0.14 | 2.15 |
| *Ephedra gerardiana* | 831 | 0.99 | 0.27 | 9.8 | 0.2 | 1.73 |
| *Ephedra intermedia* | 1320 | 0.79 | 0.2 | 4.15 | 0.1 | 1.73 |
| *Hippophae rhamnoides* subsp. *turkestanica* | 813 | 0.32 | 0.91 | 14.87 | 0.21 | 1.84 |
| *Hippophae tibetana* | 2230 | 0.78 | 0.39 | 68.6 | 0.24 | 1.59 |
| *Potentilla arbuscula* | 100 | 1 | 0 | 20.4 | 0.17 | 2.09 |
| *Astragalus strobiliferus–Ephedra gerardiana* mixed | 655 | 0.39 | 0.28 | 7.93 | 0.21 | 1.74 |
| *Astragalus strobiliferus–Rosa webbiana* mixed | 410 | 0.26 | 1.56 | 8.3 | 0.15 | 2.04 |
| *Caragana versicolor–Ephedra gerardiana* mixed | 570 | 0.57 | 0.62 | 32.6 | 0.16 | 2.23 |
| *Ephedra gerardiana–Ephedra intermedia* mixed | 170 | 0.5 | 0.69 | 29.9 | 0.23 | 1.85 |
| *Ephedra gerardiana–Hippophae tibetana* mixed | 1270 | 0.38 | 1.02 | 15.75 | 0.24 | 1.64 |
| *Hippophae rhamnoides* subsp. *turkestanica – Myricaria germanica* mixed | 1150 | 0.42 | 1.09 | 49.7 | 0.13 | 2.26 |
| *Hippophae rhamnoides* subsp. *turkestanica –Rosa webbiana* mixed | 190 | 0.4 | 0.99 | 6.9 | 0.22 | 1.72 |
| *Krascheninnikovia lanata–Ephedra gerardiana* mixed | 390 | 0.5 | 0.69 | 7.65 | 0.16 | 2 |
| *Potentilla arbuscula–Ephedra gerardiana* mixed | 150 | 0.52 | 1.22 | 20.5 | 0.15 | 2.12 |
| *Krascheninnikovia lanata–Myricaria germanica–Hippophae rhamnoides* subsp. *turkestanica* mixed | 1080 | 0.24 | 1.46 | 13.2 | 0.09 | 2.48 |
| *Rosa webbiana– Hippophae rhamnoides* subsp. *turkestanica – Ephedra gerardiana* mixed | 216.67 | 0.67 | 0.58 | 33.2 | 0.25 | 1.89 |

**Conservation and Management of Pollinators for Sustainable Agriculture through an Ecosystem Approach *(2010–2014, GEF, UNEP, FAO)***

In recognition of a looming pollination crisis, there has been a mobilization of effort on several levels to address pollination management and conservation. On a global level, the international community has identified the importance of pollinators. Decision III/11 of the United Nations Convention on Biological Diversity (CBD) established the Programme of Work on Agricultural Biodiversity, recognising that biodiversity is fundamental to issues of food security, and one of the important links is in the dependence of crops on a diverse variety of insect pollinators. In this context, FAO developed a global project entitled "Conservation and management of pollinators for sustainable agriculture, through an ecosystem approach". The project aims to demonstrate how the ecosystem services of pollination can be conserved and sustainably used in agriculture, through a set of targeted cropping systems in seven countries (Brazil, Ghana, India, Kenya, Nepal, Pakistan, and South Africa) with a wide diversity of ecological zones and farming patterns. In India, Apple in Himachal Pradesh, Mustard in Uttarakhand and Large Cardamom in Sikkim are the target crops.

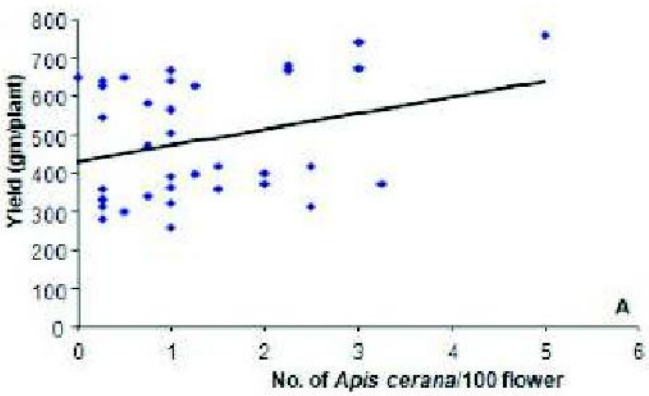
**Objectives**

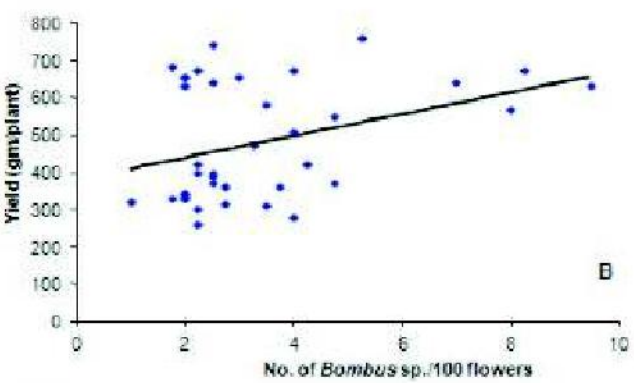
- To achieve improved food security, nutrition and livelihoods through the enhanced conservation and sustainable use of pollinators.
- To harness the benefits of pollination services provided by the wild biodiversity for human livelihoods and sustainable agriculture, through and ecosystem approach in selected countries.
- To disseminate the knowledge base
- To promote pollinator friendly best management practices
- To build capacity of the stakeholders on conservation and management of pollinators and pollination services

**Achievement**

- Successfully implemented the Pollination Deficit Protocols (PDP) in Three STEP sites (Mustard, Apple and Large Cardamom) STEP sites for three consecutive years (Mustard for 2 year). Based on the results of PDP following broad trends were revealing; (i) in case of Large Cardamom the bumble-bee (*Bombus* sp.) and honey-bee (*Apis cerana)* were most frequent visitors and the density of pollinators responded positively with the flowering phenology of the target crop. It was revealing that the increasing density of bumble-bee (*Bombus* sp.) resulted in significantly ($p$ <0.03) higher yield of the crop (on an average 21–41 gm/plant), Fig. 29; (ii) in case of apple, higher population density of *Apis cerana, Bombus* sp. and wild bees was revealing in orchards near natural habitats. Higher fruit set and fruit yield was observed in orchards supplemented with bee colonies irrespective of the relative location of orchards with respect to natural habitat; (iii) for mustard, although there has been a declining trend for pollinator density in the second year yet no significant impact was revealing when compared with the yield.

- Collection of key/native pollinators was made in three successive years. The representative specimens collected so far (through sweep net capture and bowl trap), have been maintained for reference and identification. So far 70 insect visitors/pollinators have been recorded/ photographed from the STEP sites. Laminated field guides on insect visitors /pollinators have been prepared for distribution amongst farmers and other stakeholders.
- Towards addressing the issue of taxonomic impediment, a week long, on site, Para-taxonomists training were organized (June 26–30, 2013 in Apple STEP site) involving +45 researchers and progressive farmers. Further, realizing the importance of herbarium maintenance while undertaking studies on plant–insect interaction, a five day on site training on herbarium preparation and surveys was organized for researchers, including the researchers of the GPP and the GBPIHED– Earthwatch Institute project, at GBPIHED (June 17–21, 2013).



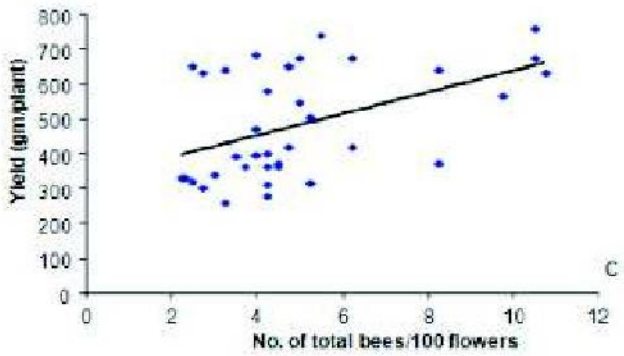




Fig. 29: Impact of pollinators abundance on yield of large cardamom crop: (A) impact of the abundance of *A. cerana* ($t_{cal}$ = 1.856; p> 0.05), (B) *Bombus* sp. ($t_{cal}$ = 2.307; p< 0.05) and (C) total bees ($t_{cal}$ = 3.161; p< 0.01).

**Preventing Extinction and Improving Conservation Status of Threatened Plants through Application of Biotechnological Tools *(2012–2017, Department of Biotechnology, New Delhi)***

The Indian Himalayan Region (IHR), a part of the Himalayan Global Biodiversity Hotspot, supports a representative, natural, unique and socio-economically important biodiversity. The rural population of the region is largely dependent on biodiversity as it (biodiversity) provides various services to mankind for sustenance. But, due to over exploitation and habitat degradation through 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 in future. Therefore, there is a need for their population inventory, Ecological Niche Modeling (ENM), meta-population characterization, molecular and biochemical profiling of populations (species with relatively wider distribution as well as those facing extinction), reproductive biology studies, standardization of tissue culture and other macro-propagation techniques, and reintroduction of the species for genetic enrichment and ecosystem/species restoration. The study aims to test the hypotheses that the biotechnological tools can help

in improving the conservation status of the threatened species.

**Objectives**

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

**Achievements**

- A total of 60 populations Threatened plant [*Arnebia euchroma* (15), *Dactylorhiza hatagirea* (2), *Podophyllum hexandrum* (14), *Angelica glauca* (12), *Aconitum heterophyllum* (3), *Picrorhiza kurrooa* (6) and *Rheum australe* (7) populations] were studied between 2,096– 4,492 m amsl in the Himachal Pradesh.
- Across *Arnebia euchroma* populations, the total shrub density ranged from 20–940 Ind $ha^{-1}$; and total herb density, 6.80–42.65 Ind $m^{-2}$ and relative density of *Arnebia euchroma* ranged from 0.67–28.31 %.
- In case of *Angelica glauca* populations, the total tree density ranged from 60–380 Ind $ha^{-1}$; shrub density, 170–1500 Ind $ha^{-1}$ and herb density, 23.20–98.80 Ind $m^{-2}$ relative density of *Angelica glauca* ranged from 0.62–3.45 %.
- In the studied *Podophyllum hexandrum* populations, the total tree density ranged from **60–590** Ind $ha^{-1}$; total shrub density, 105–1300 Ind $ha^{-1}$ and total herb density, 22.10–112.48Ind $m^{-2}$ and relative density of *Podophyllum hexandrum* ranged from 0.10–2.09 %.
- Seventy (70) distributional records, Bioclimatic, NDVI, Physiographic, Topographic, Bathymetric and hydrology variables were utilized for the prediction of potential areas of *Arnebia euchroma, Angelica glauca and Podophyllum hexandrum* with the help of ecological niche modeling packages.
- The model test yielded satisfactory results for *Arnebia euchroma* ($AUC_{train}$ = 0.998 ± 0.055 and $AUC_{test}$= 0.978 ± 0.046), *Angelica glauca* ($AUC_{train}$ = 0.998 ± 0.215 and $AUC_{test}$= 0.941 ± 0.129) *and Podophyllum hexandrum* ($AUC_{train}$ = 0.983 ± 0.073 and $AUC_{test}$= 0.959 ± 0.048) (Fig. 30).
- Seed germination trial for *Angelica glauca,* conducted in lab conditions, showed maximum seed germination (98.33%) in $GA_3$ 5µM, followed by 96.67 % in $GA_3$ 45µM and $KNO_3$ 190 mM. Seeds of *Angelica glauca, Podophyllum hexandrum and Aconitum heterophyllum* were collected from Tosh, Shilla and Malana area of upper Parvati valley and Rohtang area, Kullu, Himachal Pradesh.

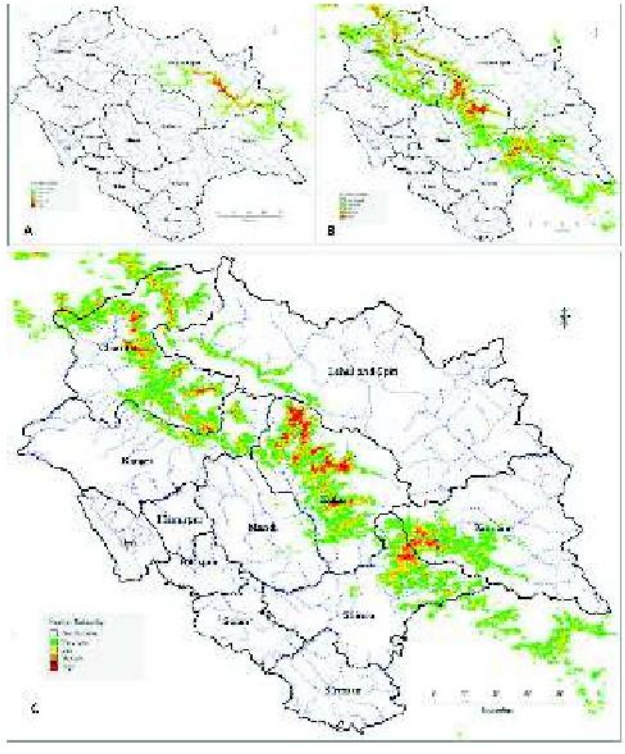


Fig. 30: Habitat suitability and distribution of (A) *Arnebia euchroma, (B) Podophyllum hexandrum and (C) Angelica glauca* in Himachal Pradesh.

**Kailash Sacred Landscape Conservation and Development Initiative *(2013–2016, ICIMOD, Nepal)***

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

**Objectives**

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

**Achievements**

- The Institute, as a co-ordinating Institute for India, entered into Agreement with International Center for Integrated Mountain Development (ICIMOD) on October 26, 2013 for implementation of KSLCDI in the Indian part. Agreements for implementation of KSLCDI activities were signed with Uttarakhand State Biodiversity Board (UKSBB) for work component 3-Access and Benefit Sharing, and Uttarakhand Forest Department (UKFD) for work component 2 - Ecosystem Management, and work component 4- Implementation of Conservation Strategy and Monitoring Plans.
- Conducted extensive field surveys and consultation along the Horizontal transect for: (a) assessment and mapping of resources and their status, (b) conducting needs assessment, and (c) identification of sites for long term monitoring. A stakeholder's consultation and needs assessment workshop was organized for the villages of the horizontal transect (Fig. 31).

Fig. 31: Stakeholders consultation and needs assessment workshop – Gangolihat.

- Towards establishing a more dynamic process of awareness generation in the landscape, students and teachers of 13 schools falling within the horizontal transect were motivated and facilitated for participation in National Nature Camps during March 2014. These schools have been identified for long-term association with the project, for extensive information generation on landscape resource, poverty mapping, people's needs and priorities (Fig. 32).

Fig. 32: KSL Schools participated in National Nature Camping Programme – GBPIHED.

**Khangchendzonga Landscape Conservation and Development Initiative – India *(2013–2014, ICIMOD, Nepal)***

Surrounded along the southern stretches of Mount Khangchendzonga, the targeted Khangchendzonga landscape (KL) includes eastern Nepal, Indian state of Sikkim, parts of north Bengal extending to Toorsa Strict Nature in Bhutan and thus connecting to Jigme Dorjii National Park (Bhutan). The KL is one of the biodiversity vise and culturally richest landscapes in the Himalaya and three countries, India, Nepal and Bhutan, the signatories of CBD, have been giving significant attention towards conserving the biodiversity of the KL. The KL has 15 designated PAs, of which six are transboundary in nature. The Governments of India, Nepal and Bhutan have agreed to collaborate on long term conservation and development of this transboundary landscape to be facilitated by the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu. The KLCDI is an attempt on the part of three member countries (Bhutan, India and Nepal) to join hands to help preserve the unique biological diversity and ecosystem goods and services, while developing the livelihoods of the local communities at the same time; the countries have agreed to collaborate and set the desired targets.

**Objectives**

- To prepare country wise as well as regional Feasibility Assessment Report (FA), Conservation and Development Strategy (CDS), and Comprehensive Environmental Monitoring Plan (CEMP) with special focus on long term monitoring including conservation and development activities
- To prepare a Regional Cooperation Framework (RCF) for conservation and management of rich biological diversity, cultural heritage, and vital ecosystem services through transboundary ecosystem management and participatory approaches fostering human wellbeing in the landscape
- To enhance cooperation among the participating countries with a common goal of conservation and sustainable development within the landscape.

**Achievements**

- Secondary information from different secondary sources was generated and gathered and is being computed for further analysis.
- A Two-day National consultation (Inception meeting ) was organized on 28–29 January 2014 which addressed major issues; over 30 identified partners/experts from Govt. and NGOs etc. interacted; consultation brought up major initiatives, viz. (i) delineated proposed landscape, covering Sikkim, and parts of West Bengal (Darjeeling and Jalpaiguri districts); (ii) identified two nodal persons (Sikkim and WB); (iii) Core group formation; (iv) two working groups (Sikkim and West Bengal) for providing inputs for preparation of Feasibility Assessment; and (v) various issues identified and future planning discussed.
- Stakeholder's workshop for West Bengal part of KL was organized in Sukna; over 50 participants

interacted and identified various conservation and development of issues and suggested possible approaches to address the same.

- In a high level meeting in the MoEF, New Delhi, for KL, the blocks along the Bangladesh border, were suggested to be exclude for KL, India. Initial maps were prepared jointly by Sikkim and WB forest departments, GBPIHED and ICIMOD, as per the suggested revision the total geographic area of KL (India) is 14126.36 sq km, spread along attitudes between 40m to 8585m, amsl.
- Drafting of Feasibility assessment report progressed by using inputs from various partners and individual experts; on-going.

**Status Assessment of Endemic Threatened and High Value Medicinal Plants of Cold Desert Areas in Indian Himalayan Region *(2013–2016, CSIR, New Delhi)***

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

**Objectives**

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

**Achievements**

- Following detailed information search at Botanical Survey of India (BSI), Dehradun, Forest Research Institute of India (FRI), Dehradun and National Botanical Research Institute (NBRI), Lucknow, an inventory of the existing flora of Uttarakhand Cold desert was prepared. The inventory suggests that the Uttarakhand Cold desert comprises of 549 species distributed in 276 genera and 68 families (Fig. 33). The species rich families included Asteraceae (74 spp.), Ranunuculaceae (46 spp.), Rosaceae (33spp.), Caryophyllaceae (28 spp.), Polygonaceae (26 spp.), Poaceae (22 spp.) and Fabaceae (21 spp.). Of the total 549 species, Uttarakhand cold desert comprises of 206 species (Fig. 34) of medicinal plants used in different medicinal systems. However, 37 species fall under different threatened categories.
- The population status assessment was also done in six sites of the Johar valley [viz. Burfu (3200 m), Belju (3300 m), Milam Bugyal (3400m), Above Milam (3500 m) and Milam Glacier (3600 m)]. Across these sites a total of 74 species were recorded, of which 26 were of medicinal value. Among these 5 species fall under different RET categories. Population study reveals that the density of *Dactylorhiza hatagirea* (D.Don) Soo and *Potentilla argyrophylla* Wall. *ex* Lehm. was the lowest (0.1 Ind $m^{-2}$) whereas the highest density was observed in *Hippophae tibetana* Schltdl. (21.50 Ind $m^{-2}$).

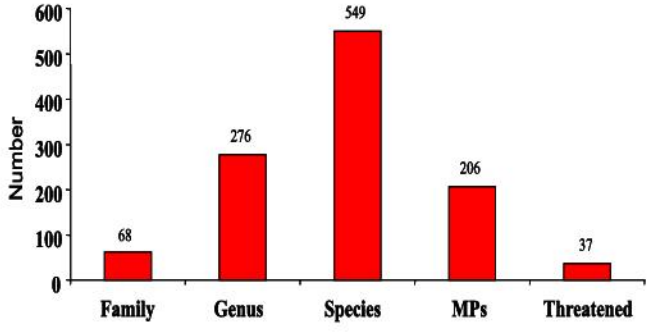



Fig. 33: Species occurrence in Uttarakhand Cold Desert.

Fig. 34: Representative flora of Johar valley [**a.** Milam track; **b.** *Juniperus communis*; **c.** *Danthonia schnrideri*; **d.** *Rosa sericea* var. *glandulosa*; **e.** *Origanum vulgare*; **f.** *Hippophae tibetana*; **g.** *Berberis umbellata*; and **h.** *Anaphalis royleana*].

**Promoting Bioresource Based Livelihood Opportunities for the Tribal Community in Lahaul-Spiti, Cold Desert Area of Trans Himalaya – TSP Project *(2012–Contd., CAZRI–ICAR, Jodhpur)***

The target area of the project is Lahaul -Spiti District of Himachal Pradesh. It is located in the north eastern part of the State of Himachal Pradesh and is scarcely populated. The entire landscape falls under the Cold Desert Region and due to its remoteness the area is known as "Forbidden land in the Himalayas". The Schedule Caste population in the district is 2,605 (7.34 %) and the Schedule Tribe population is 24,238 (72.95 %). Considering the Cold Desert landscape and predominated population of tribal people the project was initiated with the following objectives.

**Objectives**

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

**Achievements**

- Organized One Day training programme on "Preparation of pickles, jam, squash & murabba using local vegetables, fruits and wild edibles" at Mahila Mangal Bhawan, Kaza on 26.10.2013 and Sagnam on 27.10.2013 with the help of an expert resource person A total 105 and 69 people, respectively participated in Kaza and Sagnam Panchayats.
- Polythene support (Size: 20 x 6 m; Thickness: 102 GSM) was provided to 21 and 15 tribals house holds (BPL family) of Kaza and Sagnam Panchayat, respectively for growing off season vegetables (Fig. 35).
- The nutritional value of main food materials (Black pea, Green pea, Barley, Paneer, Sattu and Mustard) of tribal peoples of Lahaul – Spiti was analysed following the standard method. On the basis of nutrient analysis the highest Carbohydrate content (30%) was recorded in local food *Sattu* (mixed grains of *Hordeum vulgare* and *Pisum sativum / arvense*); while lowest recorded in *Paneer*

Fig. 35: Landscape and various events in providing polythene materials for polyhouse at Kaza and Sagnam Panchayat.

(Cheese). In respect of Fat, *Sattu* and *Paneer* were almost similar (around 8%). The content was not much varying among the villages. *Sattu* is preferred in Cold Desert condition as it has highest Carbohydrate and Fat content.

**Inventorization and Monitoring of Biosphere Reserve in India Using Remote Sensing and Geographical Information System Technology *(2010–2014, MoEF, New Delhi)***

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

**Objectives**

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

**Achievements**

- Mapping of Cold Desert Biosphere Reserve in Himachal Pradesh has been completed and GIS database has been created. The Land Use Land Cover of CDBR (Fig. 36) has been classified total area into 10 classes. Each and every class was identified on the basis of signature and ground truthing. Area covered by different vegetation and non-vegetation classes in CDBR is shown (Table 10).
- The LULC map shows that in CDBR, vegetation covers only an area of about 247.3 $km^2$ (3.19%) and all non-vegetation classes cover 7522.67 $km^2$ (96.81%) area, out of which largest portion of land (78.16%) is rocky and barren due to almost complete sequence of exposed sediments from the Pre-Cambrian era to the Cretaceous period.
- Land use/land cover mapping of 1990 and 2005 for Nanda Devi Biosphere Reserve has been completed and GIS layers for BR have been completed.
- Landscape analysis, along the time series of Dibru-Saikhova Island in the Dibru-Saikhova Biosphere Reserve was done for policy inputs (Table 10).

Table 9: Area covered by different vegetation and non-vegetation classes in CDBR

| Classes | Area ($km^2$) | Percent (%) |
|---|---|---|
| **A. Vegetation** | | |
| Alpine scrub | 5.96 | 0.08 |
| Alpine pastures | 241.33 | 3.11 |
| **B. Non-vegetation** | | |
| River | 50.62 | 0.65 |
| River bed | 40.17 | 0.52 |
| Glaciers | 456.17 | 5.87 |
| Snow and moraines | 868.86 | 11.18 |
| High altitude lakes | 0.57 | 0.01 |
| Agricultural and agroforestry land | 26.91 | 0.35 |
| Fallow land | 1.97 | 0.03 |
| Plantation | 4.25 | 0.06 |
| Open rock | 6073.19 | 78.16 |
| **Total** | **7770.00** | **100** |

Table 10: Changes in Dibru Saikhowa National Park in different years (area in km$^2$)

| Landform | 1973 | 1999 | 2005 | 2010 |
|---|---|---|---|---|
| **Brahmaputra river** | 57.3 | 156.0 | 173.1 | 164.2 |
| **Dibru Saikhowa** | 376.5 | 235.8 | 243.4 | 232.8 |
| **Flood plains** | 32.4 | 41.5 | 46.5 | 47.9 |
| **Fragments** | 22.5 | 36.1 | 17.1 | 24.2 |
| **Islands** | 4.3 | 32.5 | 21.6 | 32.4 |
| **Tributaries** | 9.8 | 1.0 | 1.3 | 1.5 |
| **Total** | 502.9 | 502.9 | 502.9 | 502.9 |

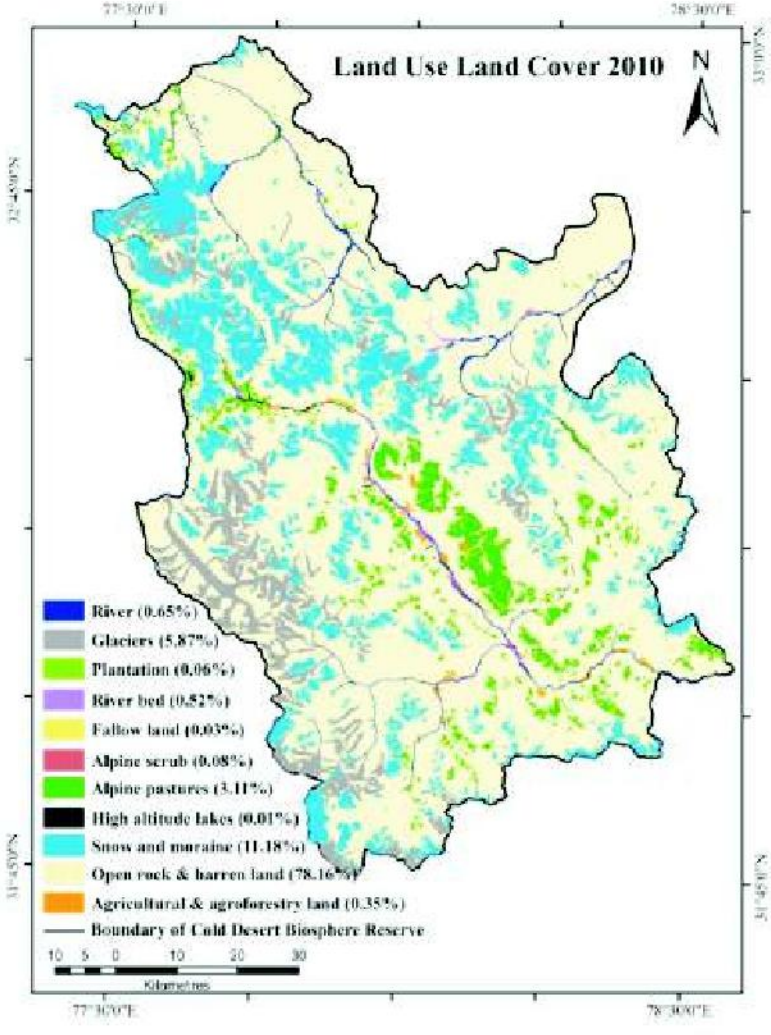



Fig. 36: Land use and land cover map of Cold Desert Biosphere Reserve.

Theme

# Environmental Assessment and Management (EAM)

The developmental issues in the Indian Himalayan Region (IHR) have many times become a cause of conflict between man and nature. The exploitation of natural resources with the increasing demand of population (local communities and visitors) usually creates situation of imbalance in an ecosystem. Human activities beyond a carrying capacity result in lots of environmental disorders and cause pollutions in the ecologically sensitive and topographically fragile parts of the IHR. If traditional know-how techniques in combination with hitech are used in modern days, ameliorating environmental threats and mitigating load of pollution would become easier for the planners and implementers. Establishing holistic approach stands as one of the sustainable ways between man and nature. Looking at ameliorating environmental threats and seeking alternative paths for ecological and economic sustainability is possible. EAM theme is therefore the backbone of the Institute wherein such studies are carried out. Developmental interventions, such as introducing hydropower projects, vulnerability, hazards and risks in the form of flash floods, cloud bursts, and landslides, etc. in the mountain ecosystem, climate change impacts on ecosystem services, indicators of climate change in context to the forest ecosystems, aerosol (gaseous, particulate, black carbon, liquid), climate change, glacier melting and mitigation measures, and LULC changes and its management options in biosphere reserves are of especial concern within the EAM theme of the Institute in the IHR. The objectives of the theme are: (i) Assessment and monitoring of physical, biological and socio-economic environmental attributes related to various developmental interventions/policies/plans in the Indian Himalayan Region (IHR), and (ii) Development/formulation/ suggestions of appropriate management plans ensuring ecological and economic sustainability

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

Hydropower is one of the important sources of energy in the Indian Himalayan region (IHR). Spreading from Arunachal Pradesh in the northeast to Jammu & Kashmir in the northwest region and covering a geographical area of 530,795 km², the region is characterized with steep topography and glacier-fed perennial rivers that provides opportunities for hydropower development. The major river systems of the IHR comprise of Indus, Ganges and Brahmaputra. To assess strategic environmental impacts of hydropower projects in the Indian Himalayan region, three river basins were taken into account; the Satluj basin (26°48'N to 27°40' N & 93°12' E to 94°24' E) in Himachal Pradesh, the Alaknanda basin (30°0' N to 31°0' N & 78° 45' E to 80° 0' E) in Uttarakhand, and the Ranganadi basin (26°48' 00" N to 27°30' 00"N & 94°06'00" E to 93°30' 00" E) in Arunachal Pradesh. The aim was to assess the EIAs practiced of the individual projects, ongoing impacts of the introduced projects (commissioned, under-

construction and proposed) and their strategic planning to determine their numbers based on cumulative impact assessment.

**Objectives**

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

**Achievements**

- Seven hydroelectric projects in the Satluj basin, viz. Naptha-Jhakri (1500 MW), Shongthong (412 MW), Karchham-Wangtu (1000 MW), Shayang (2 MW), Tangling (3 MW), Baspa-II (300 MW) and Kashang (243 MW) that vary from 1350 m to 2829 m in altitude were taken into account for soil (N,P,K) and air quality analysis (respirable particulate matter $PM_{10}$, and gaseous pollutants like nitrogen dioxide $NO_2$ and sulphur dioxide $SO_2$).
- The mean highest values of $PM_{10}$ at Shongtong showed 64.1±9.6 $\mu g\ m^{-3}$ and 27.5±4.9 $\mu g\ m^{-3}$ during post- monsoon and pre-monsoon periods, respectively. Among gaseous pollutants, $NO_2$ during post-monsoon season was measured between 3 and 3.7 $\mu g\ m^{-3}$ at Shongtong and Rampur, respectively. While during pre-monsoon $NO_2$ stood to be 3.4 and 4 $\mu g\ m^{-3}$ at Shongtong and Rampur, respectively. $SO_2$ representing post-monsoon season stood to be from 4±0.5 to 4.5±0.5 $\mu g\ m^{-3}$ at Rampur and Shongtong HEPs, respectively. While its values in pre-monsoon season remained 3.3±0.3 and 3.7±0.4 $\mu g\ m^{-3}$ at Shongtong and Rampur HEPs, respectively.
- Mean N, P, and K content in soils adjacent to HEP affected areas were found to be 221, 19 and 312 kg $ha^{-1}$ respectively in the Satluj basin (Fig. 37). However, the NPK values in soil of adjacent sites of HEPs ranged between 150–326, 6–85 and 114–583 kg $ha^{-1}$, respectively.
- Highest value of N was observed at Tangling HEP (326 kg $ha^{-1}$), while its lowest N (150 kg $ha^{-1}$) was found at Shongtong HEP. Similarly, highest phosphorus was observed at Nathpa-Jhakri HEP (49 kg $ha^{-1}$) and lowest at Kashang, Shongtong and Nathpa Jhakri HEP (6 kg $ha^{-1}$). In case of potassium, it was observed highest at Nathpa-Jhakri HEP (583 kg $ha^{-1}$) and lowest at Karcham-Wangto HEP (114 kg $ha^{-1}$).
- In Arunachal Pradesh the government has already allotted 132 projects up to October 2010 for a total installed capacity of 40140.5 MW as against existing potential of 50000 MW in the State. Recently 100 dams were planned to be constructed in the upstream of Arunachal Pradesh. In this project the downstream impact assessment was made in Ranganadi hydroelectric project (405 MW).
- Arunachal Pradesh receives the highest average annual rainfall of about 3000 mm varying from 1400 to 6000 mm. However, according to collected data from the last 177 years (1829-2006), found a decline was found in the annual rainfall in the northeastern region. Water availability in the downstream mainly in Assam seems to be one of the most important environmental issues. Dam induced floods from hydropower projects such as Ranganadi in Arunachal Pradesh face a strong opposition for the Lower Subansiri hydroelectric project (2,000 MW) under-construction at Assam – Arunachal Pradesh border.

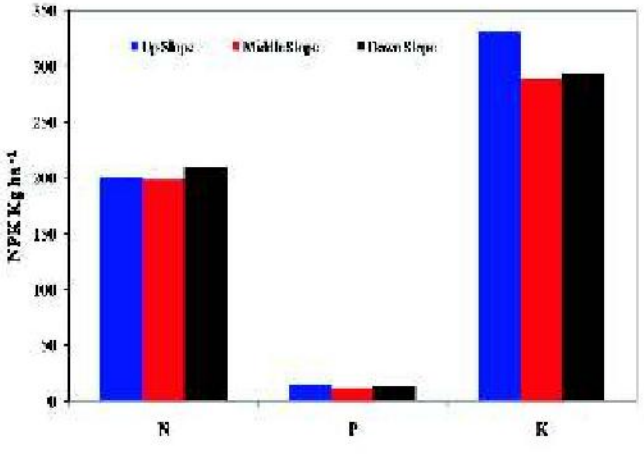



Fig. 37: Average nitrogen (N), phosphorus (P) and potassium (K) in up, middle and downslope soils surrounding to HEPs in the Satluj basin.

## Climate Change Impacts on Ecosystem Services in the Indian Himalayan Region *(2012–2017, 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 (both highland-lowland) inhabitants in particular. However, in recent decades under the changing climate (CC) scenarios, the ecosystem goods and services such as provisioning of Non- Timber Forest Products (NTFPs) to support the local livelihoods, habitat provisioning for rich biodiversity, storage of rainwater in vegetation-soil pool and hydrological flow regulation in the rivers arising from the region, C-sequestration potential and cultural values, etc. have been deteriorating at an alarming rate. Realizing the above needs, the present project has been initiated with the objective to undertake systematic study across an altitudinal gradient (a proxy of temperature variations) on major forest ecosystems of the western Himalayan region to monitor occurrence of life cycle phases (phenophases), such as growth initiation, regeneration of plant taxa, flowering, fruiting to relate the timing of these events with weather patterns and CC. Also, recreational services of these ecosystems are important and likely to be affected due to CC. In this region, due to continued biotic pressure on the forests, several areas have been converted into waste/degraded lands which need to be rehabilitated for provisioning of ES. This project seeks to integrate all these aspects to improve understanding on the impacts of CC on mountain ecosystems of the IHR and come up with certain mitigating mechanisms

### Objectives

- Study early indicators of CC on forest vegetation through phenological studies in the region.
- Assess 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

- Four major forest types from the foothill Sal (*Shorea robusta*) to high altitude Tilonj Oak (*Quercus floribunda*) that were located between 200 to 2100 m asl in the central Himalaya were studied for structural and functional attributes. Considering the species phenology is an early indicator of climate change.The important tree species at canopy and sub-canopy levels were further investigated for change in phenophases with relation to past data set (i.e. for the year 1985–87). Though the data collection is still in progress, the preliminary results marked variation across altitude and slope aspects (Fig. 38A–D). In general, leaf bud break and leaf drop were initiated earlier in low altitude species as compared to high altitude species. Sub-canopy species generally initiated all the phenophases a little later than the canopy species probably due to the shading effect.
- Data of Kullu district and Himachal Pradesh for the period 2004 to 2013 suggest 9.62 % growth in tourist inflow during this period. In all, 227 persons from the business community of Manali town and its suburban tourist pockets were randomly surveyed for assessment of earnings through tourism. The results show a clear cut impact of three month's summer season, on the income of all the above business types (Hospitality Business N=66, $p<.01$; Travel Business N=36, $p<.01$.; Café & Restaurants N=29, $p<.01$; Adventure Sports Equipment & Agencies N=13, $p<.01$).
- Restoration of ecosystem services in degraded land through community led rehabilitation by planting broad leaved species for ensuring long-term benefits to the inhabitants were also taken up. In the reporting year 500 saplings of Tej Patta (*Cinnamomum tamala*) were added in the restoration model. Data are being taken on species mortality, growth, and soil nutrient dynamics. People's perception on the climate change and its impact on agriculture, forests and other natural

resources, and possible adaptation measures was gathered by involving 54 farmers from 16 villages, which will be continued.

- Meteorological data for the duration 1951 to 2007 was procured from IMD and trend analysis of summer monsoon rainfall and extreme rainfall events for the IHR has been initiated.

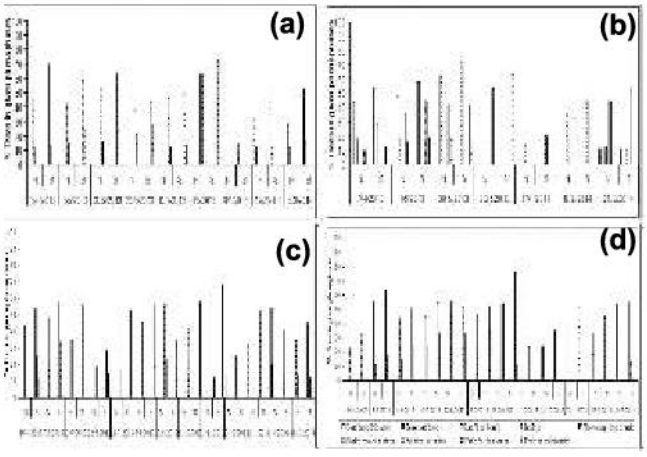



Fig. 38: Phenological events in *Shorea robusta* (A), *Pinus roxburghii* (B), *Quercus leucotrichophora* (C), and *Quercus floribunda* (D) trees at different slope aspects.

## Indicators of Climate Change in the Context of Himalayan Forest Ecosystems along an Environmental Gradient *(2012–2015, DST, New Delhi)*

Mountain regions have emerged among the most sensitive ecosystems under the global climate change (CC) scenario. These ecosystems, with their great vertical dimensions representing gradients of temperature, precipitation and solar radiation, form unique conditions to detect and analyse impacts of global change. Particularly, the plant species and community distribution range, and their phenologies are predicted to experience varying levels of shifts across these gradients, and thereby act as potential indicators of change. Among global mountains, the Himalayan region, is most prominent on account of its horizontal and vertical extent and represents one of the 'Global Biodiversity Hotspots'. The richness of endemic species with restricted distribution and life support values (goods and services) of this hotspot are highly vulnerable under the CC scenarios. Unfortunately, poor availability of systematic long-term data sets from the region has severely limited our capability to objectively define intensity of impacts and develop mitigation and adaptation strategies against the emerging reality of CC. In this context, this project was initiated to undertake studies across an altitudinal gradient (500 – 2200 m) in the Kumaun part of the Indian Himalayan Region (IHR), covering major forest types from the foothills to temperate conditions. In this transect,data sets of the past two three decades on many aspects of ecosystem characteristics (e.g., phenology, leaf characteristics, forest composition and recruitment patterns and other structural and functional aspects of forests) are available that may serve one of the strong benchmarks to understand the CC impacts. Therefore, studies were undertaken in the same forest stands/sites, with a view to compare the same with the past available data, and make an attempt to relate the observed changes with CC. The ultimate goal is therefore to integrate diverse aspects of the study, to propose an identified altitudinal transect, to come-up with indicators as well as to establish trends of climate induced changes for long-term monitoring and mitigation strategies

### Objectives

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

### Achievements

- Phenological observations on dominant canopy (*Shorea robusta*, *Pinus roxburghii*, *Quercus leucotrichophora* and *Q. floribunda*) and sub-canopy (*Mallotus philippensis*, *Myrica esculenta*, *Rhododendron arboreum* and *Machilus duthei*) forest tree species along the identified altitudinal gradient in the Kumaun Himalaya revealed that proportion of population of each tree species in a given phenophase varied across the canopy positions, aspects and altitudes. In general, sub-canopy species initiated all the phenophases or little later than the canopy species, may be partly due to low amount of sunlight and temperature.

- Leaf area ($cm^2$/ leaf) of the dominant tree species at mature leaf stages was recorded in the north (N) aspect for *S. robusta*, *P. roxburghii*, Q. *leucotrichophora* and *Q. floribunda* and (0.20, 1.93 2.16, and 2.49 $cm^2$/ leaf) and south (S) aspect (14.21, 0.21, 2.86 and 2.49 $cm^2$/ leaf), respectively. These species were followed by sub-canopy tree species such as *M. philippinensis*, *M. esculenta*, *R. arboreum* and *M. duthei* in N aspect (6.86, 2.27, 2.76 and 2.19) while S aspect (7.07, 2.89, 3.08 and 2.54) showed leaf area is slightly greater as compared to N aspect.
- Leaf mass (dry weight g / leaf) of the above mentioned tree species measured at mature stage. In N aspect, *S. robusta*, *P. roxburghii*, *Q. leucotrichophora* and *Q. floribunda* showed 2.05, 0.209, 1.02 and 1.06 respectively, while in south aspect the leaf mass values for these simultaneous species stood to be 1.93, 0.22, 1.41 and 1.12 respectively. Similarly, leaf dry weight at mature stage for sub-canopy tree species like *M. philippinensis*, *M. esculenta*, *R. arboreum* and *M. duthei* in N aspect was recorded 1.25, 1.05, 1.12 and 1.21 g/leaf, and in south aspect it was 1.02, 1.16, 1.06 and 1.33 g/leaf, respectively.
- A comparative account of various structural aspects of the above forests at two points of time (once in 2014 and the other in three decades ago by earlier scholars) revealed that: (i) All oak forests exhibit increase in density (maximum in *Q. leucotrichophora*), whereas P. *roxburghii* forest show a decline in total density. (ii) Dominant species in most forests have a declining trend of IVI, whereas *P. roxburghii* has gained IVI. (iii) Mixed forests in sapling stage were found to have an increase in the number of species. (iv) All forests exhibit considerable increase in species mainly in terms of seedlings with maximum increase for *Q. floribunda* and *Q. leucotrichophora* forests. (v)There was a decline in total shrub density in most of the forests except that of *P. roxburghii*.
- Using MODIS data, detection of the timing of offset and onset of greenness were analysed across 18 sites in Sal (*S. robusta*) forests in the foothills of the Kumaun Himalaya. Statistically significant trend in vegetation growth was observed using t-test method. Healthy vegetation has high NDVI value, whereas unhealthy or dry vegetation shows low NDVI value. Sal forests shed their leaves during the spring season (from late February to early April), but do not become fully leafless. Leaf flushing starts from late March and reaches at its maximum during April, but this extends till mid June. Full canopy at the forest community level was achieved in September. NDVI curve of the detected changes in Sal forests is shown in Fig. 39.

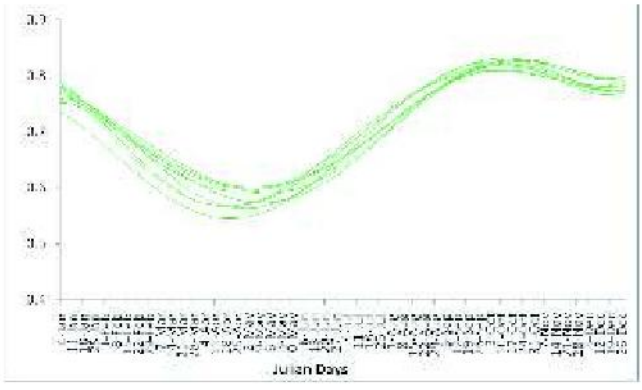



Fig. 39: NDVI curve for the Sal forest.

## Gaseous Air Pollution in the Background Site of Sprawling Urban Environment of Himachal Pradesh *(Start 2008–09, Long Term Science Programme, ISRO-PRL, Ahmedabad)*

Tropospheric or surface ozone ($O_3$) is an important air pollutant threatening human health, vegetation growth and increase in local temperature as one of the greenhouse gases. $O_3$ is a secondary pollutant. It is the key species affecting the chemical properties of the atmosphere where it is a precursor for the highly reactive hydroxyl radical. $O_3$ and its precursors play an important role in affecting regional climate 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 gaseous pollution. Ozone concentration depends on the absolute and relative concentrations of its precursors and the intensity of solar radiation. An analysis of the influence 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. Nitric oxide (NO) is emitted from soils and natural fires, and is formed in situ in the troposphere

from lightning, and is emitted from combustion processes like vehicle emissions and fossil fuelled power plants. NO is short lived because it oxidizes to produce nitrogen dioxide ($NO_2$) 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 carbon monoxide (CO). Its oxidation leads to $O_3$ formation or destruction, depending upon the level of 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 exhausts, 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 analyse them in the background of long range transport sources, and
- To suggest some feasible mitigating measures to be implemented at policy level.

**Achievements**

- The measurement of surface ozone ($O_3$) and its precursors, nitrogen oxides $NO_x$ (NO+ $NO_2$) and sulphur dioxide ($SO_2$) were carried out in Himachal Unit of the institute using online UV photometric ozone analyser (Thermo Fischer, Model 49i) and $NO_x$ analyser (make Thermo Fischer, Model 42i) since November 2011. However, the measurement of CO, an important precursor of $O_3$, was started since November 2013.
- Like $NO_x$ precursor, CO has also shown two peaks, one during the morning at 0800:0900h IST and the other during the evening at 20:00–21:00h IST. Both of these precursors are emitted due to anthropogenic reasons like vehicular emissions and biomass burning in the Kullu valley. Both these pollutants are primary pollutants (Fig. 40a).
- Maximum concentration of surface ozone was observed in the months of March, April and May. The daily maximum concentration of $O_3$ was 51 ppb on 2 May, 2013. This episode when plotted on the Model of Atmospheric Transport and Chemistry- Max Planck Institute for Chemistry (MATCH-MPIC) for 2 May, 2013, showed high concentration in our region (Fig. 40b).
- The fire counts are considered to be the indicators of natural and anthropogenic biomass burning, where large amount of CO, Methane ($CH_4$), Volatile Organic Compounds (VOC) and Non-Methane Hydrocarbon (NMHC) are emitted besides $NO_x$. Ozone is formed when CO, $CH_4$ and NMHC react in the presence of $NO_x$ and sunlight.
- The average fire counts for the period 2010–2012 from MODIS Terra and Aqua satellites show their higher numbers in the month of May, June, October and November (Fig. 40c) which is the post harvesting and relatively dry season in Kullu valley. It is the summer and autumn season when the fire counts were observed to be higher in the valley. The annual burning activity in the valley peaks in summer and autumn. It is interesting to note that the seasonal pattern of fire counts and surface ozone is found to be similar in the region of the present study.

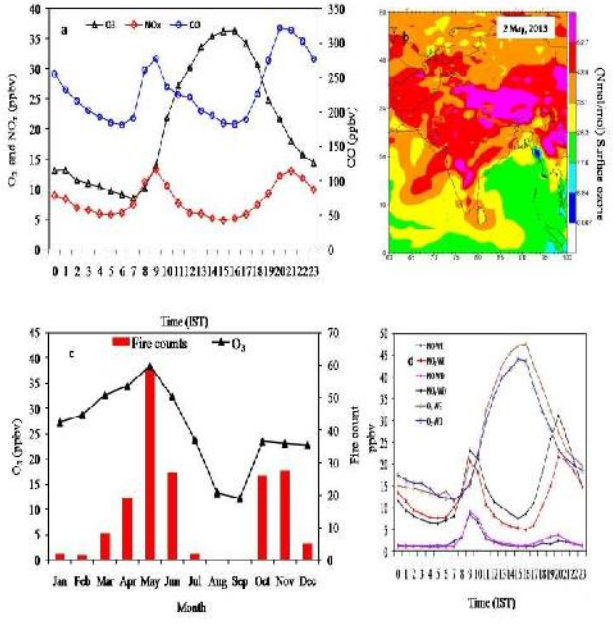



Fig. 40. **(a)** Variation of diurnal value of $O_3$ in relation to $NO_x$ and CO concentration, (b) plot of $O_3$ concentration from MATCH-MPIC Model, (c) relation of $O_3$ with fire counts, and (d) weekday and weekend concentration of NO, $NO_2$ and $O_3$.

- The surface ozone concentration was observed to be 38 ppbv, 32 ppbv, 24 ppbv and 23 ppbv for the months of May, June, October and November respectively, while the number of fire counts in the corresponding months were found to be 59, 27, 26 and 28 (Fig. 40c).
- Fig. 40d shows the daily variation of the mean values of the $NO_x$ and OX concentration levels during weekdays and weekends. In the comparison with weekends (WE), with the weekdays (WD) concentrations were higher for NO, $NO_2$ and $NO_x$, while an opposite trend was observed in the case of $O_3$.

## Aerosol Climatology over the Northwestern Indian Himalayan Region, Himachal Pradesh *(Start 2005–065, Long Term Science Programme ISRO-SPL, Thiruvananthapuram)*

Aerosols are considered to be one of the primary causes for increasing the Earth's atmospheric temperature. There are a number of atmospheric effects like formation of fog, mist and clouds which are directly or indirectly produced by aerosols. The nucleation or fine mode aerosol is produced through gas to particle conversion and arises mainly due to anthropogenic activities, while coarse mode aerosols such as wind blown mineral dust and sea salt particles mainly arise due to natural sources. On a global scale, the abundance of natural aerosols (sea salt, soil dust, natural sulphates, volcanic aerosols, natural forest fire, etc.) is several times greater than the major anthropogenic aerosols (sulphate, soot, etc.). Black carbon is now-a-days of special interest because it absorbs short wave solar radiation, warms the air, and ultimately contributes to global warming, unlike most of the aerosols, which reflect short wave solar radiation into space and have a global cooling effect. The Himalayan glaciers could be the first to be adversely affected by local temperature rise. The zones of glaciers, which may be affected worst, could be ablation and accumulation zones. These are separated by the Equilibrium Line Altitude (ELA). The change in ELA may cause glacier disappearance in the future. The Beas Kund glacier is one of such glacier in the Kullu valley which is lying in the Himalayan range and is taken into account under the present context for aerosol loading and its adverse affect on it. The measurement of aerosols in such a background site is important not only to compare its loading from thevalley base but also to know the extent of aerosol loading on the pristine environment affecting the glacier due to anthropogenic activities

**Objectives**

- To obtain aerosol optical depth (AOD) at ultra-violet, visible and near infrared spectrums (380–1025 nm) using Multi-wavelength Radiometer (MWR).
- To study the concentration of soot and aerosol over the surrounding glaciers in the Kullu Valley.
- To study the aerosol radiative forcing over the valley base locations and other selected glaciers.
- To determine the impact of aerosols on climate change in the Himalayan region.

**Achievements**

- Due to the continuously increasing anthropogenic activities, solar attenuation in the form of aerosol optical depth (AOD) from 2006–2013 at 500 nm has been increasing at a rate of 0.02 per annum (Fig. 41a). AOD from forenoon to afternoon was observed from 2006 to 2013, and it was found that as a result of increase in the convective process, afternoon AOD showed high values as compared to the forenoon AOD. On an average, the solar flux due to atmospheric aerosols attenuated from forenoon to afternoon by 50% at 500 nm and 51% at all wavelengths (380–1025nm) (Fig. 41b).
- When alpha (corresponds to fine size particles) and beta (corresponds to coarse size particles) were computed on monthly basis, maximum value of alpha (2.10) was noticed in November, 2006 and minimum (0.38) in February, 2013. However, maximum beta (0.43) was in August, 2012 and minimum (0.04) in December, 2006 (Fig. 41c).
- While observation of Black carbon concentration (BCA) from 2009 to 2012 was made, its trend was found to decrease in a number of fire cases which stood to be check during 2009–2010, 870 during 2010–2011 and 168 during 2011–2012. However, there was a slight increase in a number of fire cases (i.e., 1798) during 2012–2013 and as a result there was again a small increase in BCA in 2013.
- While noticing relationship of AOD with

temperature conditions as correlation coefficient, it was found positive (r =0.28), indicating an increase in air temperature with the simultaneous increase in AOD (Fig. 41d). The average total ionic concentration of different water soluble components at different depths of snow in the Beas Kund glacier stood to be 3.69 mg $l^{-1}$ (0–10 cm), 13.67 mg $l^{-1}$ (10–20 cm), 5.7 mg $l^{-1}$ (20–70 cm) and 8.45 mg $l^{-1}$ (70–85 cm) (Table 11; Fig. 42).

- The mass loading of total suspended solids (TSS) varied from 2 to 300 mg $l^{-1}$ with an average of 108 mg $l^{-1}$. This study found that the TSS accounted for 6.9% of the total snow samples. The trajectory analysis shows that polluted air reaches the Beas Kund glacier from the northwest (NW) direction. An Earlier study also reveals that these regions are associated with the influence of northwestern inflow of air mass laden with mineral dust.
- The instantaneous aerosol Radiative forcing estimated at the top of the atmosphere, surface and atmosphere were –12.31 ± 6.28 $Wm^{-2}$, –37.781 ± 15.34 $Wm^{-2}$ and +25.47 ± 11.33 $Wm^{-2}$, respectively.

**Table 11: Ionic concentration, pH, EC and TDS in snow samples at different snow depth**

| Snow depth (cm) | Cation mg $l^{-1}$ (%) | Anion mg $l^{-1}$ (%) | pH | EC (mS $cm^{-1}$) | TDS (mg $L^{-1}$) |
|---|---|---|---|---|---|
| 0–10 | 1.01(27) | 2.68 (73) | 5.4 | 72.0 | 35.5 |
| 10–20 | 6.46 (47) | 7.21 (53) | 6.6 | 106.5 | 51.0 |
| 20–70 | 2.25 (39) | 3.47 (61) | 5.2 | 13.4 | 0.8 |
| 70–85 | 2.53 (30) | 5.91 (70) | 6.1 | 7.0 | 3.4 |

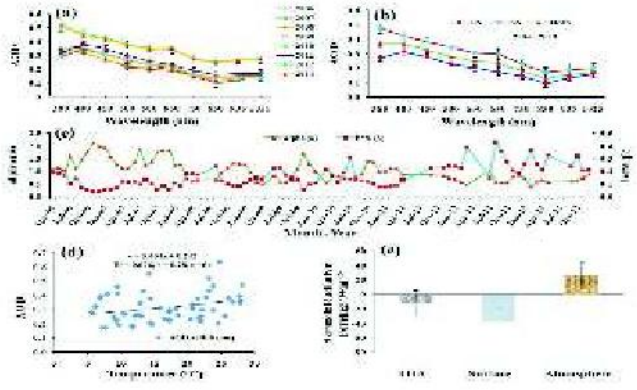


Fig. 41: Data representing **(a)** annual variation in AOD at ten wavelengths, **(b)** forenoon to afternoon variation in AOD, **(c)** monthly values of alpha and beta, **(d)** relationship between AOD and Temperature (2008–2013), and **(e)** Aerosol Radiative Forcing (2006–2013).

Fig. 42: An overview of Beas Kund Glacier and observation of aerosol and meteorological parameters.

## Black Carbon and Other Aerosols Loading, and their Impact on the Parbati Glacier in the Northwestern Himalaya, India *(2013–2016, DST, New Delhi)*

It was a century ago, when some attention was paid on the possible impacts of the rise in atmospheric temperature on mountain glaciers. A large number of the glaciers, during the last three decades of 20$^{th}$ century have shown cumulative negative mass balance. Maximum discharge from the glaciers takes place from mid-July to mid-August. As far as melting of glaciers is concerned, an aerosol / dust cover of 400 gm $m^{-2}$ (a thickness of about 2 mm) has the maximum effect on snow/ice. The present study is focused on the inventory on black carbon and other aerosols loading over the Parbati glacier in Himachal Pradesh of the northwestern Indian Himalaya. The Parbati glacier one of the largest glaciers in the Parbati basin, a major tributary of the River Beas, is fed by almost 36 glaciers covering an areal extent of 188 $km^2$. Due to steep slope in the upslope region from the mouth of the Parbati glacier, this basin is highly potential for hydropower development where some major hydropower projects (800 and 520MW) are under construction. For the Parbati glacier, the retreat from 1962 to 1990 and from 1990 to 2001 was 5991 m and 578 m respectively. This rate of retreat seems to be very high and may be alarming for the future. The natural as well as anthropogenic aerosols, affect the climate adversely. The direct effect of aerosols is the absorption and

scattering of solar radiation which finally leads to change in radiation budget and may situation create imbalance in the glacier environment.

**Objectives**

- To obtain black carbon (BC), and aerosols loading over the Parbati glacier.
- To measure BC and ionic concentration from the glacier's snow/ice.
- To obtain melting and retreating rate of glacier, and
- To suggest the feasible options for policy implications to regulate retreating of the glacier.

**Achievements**

- Based on a preliminary review of literature and different satellite imagery analysis, various studies suggest that a significant number of the mountain glaciers are shrinking due to climatic variation. In this connection, unusual retreat of the Parbati glacier in the River Parbati, Kullu district, Himachal Pradesh has been reported. Being the largest glacier in the Kullu valley, the satellite data of Landsat MSS (October 1980), Landsat TM (September 1989), Landsat ETM (October 2002) and Landsat TM (October 2013) were used for cloud free days under the present analysis.
- The glacier had lost 3.54 $km^2$ from 1980 to 1989, which is a decrease of about 7.93% in the glacier surface area. The period between1989 to 2002 showed a retreat of the glacier about 5.85 $km^2$ which is nearly a decrease of 14.23% in the glacier's area (Fig. 43a–d).
- In essence, between 2002 to 2013, the Parbati glacier had retreated about 5.36 $km^2$ which is a decrease of about 15.19% in the glacier area. The average retreat of the Parbati glacier during the period 1980 to 2013 is 4.92 $km^2$ which accounts for 33.02% decrease in the total glacier area (Table 12).

Table 12: Changes in the Parbati Glacier between 1980 to 2013

| Year | Areal extent ($km^2$) | Loss in area ($km^2$) | % change | Decrease | % change 1980 to 2013 |
|---|---|---|---|---|---|
| 1980 | 44.67 | – | – | – | 33.02 |
| 1989 | 41.13 | 3.54 | 1980–1989 | 7.93 | |
| 2002 | 35.28 | 5.85 | 1989–2002 | 14.23 | |
| 2013 | 29.92 | 5.36 | 2002–2013 | 15.19 | |

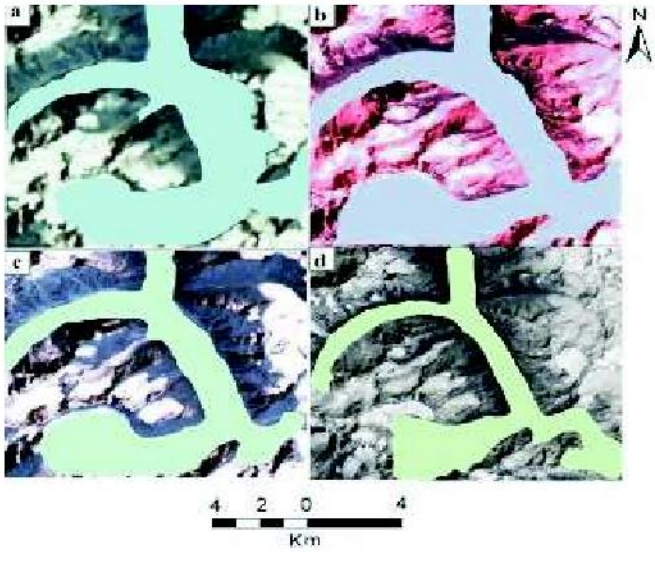



Fig. 43: Landsat Imageries- **(a)** MSS October 1980, **(b)** TM September 1989, **(c)** ETM October 2002 and **(d)** TM October 2013.

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 ecosystems are rich and unique. However, the capacity of the mountain ecosystems are fast approaching many of its 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 in poverty in this ecosystem through ecologically appropriate and socio-culturally acceptable interventions, and promotion of innovative livelihood and skill enhancement of the local communities for rational and judicious use of local resources 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, documentation of local health traditions, which have potential to benefit the economically disadvantaged communities of the IHR and reversing the trend of poverty. In the process, the Theme has also emphasized on identification and implementation of region specific sub-activities such as strategy for economic development of smallholders farming systems, up scaling innovative resource management practices, promoting village tourism, developing entrepreneurship skills, strengthening community indigenous knowledge through training and capacity building, technology development, dissemination and backstopping, managing shifting agriculture focusing on enhancement of fallow period, participatory assessment of sustainable scenarios for Himalayan pastoralism, and culture in conservation and sustainable development and many others**.** The main objectives of the theme are: (i) Sustainable tourism; (ii) Entrepreneurship and self employment in the Himalaya; (iii) Indigenous knowledge: traditional lifestyle, architecture and healthcare practices; and (iv) Migration: socio-economic and cultural implications.

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

Indian Himalayan Region (IHR) is biologically and culturally one of the richest regions in the country. IHR offers immense opportunity for the development of various types of tourism, such as, nature based, adventure, cultural tourism, pilgrimage, leisure, agro-tourism, etc. Tourism, in turn, has potential for economic development of the ethnic communities and conservation of the rich biodiversity of the region. The project envisages developing an eco-tourism model by linking tourism with economy, culture and biodiversity conservation, so as to advance it as a potential means for rural livelihoods on one side, and provide impetus to conserve the forests and associated biodiversity of the

region on the other. By analyzing the status of selected eco-tourism sites in different Himalayan States (viz. Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh) and assessing its economic relevance along with impact on people and environment, the project aims to document successful case stories so as to address policy development on the subject.

**Objectives**

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

**Achievements**

- In the reporting year selected potential ecotourism destinations across IHR (i.e. Arunachal Pradesh, Uttarakhand, Sikkim and Himachal Pradesh) were evaluated for their status in terms of the arrival of tourists over a period, existing policies related to promotion of eco-tourism, institutional approaches to promote tourism, etc after a reconnaissance survey. These sites comprised of Tawang, Bomdilla and Apatani plateau in Arunachal Pradesh, Hadimba Temple in Manali, white river rafting in Beas in Kullu valley and the Great Himalayan National Park in Himachal Pradesh, high altitude Tsomgo Lake in East Sikkim district and nature trail in Yuksam in West Sikkim district, and Tehri dam in Uttarakhand.
- Each site was assessed to develop as an ecotourism model integrating tourism with ecology, economy and culture and strengthening community conservation approaches to improve the quality of the product. An analysis of tourist arrival revealed a positive trend in all the states over the period of 2000-2012 with Assam receiving maximum tourists while Arunachal Pradesh registered maximum percentage growth among other northeastern states (Fig. 44).
- An analysis of cultural tourism at Hadimba Temple at Manali and nature based tourism of white water rafting in river Beas in Kullu Valley in Himachal Pradesh revealed that the former site being a national heritage monument of archaeological importance, is visited by a large number of tourists that brings good income for local vendors. Perception of local stakeholders for management of the site was gathered. In response to satisfaction gained for visiting Hadimba Temple site, the tourists (n=236) showed different levels of satisfaction with relation to environmental cleanliness, waste management, rituals, implementation of good practices and knowledge gained (Fig. 45).
- Tourists visiting Beas river for rafting purposes (n=124) were interviewed at three different locations to assess quality of rafting services, who found the experience of 'very good' and 'good' categories in terms of experience of adventure and enjoyment, infrastructure and facility, staff interaction, and monetary satisfaction (Fig. 47), which is better than average rating.
- In Sikkim, the Tsomgo Lake (length 1 km, depth 15 m approx.) located at an altitude of 3780 m, is considered sacred by the local inhabitants. Yuksam is situated at an altitude of 1780 m and serves as the base for trekkers to the Khanchendzonga National Park that attracts tourists far and wide. Yuksam, the first capital of Sikkim, with an area of 812 ha has rich natural and cultural ethnicity. Khanchendzonga Biosphere Reserve covers an area of 2931.12 $km^2$ and includes the Khanchendzonga National Park (1784 $km^2$), a

buffer of 835.92 km$^2$ along with a transition zone of 311.20 km$^2$. In order to understand the status and trends of tourists, data has been collected and analysed for the state over a period of thirty-three years, i.e., from the year 1980 to 2012. The data showed steady arrival of tourists to Sikkim with the exception of the arrival of domestic tourists in 2011 owing to the devastating earthquake that occurred in Sikkim during Sept 2011. (Fig. 48).

- In Uttarakhand, the potential of Tehri dam site as a potential ecotourism destination is being evaluated. In a preliminary meeting that was attended by 153 villagers, a consensus has been made on broad areas of collaboration, village eco-development committees and a green brigade has been made.
- Multi stakeholders consultative and awareness meetings were organized across these sites with regards to positive and negative impacts of the tourism on environment, wildlife, community, area management, and identification of gaps and conflicts, if any. Efforts are also being initiated to document success and failure initiatives on tourism in different states along with community participation in ecotourism/conservation/ livelihood programmes.

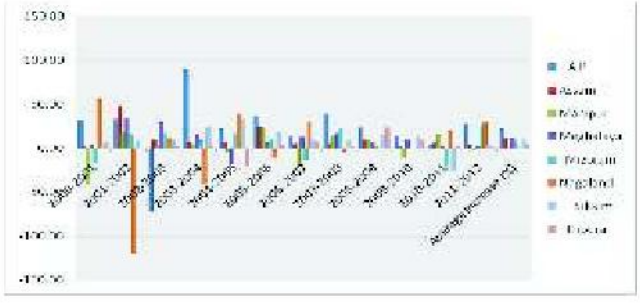


Fig. 44: Growth rate of tourist in Northeastern states over the period 2000–2012.

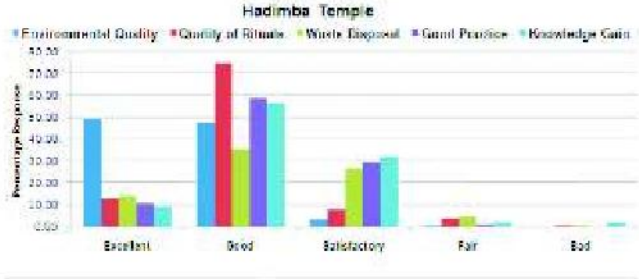



Fig. 45: Status of site quality at Hadimba temple site as assessed by tourists.

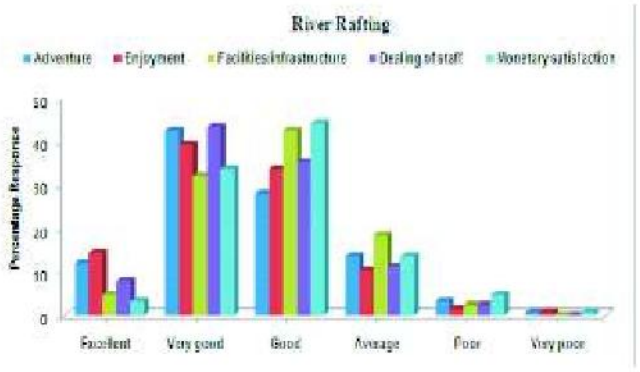



Fig. 46: Percentage of satisfaction gained by tourists from quality of rafting activities.

Fig. 47: The Scenic Siang (River) in Arunachal Pradesh, 2. Rafting activity in Beas River, 3. The Ecotourism model being developed at Apatani Plateau, and 4. Tsongmu Lake in Sikkim.

**Wildlife Management/Biodiversity Conservation Plan for Trans-Arunachal Highways *(2012–2015, Government of Arunachal Pradesh)***

Road network in the hilly region, especially in the context of Indian Himalayan Region (IHR), is considered to be the lifeline. The roads and highways in India account for about 80% of the total passenger traffic and about 60% of the total freight traffic in the country. Despite the world's second largest road network, a major portion of the country is still not well connected with the national highways. Arunachal Pradesh has a road network of 21066.36 km, which yields a road density of 25.16 km per 100 km$^2$. However, if one talks about the National Highways in the state, as per the National Highways Authority of India (NHAI) the state has only a 2027 km length of National highways, which is much lower than most of

the other states. Development of Trans-Arunachal Highways (Fig. 48) is supposed to strengthen the states' connectivity to the remote villages as well as to address rapid socio-economic development of the areas falling in the vicinity or command of the projected roads. Although the entire state is going to be benefited by the development of these highways, the proposed highways (undertaken in this project) are passing through only 5 districts namely East Kameng, West Kameng, Lower Subansiri, Papum Pare and East Siang district of the state. Trans-Arunachal Highways is an important initiative in the line of development of Arunachal Pradesh; but this development can have serious implications on rich biodiversity and the natural resources of the State. Therefore, it becomes imperative to carry out realistic assessment of the envisaged ecological damages necessitating assessment and formulation of management plans, so that the negative impacts of highway development can be minimized and mitigated. With these in view, the present study was assigned to North East Unit of GBPIHED by the Department of Environment and Forest, Government of Arunachal Pradesh with the following objectives

**Objectives**

- Biological study of road sites for flora and fauna.
- Assessment of the present status of biodiversity of the tracts along the roads.
- Assessment of threats to flora and fauna.
- Identification of biodiversity corridor zones and corridors of important mammals.
- Preparation of 'Biodiversity Management Plan'.

**Achievements**

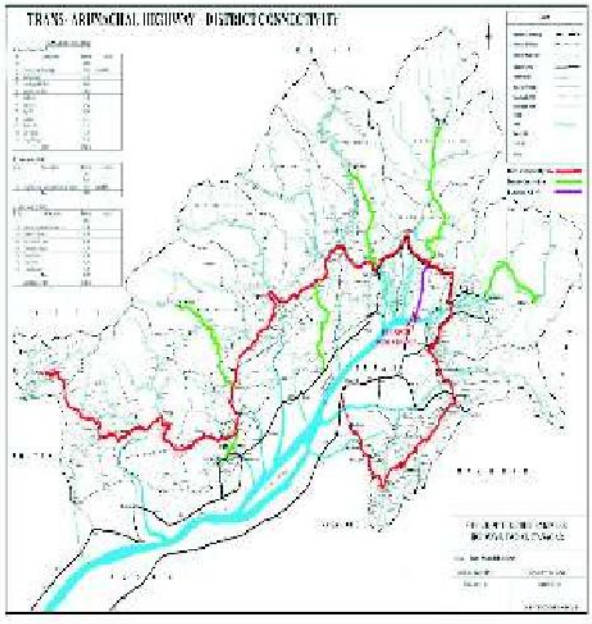
- In the reporting years the study was confined to assessment of biological diversity and preparation of biodiversity and wildlife management plans for the five road sectors, viz. 1. Potin-Bopi, 2. Godak-Tai, 3. Tai-Bame, 4. Nechipu to Bana, and 5. Seppa to Passa. (Table -14).
- The proposed highway is passing through rich biodiversity zones falling partly in the districts of Papumpare, Lower Subansiri, Upper Subansiri, West Siang and East Siang District of Arunachal Pradesh. The major ethnic communities living along the forests of proposed segments of Trans-Arunachal Highway are *Nyishi, Apatani, Tagin, Galo* and *Adi*, together known as *Abo Thani* tribes as they trace their origin from *Thani*, the mythical first human being. They follow an indigenous form of religion, which is known as *Donyi Poloism*. The road segment is covering a total distance of about 386.94 km connecting Lower Subansiri, Upper Subansiri, West Siang and western border of East Siang Districts of Arunachal Pradesh. The forests and vegetation of the road sector are basically tropical evergreen, tropical deciduous, subtropical evergreen, subtropical deciduous and temperate evergreen which are rich in species composition and diversity. Torrential rain and cyclonic wind, and heavy precipitation during summer months are the main characteristic features of these tropical rainforests. The forest crops are mostly of mixed type, composed of grass flora at the ground floor while the middle storeys are dominated by herbs, shrubs, climbers and lianas. The collected samples are inventorized as -(1) General checklist of plants along the proposed highway, (2) Species of ethnobotanical significance (medicinal, food, timber and culturally valued plants), and (3) Rare, Endemic and Threatened flora.
- Of the total 859 species reported along the road sector, almost 724 (84.28%) species are reported as ethnobotanically significant plants, which include food, medicine, cultural and timber plants. Among the ethnobotanical plants, tree habit represents 231 (31%) species, followed by herbs with 224 (30%) species, shrubs with 151(21%) species and climbers with 109 (15%) species. Some of the ethnobotanically significant plants also have deep cultural links with indigenous communities of the area. Of the total 859 species, almost 287(33%) species are reported as Rare, Endemic and Threatened (RET) while 23 species are endemic to North East India, Indo-China and Arunachal Himalayan region.

§ Besides, 52 animal species of prime ethnozoological significance were inventoried along the Trans-Arunachal Highway, which comprised 80% mammals, 12% birds and fish, and remaining 8% of other species. Most animals were closely linked with indigenous faiths & beliefs.

Table 14: Road segments of proposed Trans-Arunachal Highways considered for preparation of Wildlife Management and Biodiversity Conservation Plans

| S. No. | Tract | Length (km) | District |
|---|---|---|---|
| 1. | Nechipu to Bana | 62.58 | West Kameng |
| 2. | Seppa to Passa | 70.00 | East Kameng |
| 3. | Potin to Bopi | 157.12 | Lower Subansiri |
| 4. | Godak to Tai | 141.39 | Upper Subansiri |
| 5. | Tai to Bame | 38.43 | Multiple disticts |

Fig. 48: Layout map of Trans-Arunachal Highways in Arunachal Pradesh.



***Summary of Completed Project/Activity***

**Enhancement of Livelihood through Sustainable Farming System and Related Farm Enterprises in North West Himalaya (2007-2013, ICAR)**

The Institute has implemented "Enhancement of Livelihood Security through Sustainable Farming systems and Related Farm Enterprises in North-West Himalaya" project supported by World Bank-ICAR since 2007.It addressed the challenge of technological expansion, extension of services and adoption/ adaptation and to generate additional income and employment for the poor. Given the limited scope for area expansion and increase in productivity, profitability and competitiveness have been addressed through innovations and applications of available S&T knowledge, coupled with traditional/indigenous practices and skills. Integrated farming system approach along with improved livelihood and community based natural resource management strategies were strengthened through this project. The project sites were located in Champawat and Tehri districts of Uttarakhand. An emphasis was given to improve the sustainability of the farming systems and natural resource management in less favorable environments, particularly rain-fed agriculture, common lands and waste lands of the adopting community based natural resource management and village cluster based approach.

With the help of the project six mother nurseries were established for germplasm distribution and facilitation for cultivation of 7 MAPs species on 15.9 ha of land and cultivation of two species of cut-flowers in 12.5 ha land that ensured short term benefits to the farming community through participatory approach. It also improved cash inflow and overall livelihoods of the farmers. Facilitation for registration of 200 farmers with Herbal Research and Development Institute (HRDI) for legal marketing of MAPs, strengthening of market linkages through signing of MOUs between farmers and traders for the buy-back process of MAPs and cut-flowers and regular technical backstopping were strengthened that provided additional income of Rs 29,380 to Rs. 11,98,750 within a span of six years to 143 families. Scarcity of fodder had been addressed through harvesting of grasses from rehab sites which increased fodder output from 2.74 tons/ha/year to 18.76 tons/ha/year in target villages. The horticulture model developed in 3 clusters of Tehri district have started fruit production and village level collection centers have been established for gathering, packaging and marketing under the supervision of the village management committee.

*Summary of Completed Project / Activity*

**Biodiversity Conservation through Community Based Natural Resource Management in Arunachal Pradesh** *(2008-2013, UNDP & MOEF, New Delhi)*

The Ministry of Environment and Forests, Government of India implemented this project through a Country Cooperation Framework of United Nations Development Programme in four states, viz Arunachal Pradesh, Jharkhand, Chhattisgarh and Odisha to provide working models for biodiversity conservation in different biogeographic areas. ***The Institute implemented the project in partnership with WWF-India, State Forest Research Institute, Arunachal Pradesh, North Eastern Regional Institute of Science and Technology, Arunachal Pradesh, and Nature Care and Disaster Management Society, Arunachal Pradesh.*** The main objective of the project was facilitating and strengthening community initiatives for biodiversity conservation and enhancing livelihoods for local communities. The overall aim of this project was to develop viable, replicable and effective conservation mechanism through community based resource management system in bio-culturally rich Arunachal Pradesh. The area covered under the project included (1) Tawang-West Kameng proposed Biosphere Reserve (TWKBR) in Tawang and West Kameng districts of Arunachal Pradesh, which has been designated as World Peace Park and also proposed for high altitude Biosphere Reserve, and (2) Apatani plateau in Lower Subansiri district of Arunachal Pradesh, which is proposed as UNESCO's Globally Important Agriculture Heritage Site. The issues addressed through this project are (i) conservation of ecologically and socially valuable wild flora and fauna; (ii) restriction on unsustainable extraction of timbers and NTFPs; (iii) prohibition of hunting with exception for ritualistic purpose; (iv) revival of threatened wild flora and fauna through *in-situ* or *ex-situ* conservation; and (v) revenue generation and livelihood promotion.

The key activities carried out in the project villages included formation of village **institution building by creating 22 Biodiversity Management Committees (BMCs), creation/strengthening of a series of Community Conserved Area (CCA) and Sacred Groves for *in-situ* and *ex-situ* conservation; p**lantation of economically important species (75 ha), MAPs (230 ha), *Taxus wallichiana* (145 ha), *Alnus nepalensis* (40 ha), *Michelia champaca* (30 ha); distribution of 130 LPG sets to BPL families and introduction of bio-briquette that reduced pressure on forest and enhances the quality of life of women in particular; promoting **community based tourism (CBT);** strengthening of culturally patterned livelihoods such as paddy-cum-fish cultivation by distributing over 3 lakh fish seedlings to 460 families, piggery through distribution of 190 piglets in 18 project villages, beekeeping, capacity enhancement through training to over 100 farmers on appropriate low-cost technologies and over 220 villagers on CBT, gender focused entrepreneurship like tailoring, weaving, handicrafts, etc. Many of the activities such as creation of BMC were quite new to the state. BMCs in project villages are made sustainable with their adoption by Arunachal Pradesh Biodiversity Board (APBB). To be financially self-sustaining, the BMCs have developed their corpus fund and started generating funds from sources like APBB and CAMPA. **Development of Peoples' Biodiversity Register (PBR) and training locals as village botanists were other activities of the contribution.**

Three conservation and livelihood concerned policies/guidelines for the State of Arunachal Pradesh, i.e., (1) **Guidelines for Promotion of Homestays in Arunachal Pradesh,** (2) **Guidelines for promotion and management of Community Conserved Areas (CCA) in Arunachal Pradesh,** and (3) Arunachal Pradesh Ecotourism Policy were developed under the project. ***The project also developed a strong interface with various departments of the Government of Arunachal Pradesh thereby generating new opportunities for the various activities of the project to sustain themselves***.

The project activities were continuously monitored at various levels by State Level Steering Committee, The Technical Consultant of MoEF. The project has been awarded SCHOLL Research Challenge Award 2010 for high calibre action research in development and governance. The project also aimed at addressing serious ecological problems shifting cultivation through technological interventions, problem of hunting by making alternate sources of meat available and creating awareness, and developing ***protocols to benefit the locals economically*** from wildlife conservation and promoting their long term commitments towards biodiversity conservation.

Theme

# BIOTECHNOLOGICAL APPLICATIONS (BTA)

The thematic area 'Biotechnological Applications' is complementary to the first theme of the group, i.e., Biodiversity Conservation and Management. The background of the theme is based on identification, documentation and application of the bioresources of Indian Himalayan Region (IHR). Studies related to three major groups of bioresources *viz*., plants, animals and micro-organisms are the main aspects of the theme. A thorough understanding of the mechanism of plant adaptation to stress, be it physiological, biochemical or molecular in aspect, is extremely relevant for increasing productivity of plants, the primary producers. Plant propagation packages, addressing the need of local people, have been developed using conventional and biotechnological tools.

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

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

The Microbiology Laboratory of the Institute has taken initiatives on various microbiological research aspects of IHR, covering a wide altitudinal range in last two decades. The focus of these studies has been on the isolation, characterization and associated applications. A high altitude microbial culture collection, including extremophiles, has been developed in the laboratory over the years. One important issue, complementary to these studies, that requires attention is 'ecological resilience' possessed by these micro-organisms. Besides, microbial activities performed under extreme climates are likely to have applications of 'environmental' as well as 'biotechnological' importance. The present proposal is, thus, formulated to address these issues considering the characterization of extremophiles with particular reference to their biotechnological applications and ecological resilience. Selected cultures, that have been established as suitable bioinoculants, will be used for conducting nethouse / greenhouse / field assays with particular reference to (1) improved plant health, and (2) reducing the heavy metal load at contaminated sites (in collaboration with Kullu and Sikkim unit).

**Objectives**

- Phenotypic and genotypic characterization of extremophiles, inhabiting the extreme climatic regions in IHR (HQs), heavy metal contaminated sites (Kullu unit) and rhizosphere micro-organisms (Sikkim).
- Determination of microbial activities, with special

reference to production of secondary metabolites, such as enzymes, pigments, antimicrobials, with reference to the role of suboptimal conditions on microbial growth and related activities, in view of their survival under extreme temperature conditions (HQs).

- Applications of promising microbial cultures in environmentally important aspects, such as, improved plant growth through inoculation, biological hardening of *in vitro* raised and conventionally developed plants (HQs & Sikkim unit), and bioremediation with particular reference to heavy metal contaminated sites (Kullu unit) under the 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**

- Twenty eight bacterial cultures, isolated from Soldhar and Ringigad hot springs in Uttarakhand, have been characterized and identified with particular reference to wide temperature and pH tolerance and production of enzymes in thermophilic range. Based on 16S rDNA similarity, 20 bacterial isolates belonged to *Bacillus licheniformis*, 5 to *Paenibacillus ehimensis* and 1 each to *B. sonorensis*, *Bacillus tequilensis* and *Staphylococcus epidermidis*. Bacterial isolates exhibited tolerance to wide temperature range (20–80 °C), covering mesophilic (+11° to +45 °C) to thermophilic (+46 ° to +75 °C); few approaching the hyperthermophilic range (+76 °C). The isolates also tolerated wide pH range (4–14) and moderate salt concentration. The optimum growth of bacterial isolates was observed at 55 °C and 7 pH, respectively. Out of 28 isolates, 25 produced lipase, 25 amylase, 24 cellulase, 22 protease and 13 xylanase at 55 and 65 °C. Tolerance to wide temperature and pH range and production of enzymes in thermophilic temperature range are considered as indicators of ecological competence of these bacterial isolates for colonizing the high temperature environment. The nucleotide sequences of all the bacterial cultures have been accessioned by NCBI.
- Phenolic and flavonoid contents in leaf extracts of *Bergenia ligulata* have been analysed for their contribution in antimicrobial and antioxidant activities. The extracts were prepared in three solvents (separately) following maceration and Soxhelt methods. The antimicrobial activity was tested using *disc diffusion assay* against a range of micro-organisms along with the determination of minimum inhibitory concentration (MIC), while the antioxidant activity was performed following DPPH assay. In general, the methanolic extracts prepared through maceration favoured the determination of antimicrobial as well as the antioxidant activities. Maximum values for phenolic and flavonoid **content were obtained** in macerated methanolic and ethyl acetate extracts, respectively.
- *Experiments on hardening of tissue culture raised plants of Rhododendron niveum and Phoenix rupicola, important plant species of Sikkim, are under progress. Plant growth*-promoting rhizobacteria (species of *Bacillus* and *Pseudomonas*) in view of their plant growth promotion and biocontrol properties have been used as a tool of biological hardening at the time of lab to land transfer of these plants. Bacterial inoculum in varying concentrations has been applied for standardization of this microbe-based technology. *Treatment with 1 ml bacterial medium has shown better effect on plant growth in case of P. rupicola* (Fig. 49a&b).
- *Plant growth*-promoting rhizobacteria are also being used to study their bioremediation potential with a view of scaling down the use of pesticides in apple orchards of Himachal Pradesh. Apple orchards namely Seubag, Khaknal and Palchan have been selected for this study. A preliminary study to demonstrate the effect of bacterial inoculation on soil bioavailability of cadmium and its transfer from contaminated soil to different plant parts has been completed. Bioinoculants namely *Pseudomonas putida* and *Bacillus subtilis* and two wheat cultivars (*Triticum aestivum* L Var. HPW 184 and HPW 236) have been used as test species for this study.


Fig. 49: Inoculation trial (a) control, and (b) bacterial inoculated plants of *P. rupicola.*

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

The Indian Himalayan Region (IHR), a part of the Himalayan region is very well known for its biological and cultural diversity. It represents tropical, sub-tropical, temperate, sub-alpine, alpine and tundra biomes/ecosystems. These ecosystems provide medicine, food, fuel, fodder, timber and various other ecosystem services to the inhabitants of the IHR. The high anthropogenic pressures coupled with changing environmental conditions has resulted in rapid depletion of the economically important components of biodiversity. At present, 144 species of vascular plants have been listed in the Red Data Book of Indian Plants and 120 species of medicinal plants have been categorized under different threat categories of International Union for Conservation of Nature (IUCN). About 90% raw material of medicinal plants in the global market is based on the wild harvesting. The rapid depletion of forest cover has resulted towards the climate change in the region. This has adversely affected the sustenance/security of inhabitants across the IHR.

Realizing the importance of biodiversity for the sustenance of inhabitants and overall environmental conservation, attempts at local, regional, national and global levels have increased considerably and concerns to evolve workable strategies by researchers and various others have been initiated at different levels for conservation and sustainable development. In view of this the present project focuses on the following objectives:

**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, and 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 establishing *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**

***Head Quarters (HQs), Kosi-Katarmal, Almora***

- *Propagation protocols of Valeriana jatamansi and Gingko biloba using tissue culture have been initiated.* In case of *Valeriana jatamansi* nodal explants responded best in Murashige and Skoog (MS) basal medium supplemented with 1.5 µM 6-benzylaminopurine (BAP), 0.5 µM α-napthalene acetic acid (NAA) and 0.1 µM gibberellic acid ($GA_3$);an average of 2.33 shoots/explant with shoot length of 3.20 cm/, average leaf number of 15.33 leaf/explant, root no. of 27.5 roots/explant and a mean root length of 50 cm was achieved Plant survival rate of 91% was achieved after acclimatization (Fig. 50). In case of *Gingko biloba* preliminary experiments on the establishment of explants was done. Nodal segments from mature female tree were established in hormone free MS basal medium; callus was induced on MS medium supplemented with different concentrations of BAP and auxin. Further experiments on shoot multiplication and rooting response are under progress.
- *Chemical investigation using total phenolic content, flavonoids and antioxidant activities was evaluated in different altitudinal ranges (2500–3900 m asl) of Nardostachys jatamansi.* Results revealed that total phenolic, flavonoid and tannin content increases significantly with increasing altitudes and the maximum content was observed in the populations located at 3900 m.

- Seasonal variation in ginkgolide content was observed and the highest level of ginkgolide A [1.5% dry wt basis] and ginkgolide B [0.19%] was recorded in samples collected during the month of June. Ginkgolide a (GBA) ranged from 0.058–1.5% while ginkgolide B (GBB) ranged from 0.12–0.19% throughout the season.
- *Towards characterization of different Podophyllum species using molecular markers,* two ITS [internal transcribe spacer- nuclear ribosomal cistron 18S-5.8S-26S) region] primers were used (Fig. 51). Some podophyllotoxin pathway specific genes were also identified and their expression is in progress.
- Poly cross mating in *Artemisia. annua* was carried out for gene pool exploitation. In F2 generation a wide range of variation in artemesinin content (0.06–0.33%) has been observed following the Mendelian pattern.
- Accession of different multipurpose species were done and maintained in the Surya Kunj (an *ex situ* conservation area of GBPIHED). A total of 24 species from diverse localities were collected and are growing in Suryakunj.

***Sikkim Unit***

- Propagation protocol of *Hedychium spicatum* through conventional method was initiated and five underground segment categories (full, upper half, lower half, vertical halved, and current year) were sown in open beds, using random design. Data collection on percentage rooting is under progress.
- Seed germination protocol of *Pandanus nepalensis* showed that treatment with $NaHClO_3$ for 60min significantly enhanced maximum seedling emergence (61.7%) over control (30%; Fig. 52), and overall seedling growth, seedling root length (13.8mm over control of 10mm) and upper ground dry weight (0.152 g over control of 0.116 g). Among the different presoaking treatments, *Spondias axillaries* seeds showed maximum seedling emergence (up to 80%) in $NaHClO_3$ (45 min) and $H_2O_2$ (30%) as compared to control.
- To induce germination in somatic embryos of *Quercus lamellosa and Q. pachyphylla*, embryos were sub-cultured onto the WP medium containing different concentrations of BAP, $GA_3$, 2,4–D and IBA. The various stages of somatic embryogenesis, viz; globular, heart and torpedo shapes were obtained, however, germination failed in the culture. Further experiments on the germination of somatic embryos are under progress.
- An efficient regeneration protocol for rapid multiplication of *R. niveum (State tree of Sikkim)* was developed. Nearly 90% of the culture exhibited axillary bud sprouting and multiple shoot formation from nodal segments derived from *in vitro* seedling on Anderson medium supplemented with 25 µM 2iP with phytagel (0.3%). Similarly, micropropagation of *R. griffithianum* using solid and liquid cultures was developed. About 90% of *in vitro* regenerated shoots were successfully rooted ex vitro by giving a pulse treatment of 1.0 µM IBA for 15 min, followed by their transfer to peat moss and garden soil. The regenerated plantlets were potted and acclimatized successfully in a growth chamber and then moved to the greenhouse (Fig. 53a & b).
- Over 650 seedlings of *R. maddeni* were distributed to different stakeholders i.e., State Forest Department, local inhabitants and NGOs. 100 seedlings of *Rhododendron* spp. were planted at Zoological Park, Gangtok on the World Environment Day.
- A training workshop to promote outreach through Conservation Education was conducted at Sikkim Unit, Pangthang (sponsored by DNA club, DBT). A total of 106 participants from 4 different schools of Gangtok participated. In addition, interactive of meeting farmers–scientists on wild edible fruit trees of the Sikkim Himalaya was organized on March 13, 2014 at the unit wherein over 40 participants including progressive farmers and self help groups from Lower and Upper Tintek, Lindok, Dokshing and Changrang villages participated. The participants were given exposure about the importance of wild edible fruit trees.

***Himachal Unit***

- Seed germination of *Carpinus viminea* was initiated. Treatment of *Carpinus viminea* seeds with $GA_3$ 35µM and $KNO_3$ 130mM increased mean germination percentage to 76.67% as compared to 50% in control condition. High germination percentage was also observed in $KNO_3$ (170mM, 150mM), $GA_3$ (15µM & 25µM) and IAA (15µM) (Fig. 54).
- Phytochemical assessment and antioxidant activity, of different parts of *Withania somnifera* was analysed. Maximum mean concentrations of total phenolics and flavonoids were found in fruits and stems. Mean DPPH, ABTS and FRAP activities were found in methanolic extracts of stems, roots and leaves, respectively (Table 15).
- *In-vitro* cultures of *Olea ferruginea* from nodal explants were established on MS media containing single and combination of different growths and their growth performance is under observation. The

*in-vitro* developed shoots were kept in rooting media but cultures became brown and later dried up. Further experiments are under progress.

- Training Programmes were organized in Government Senior Secondary School, Drang, Distt. Mandi Himachal Pradesh on "Biodiversity Conservation and Management in Relation to Climate Change". Participatory Rural Appraisal exercise; and Qualitative and quantitative assessment of biodiversity was done. Pre training programme feedback and post training programme feedback were taken. The training programme showed significant improvement in the skill of the participants about biodiversity and climate change. A total of 191 participants took part.

Table 15: Total phenolics contents [mg tannic acid equivalents/g fresh weight], total flavonoids contents [mg quiercetin equivalenets/g fresh weight], DPPH [%], ABTS [%] and FRAP [µg Fe (II)/g fresh weight] of methanolic extracts of different parts of *Withania somnifera L plants (n=18)*

| Plants/ parts extracts | | Total compounds | | Antioxidant activities | | |
|---|---|---|---|---|---|---|
| | | Phenolics | Flavonoids | DPPH | ABTS | FRAP |
| Roots | Mean | 200.91 | 53.45 | 84.24 | 85.34 | 4.16 |
| | Min. | 135.44 | 27.58 | 75.50 | 18.39 | 0.54 |
| | Max. | 269.60 | 99.28 | 89.11 | 99.72 | 6.18 |
| Stems | Mean | 127.24 | 93.71 | 86.00 | 62.83 | 5.17 |
| | Min. | 107.31 | 75.06 | 81.66 | 5.80 | 3.48 |
| | Max. | 152.59 | 116.90 | 88.26 | 88.26 | 6.82 |
| Leaves | Mean | 143.02 | 39.38 | 50.58 | 44.19 | 6.57 |
| | Min. | 87.12 | 22.18 | 21.39 | 4.24 | 5.57 |
| | Max. | 168.07 | 60.19 | 74.55 | 75.11 | 7.38 |
| Fruits | Mean | 225.71 | 50.99 | 38.20 | 54.01 | 5.79 |
| | Min. | 177.28 | 40.70 | 25.50 | 15.28 | 2.81 |
| | Max. | 274.60 | 64.74 | 54.09 | 90.95 | 6.91 |

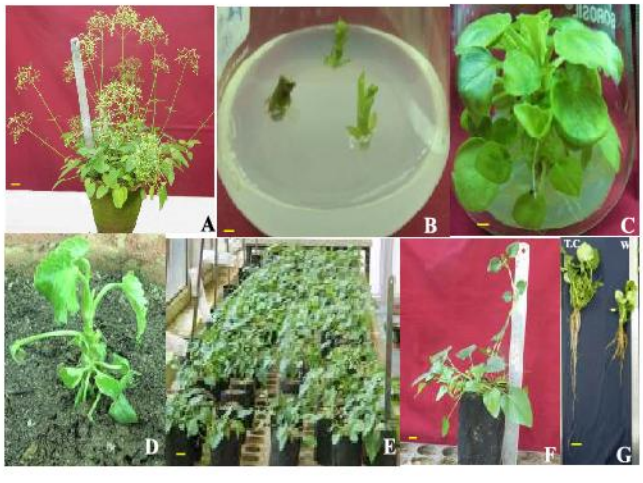



Fig. 50: *In vitro* regeneration of *V. jatamansi* and establishment of plants in soil (A-G). A: Mother plant of *V. jatamansi*, the source of explant (bar 5 cm), B: Nodal explants cultured on MS medium (bar 2 cm), C: Induction of multiple shoots and roots from 10 week old culture (bar 2 cm), D: Transfer of *in vitro* raised plants to soil (bar 1cm), E: Acclimatization of plants in green house (bar 5cm), F: Established tissue culture raised plant after 6 months growth in a polybag (bar 1cm), G: Well developed one year old & tissue culture raised plant with profuse and well established root system (bar 5 cm).

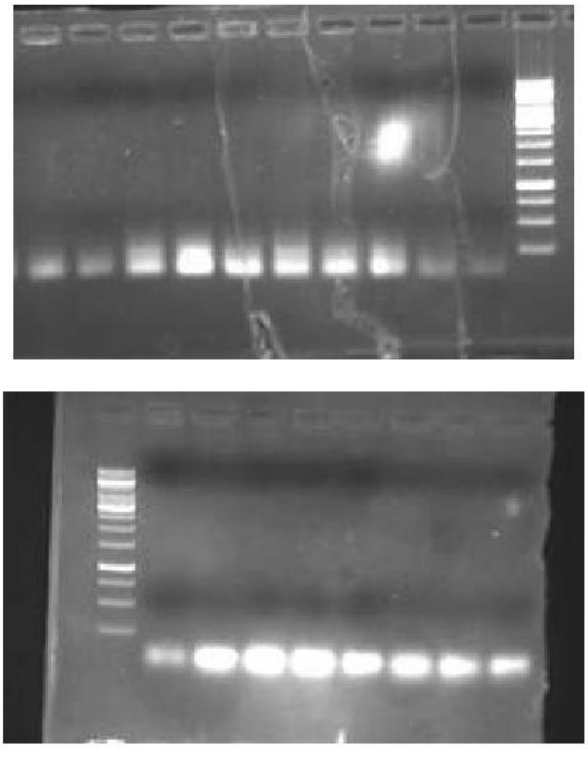


Fig. 51: Separation of *Podophyllum peltatum* and *P. hexandrum using* ITS primers.

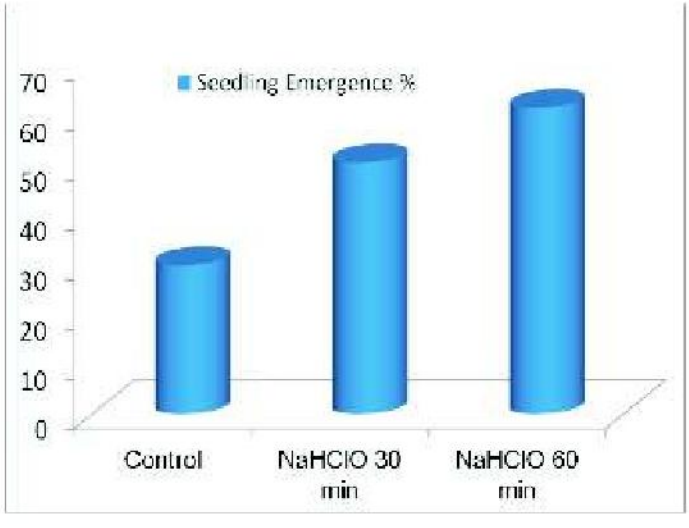



Fig. 52: Effect of pre-sowing chemical treatments on seedling emergence of *Pandanus nepalensis*.


*Fig. 53: In vitro* propagation of *R. niveum*, (a) established shoots derived from nodal segment grown on AM medium, and (b) Hardened plants in the greenhouse.

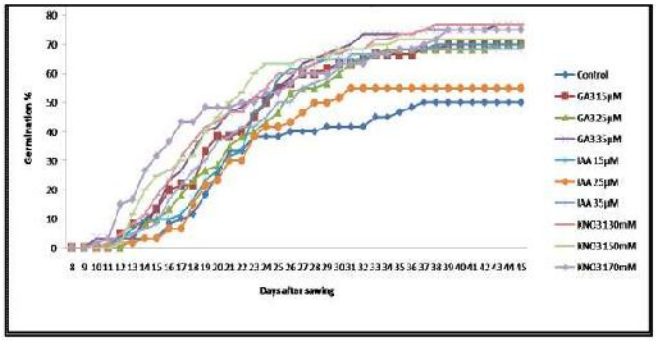



Fig. 54: Germination (%) of *C.viminea* seeds following pretreatment with different growth regulators.

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

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

**Objectives**

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

**Achievements**

- Production of laccase by a cold and pH tolerant strain of *Penicillium pinophilum* has been investigated under different cultural conditions of up to 35 days of incubation.
- The estimations were conducted at 3 temperatures (15, 25 and 35 °C), a range of pH (3.5–11.5), and in presence of supplements including carbon and nitrogen sources and vitamins and antibiotics.
- Optimum production of laccase was recorded at 25 °C and 7.5 pH. The production of enzyme was recorded maximum on day 28 following a slow decline at day 35 of incubation.
- Fructose and potassium nitrate among nutritional supplements, chloramphenicol among antibiotics and folic acid among vitamins were found to be the best enhancers for production of laccase.
- Relatively lower but consistent production of laccase for a longer period is likely to be an ecologically important phenomenon under low temperature environment.

**Determination of Antimicrobial Properties of Medicinal Value of *Ginkgo Biloba* L., Growing in Indian Himalayan Region *(2013–2015, CSIR, New Delhi)***

Medicinal plants are known to produce a diverse range of bioactive molecules, making them a rich source of different types of medicines. *Ginkgo biloba* L., often referred as living fossil, is known to possess a large number of pharmaceutically important flavonoids, glycosides and ginkgolides which improve blood flow, act as antioxidants and mainly used as

memory enhancers and anti-vertigo agents. These phytochemicals need attention for their potential of antimicrobial activity with regard to their use in treating infectious diseases.

**Objectives**

- Collection of *G. biloba* plant samples from different locations in IHR.
- Screening of antimicrobial activity of *G. biloba* plant parts (mainly leaves) against microbes (bacteria, actinomycetes and fungi).
- Chemical determination of the antimicrobial metabolites.
- Separation and purification of antimicrobial metabolites from leaf extracts of *G. biloba.*

**Achievements**

- Influence of location, seasonal variation and solvent system in production of phytochemicals and antioxidants from ginkgo leaves has been determined. Total phenolic and flavonoid contents as well as antioxidants were estimated maximum in autumn. Among solvents, acetone / water extracts gave best results for phenolic and flavonoid contents while methanolic extracts were best for antioxidants. Phenolic content, the predominant indicator of phytochemicals, showed significant correlation with antioxidant activity.
- Factorial analysis among locations, seasons and solvents with respect to the phyotchemicals and antioxidants, was found to be statistically significant. Presence of phytochemicals along with the protective feature in the form of antioxidants is indicative of the importance of this species in the pharmacological industry.

*Summary of Completed Project / Activity*

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

Fish farming has great potential to provide food security, nutritional benefits, employment generation and providing additional income, to resource poor small and marginal, farmers. Due to low investment and high return per unit area and time coupled with great potential for socioeconomic development, it is being popularized among the rural poor. Compared to the mean national pond production (2.4 tons/ha/year), a yield level of 6-8 tons/ha/year is being realized by several farmers in mid hills of Uttarakhand. There are several constraints to realize the actual potential available in fish farming. Mycoses seem to be the major constraint in the mid hills. Thus, investigation on fish diseases, their etiology, epidemiology and integrated management in the fragile environment of the region was undertaken. The prime goal was to develop various strategies for reducing production losses from diseases in small fish ponds. The objectives of the project are: (i) Survey of fish ponds in mid hills for Saprolegniasis, its prevalence and loss due to disease outbreak; (ii)To isolate, culture, characterize and identify fungal species causing infection in fingerlings and adult fish; (iii) To determine seasonal changes in physico-chemical and microbiological characteristics of water and ascertain variables that influence intensity of infection; (iv) To determine pathogenic potential of the isolates and their mode of infection based on clinical signs and histopathology; (v) To explore therapeutic and prophylactic measures for Saprolegniasis in fish and (vi) To create awareness and provide comprehensive understanding to the farmers in fish diseases and their integrated management.

Significant variations in values of physic-chemical variables were recorded at different sites. Water temperature ranged between 9.0 and 30.2°C and pH between 6.7-8.4. Dissolved oxygen ranged from 4.6-8.3 mg/l, BOD was from 5.4-14.8 mg/l. Conductivity and total dissolved solids were in the range of 98.2-215.7 mg/l and 49.8-102.5 mg/l, respectively. These ranges are well within the desirable range for the growth of fish. Microbiological analysis of pond waters revealed total heterotrophic plate count in the range of $20 \times 10^5$ and $54 \times 10^5$. There was no significant difference in the mean count across the locations. The coliform count ranged from 94-2400 (MPN/100 ml), the highest and lowest count being during rainy and winter seasons, respectively. In all, 31 species of extra aquatic fungi and 29 species of zoosporic fungi including virulent pathogens of fish, such as species of *Achlya*, *Aphanomyces, Brevilegnia, Leptolegnia* and *Saprolegnia* were isolated from pond water. Besides this, eight species of watermolds, viz., *Achlya flagillata*, *A. prolifera*. *Achlya* sp. *Aphanomyces laevis*, *Saprolegnia diclina*, *S. ferax*, *S. glomerata* and *S. parasitica* were isolated from fingerlings and adult fish showing symptoms of Saprolegniasis. The disease appeared as small patches causing dullness of the body colour, which grew in size and appeared as whitish wooly tufts. At later stages, lesions became brown or green as they trapped sediment or algae. On removal of fish from the water, the fungus appeared as a slimy matted mass. Saprolegniasis has been observed chronic in nature, resulting in steady losses. Average mortality in fingerlings of different carp species was recorded between 8.3-15.8%, whereas, in adult fish it was 6.3-20.2%. The mean cumulative mortality 12.8-32.41%, was highest in grass carp (27.6-32.4%) followed by silver carp (24.7-27.9%) and common carp (12.8-17.2%). Disease eventually resulted in substantially high cumulative mortality in these species. Incidence and intensity of diseases and mortality was highest in grass carp followed by silver carp and common carp. Fresh carps fetch a premium price (Rs 200/kg) at the local market. Economic loss due to fungal infection ranged between Rs 3500 and Rs 4000 at different sites. In pathogenicity experiments *Saprolegnia parasitica, Aphanomyces laevis and Achlya flagillata appeared* virulent and caused 80-100%, 70-100% and 50-90% mortality in different species.

Hydrogen peroxide ($H_2O_2$) was found most effective in controlling Saprolegniasis. The mortality by virulent pathogens *S. parasitica* and *A laevis* was recorded between 12.5 and 25.0% at 500 ug/ml, while neither of the pathogen could establish infection on fish treated with 1000 ug/ml of $H_2O_2$. In control aquaria, without any chemical the mortality was 90-100%. Besides, NaCl (25 mg/l) and $KMnO_4$ (100 mg/l) were found effective against the disease under laboratory conditions. Two species of *Olpidiopsis* parasitic, on species of *Saprolegnia* and *Achlya* have shown promise in controlling Saprolegniasis in the laboratory; these fungi may be helpful in combating the disease in the ponds too. In all, 492 persons including 183 women participants were trained on diagnosis and management of fish diseases, with emphasis on saprolegniosis.

***Summary of Completed Project / Activity***

## Comparison of the Plant Growth Stimulating Efficiency of Pure and Complex Cold Tolerant Microbial Consortium *(17/09/2013-14/10/2013, FICCI, New Delhi)*

The project was awarded to Dr Ali Boularbah, Professor of Environmental Microbiology and Toxicology at Université Cadi-Ayyad, Morocco, under "CV Raman International Fellowship for African Researchers 2012-13 (Senior Fellow category)".

**Objectives**

- The main objective of the project was to evaluate plant growth stimulating efficiency of the psychrotolerant micro-organisms (*Bacillus subtilis* and *Aspergillus niger)*, as pure or complex microbial consortium (*B. subtilis* + *A. niger*) in order to select specific bio inoculants for stressed agro-ecosystems (colder regions under mountain ecosystem).

**Achievements**

- Significant differences in germination and other growth and yield related parameters were recorded in inoculated treatments. Co-inoculation gave better results in comparison to the single inoculation treatments.

**Fig. 55: Innoculation under net-house conditions (From right to left)- seed innoculated with (1) *A. niger* + *B. subtilis*, (2) *A. niger,* (3) *B. subtilis,* and (4) control following 20 days of sowing.**

Theme

# KNOWLEDGE PRODUCTS AND CAPACITY BUILDING (KCB)

The knowledge accumulated, documented, produced or developed over a period of time in any field related to human well being and natural resource management, environmental conservation is required to be transmitted or exchanged through capacity building efforts and needs to provide unique paradigms designed to empower all the stakeholders and enhance their institutional and human capacities for integrating environmental considerations and related issues into development planning and decision making. The level of understanding, skill, enthusiasm and values of the user groups are considered key factors in stimulating the learner's interest and appreciation of implementation of knowledge produced. In addition, one must consider a number of other factors including policies and regulations for environment, nature of resource base, local capacities, external support, and prevailing natural resource management practices that considerably influence the effectiveness of the integrated knowledge base and its implementation. With greater realization of the value of this knowledge base, for looking at issues linked to social processes and natural resource management there is increasing realization that in many ecological/ social situations, knowledge should be an integral part of a holistic and cost-effective approach to sustainable development.

The objectives of the theme are: (a) to undertake in-depth studies on documentation and validation of knowledge (traditional/indigenous/rural or developed through science & technological interventions) system of traditional/modern societies including their cultural, biological, material, spatial, landscape as well as intellectual components and their on-going interaction, as the basis for protecting and safeguarding of the modern knowledge base; (b) to utilize natural resources for income generation using local knowledge and capacities through science and technology interventions; (c) to translate existing knowledge related to Bio and natural resources etc into products; (d) to enhance capacities and skills of human beings in harnessing the potential of knowledge systems for environmental conservation and management and socio-economic development; (e) to provide opportunity for stakeholders to interact with each other and with institutions working on knowledge building/upgrading/updating system together to address research, action and policy needs of this complex subject and help to develop appropriate 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 (RTC) *(2012–2017, In-house)*

The Indian Himalayan mountains are among the most fragile and complex ecosystems in the world. Majority of population in this region is engaged in agricultural and allied activities, from which they are neither able to generate economic surplus nor to find off-farm employment opportunities. They live in geographical isolation under ecologically sensitive and

economically constrained conditions and face a range of socio-economic and environmental problems. Poor access to appropriate technologies due to difficult topography and tough mountain conditions is one of the major causes of poverty, drudgery and natural resource degradation in the Indian central Himalaya.Therefore, attaining livelihood security and sustainable food production through efficient management of locally available natural resources and environmental protection have always been challenging in the context of mountains. Because of limited opportunities of economic development within the region, frustrated youth are migrating in large numbers to the other parts of the country in search of employment. Thus, to minimize the existing rate of migration on the one hand and to utilize diverse bioresources sustainably on the other, requires cost-effective, simple practices and technological interventions in most of the sectors of rural economy so as to provide viable alternatives for improving livelihood and food security of growing populations in a sustained manner.

The present activities being carried out in the project are expected to develop a resource conservation and sustainable utilization model of natural resource management. In addition, capacity building and generation of year round employment opportunities should positively impact the stakeholders. Attainment of livelihood security coupled with food, nutrition, energy and environmental security will ensure better quality of life on a sustained basis. Therefore, introduction/development of appropriate & hill/mountain specific technologies and the requisite training of local farmers are two important aspects required in the transfer of technology in areas where needed.

**Objectives**

- To provide various hill specific, low cost technological interventions based on locally available resources along with capacity building (through trainings/live demonstrations/ 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 in specialized skills on relatively long term basis, and to achieve livelihood security so as to achieve overall improvement in the quality of life of rural folk.

**Achievements**

- A total of 39 technologies were introduced, demonstrated, tested/modified and maintained at the RTC (HQs), Triyuginarayan (Garhwal Unit) and Pangthang (Sikkim Unit) with a view to replicate and/ or disseminate to user groups.
- During the reported period a total of 17 training and awareness programmes were conducted for different user groups (farmers/ officials selected by Govt. organizations, Non Government organizations, Institute programmes, students, etc.) of which 36% training/ awareness programmes were organized by the Institute, 22% Other Govt. organizations, 14% Watershed management department, 14% NGOs, and 14% students (Fig. 56). A total of 791 persons (Female, 339 and Male, 452) covering 6 districts and 32 villages of Uttarakhand state were benefited (Table 17).
- Technical guidance and support for infrastructure development were provided for field implementation for different selected sites which include 15 protected cultivations (Polyhouse, Nethouse, etc.), 10 vegetable cultivations, 4 Vermicomposting models, 2 water harvesting tanks for fish farming, 6 Poultry farming models, 1000 fingerlings, 400 fodder samplings and a variety of various vegetable plants and seeds.
- Identified and prioritized potential resources and options for sustainable development of disaster-affected rural landscape of Kedar valley through

Table 16: Training and Capacity Building (April 2013–March 2014)

| Trainees | Total | Male | Female |
|---|---|---|---|
| Farmers selected by NGOs | 182 | 91 | 91 |
| Farmers/officials selected by | 218 | 168 | 50 |
| Institute programs | 220 | 97 | 131 |
| Students | 163 | 106 | 57 |
| Total | 741 | 432 | 309 |
| Districts covered | 6 | | |
| Villages covered | 32 | | |

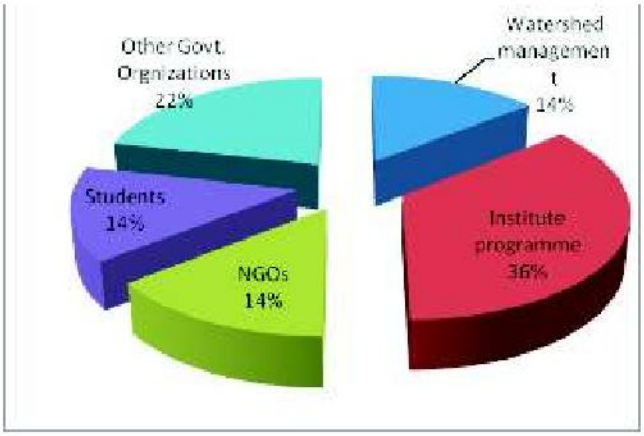



Fig. 56: Training & Capacity Building programme (2013–2014).

*Valeriana wallichii* *Innula racemosa*

Fig. 57: Training, demonstration and field implementation.

simple technological interventions. Adopted four (4) disaster affected village clusters (each cluster has 5 villages) in Kedar valley for empowering human resources particularly women and unemployed youths and farmers (Fig. 57).

## Enhancement of Livelihood Security through Sustainable Farming Systems and Related Farm Enterprises in North-West Himalaya *(2007–2014, NAIP/ICAR)*

The concept of livelihood diversification is emerging as a survival strategy of rural households in developing countries. The rural people are looking for diverse opportunities to increase and stabilize their incomes, which are determined by their portfolio of assets - social, human, financial, natural and physical capital. The contribution made by livelihood diversification to rural livelihoods is a significant one, which has often been ignored by policy makers who have chosen to focus their activities on agriculture. The livelihood diversification activities are of increasing importance for rural poor people empowerment through additional income earning and improvement in family welfare. Attaining livelihood security, sustainable food production and environmental protection has always been a challenging task in the Himalayan regions. Moreover, the natural resources are in poor status because of high dependency on them for diverse subsistence needs of the rural communities. Land degradation is a major environmental and socio-economic problem with negative effects on the livelihoods of two billion people, 90% of whom are living in developing countries. Rehabilitation of degraded abandoned lands is important from regional, national and global dimensions of sustainable rural development. Though numerous land rehabilitation projects have been implemented in the Himalayan region, the impact has, by and large, been poor because of inappropriate technologies, policies and implementation mechanisms. Hence, there is a need to develop some potential interventions which not only combat the process of desertification, but also enhance the sustainable rural livelihoods of inhabitants of Himalayan regions.

**Objectives**

- To develop selected prototypes (models) for increasing community livelihood on village commons (i.e. Van-panchayat and other community lands) and improve natural resource status in the identified village micro-watersheds.
- To document indigenous knowledge, develop local capacity and strengthen village institution for sustained people's participation and development of natural resource management.
- To develop village information system for decision support.
- To identify indicators of sustainability for the perceived success and failure of farming systems in

target districts in terms of equity (including gender), production and environmental stability, and standardize a methodology of such indicators.

**Achievements**

- A total of 24 hectare village common degraded land was brought under development of different rehabilitation models (i.e. MPT models 10 ha, Horticulture 13 ha and MAPs 1.0 ha) and a total of 3900 seedlings of various horticultural crops i.e. Pear *(Prunus persica)* – 350, Apricot (*Prunus armenica*) - 1100, Walnut (*Juglans regia*) - 800, Apple (Malus sp), 200 Peach (Pyrus communis) - 400, and Plum (*Prunus domestica*) - 600 were planted in three village clusters.
- To arrest the mortality of plant seedlings due to water scarcity, five cost effective water harvesting tanks with 12500 litres water storage capacity were constructed in different developed models in Manjgaon and Jamnikhal village clusters.
- In horticultural model, Plum trees showed the maximum survival of 88.2%, followed by Walnut 87.3%, Apple 87%, Apricot 83.8%, Peach 79%, and Pear 77.3% trees. Among the plant species planted under different prototypes the results illustrate that *Quercus glauca* had maximum survival of 79% followed by *Sapindus* spp, *Grewia oppositifolia* and *Morus alba* (76%). Other species, i.e. *Syzygium cumini* exhibited 71% of survival followed by *Bauhinia purpuria* (69.3%), *Celtis australis* 69%, and *Melia azedarach* (64%).

## Threat Assessment and Conservation of Himalayan Silver Birch (*Betula utilis* D.Don): A Keystone Species in Timberline Zone of Central Himalaya, Uttarakhand *(2012–2015, SERB, DST, New Delhi)*

The Central Himalaya is a reservoir of temperate biodiversity and is mostly occupied with timberline and alpine vegetation. The tree line zones are mainly dominated by Himalayan birch and generally cover the ecotone or buffer zone between the coniferous forests and the sub-alpine and alpine areas. 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 However, these sensitive ecosystems in Central Himalaya are now beginning to show signs of fragmentation and degradation by exogenous forces like economic development which produces a transition from subsistence to market economies, and mass tourism increase. The Himalayan silver birch (*Betula utilis*) is a multipurpose tree species belonging to the family Betulaceae. It is considered a keystone species of timberline zone sensitive to climate change and grows in moist cool conditions under complex and unique habitat and also has socio-cultural and religious value for people inhabiting in the region. It generally grows in sub-montane to alpine regions near moist places in association with *Cedrus deodara, Taxus baccata, Pinus wallichiana, Asculus indica, Abies pindrow, Acer acuminatum, Sorbus aucuparia, Prunus cornuta and Salix spp*.

**Objectives**

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

**Achievements**

- In the south aspect all the species layers were found in contagious pattern but appeared to be different in

Fig. 58: Anthropogenic pressure on *Betula utilis* in Tolma and surrounding settlements.

the north aspect, i.e. 50% in random & 50% in Contagious pattern for both tree & sapling layers of the species. The seedling and shrub layers were found 33% & 15% random and 67% & 85% in contagious pattern, respectively.

- In the south aspect diversity range started from 0.12 to 3.47 & for north aspect these were 0.56 to 2.62. The maximum diversity recorded for both aspects was herbaceous stratum and the minimum diversity for tree layer range from 0.12 to 0.56.
- The overall structure of Valley of Flowers forest is formed by 45.86% of seedlings, 27.03% of saplings and remaining 27.10 % adult trees of which *Betula utilis* contributes about 90 % in tree layer, 7% in sapling layer and 51% in the seedling layer in pure forest. However, in Tolma region the forest is formed by 52.27% of seedling, 19.95% of sapling and 52.27 % forest comprises of adult trees of which *B.utilis* contributes 78% in tree layer, 58% in sapling layer and 57% in seedling layer in pure forest.
- The maximum anthropogenic pressure is found on *C. deodara* (5185.14 kg) followed by *B. utilis* (4787.48 kg), *A. pindrow* (4642.14 kg) and *T. baccata* ( 3373.5 kg) in the terms of fuel wood, fodder, timber and other purposes (heating room, boiling water etc) during the summer settlement (for six months) in the Dhaully valley (Fig. 58).

## Community Driven Climate Resilient Hill Farming in Village Ecosystem of *North-West Himalaya,* Uttarakhand *(2011–2014, NICRA/ ICAR)*

Many rural/indigenous communities across the Indian Himalayan region and particularly in Central Himalaya still follow traditional lifestyles and are heavily dependent on natural resources for their livelihood. Recently, it has been increasingly recognized that climate variability/change is one of the most important global environmental challenges facing humanity, which has its implications on food production, natural ecosystems, retreat of glaciers and fresh water supply and human and animal health and overall human well being. Marginal traditional farmers have a great experience of adapting to their complex, diverse and risk prone environment. However, agriculture in the hills is now becoming even more difficult and risky because of greater unpredictability in the timing of rainy seasons and the pattern of rainfall within seasons, making it more difficult to decide when to cultivate, sow, harvest, and needs more resources to seize the right time for planting, and maintaining crops and animals through dry spells. Heat stress, lack of water at crucial times, and pests and diseases are serious problems that climate change appears to be exacerbating. All these interact with ongoing pressures on land, soils and water resources that would exist regardless of climate change. There is an urgent need to help traditional/marginal communities adapt to the impact of climate change on climate variability or expected changes in order to secure sustainable livelihood. To do this more effectively, it is important to follow the approaches that are rooted in local knowledge and cope with strategies, in which communities are empowered to take their own decisions which are likely to be a more successful since traditional communities have a wealth of knowledge about the local environment, and have been adapting to and coping with change for years. Traditional communities already struggle to cope with existing challenges of poverty and climate shocks, but climate change could push many beyond their ability to cope or even survive. It is vital that these communities are helped to adapt to these changes.

### Objectives

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

### Achievements

- Nursery of high value low volume medicinal plant species such as Puskar mul (*Inula racemosa*), Tagar (*Valeriana wallichii*), Kutki (*Picrorrahiza kurooa*) and Kut (*Sassurea costus*) were established at Triyuginarayan village cluster at 2200m asl since climate conditions are more conducive for their large scale cultivation and has been considered one

of the potential options for adaptation and coping with changing climate scenarios.

- Community-based adaptation and coping mechanisms particularly in agriculture, livestock and forestry sectors (i.e. collection of forest based bioresources such as *Rhododendron arboretum, Ficus auriculata, Diplazium esculentum, Peonia emodi, Vibarnum mullaha, Allium humile, Angelica glauca, Carum carvi, Cinnanomum tamala,* etc. and medicinal plant cultivation for food and income generation) were identified as appropriate livelihood options and strategies to reduce vulnerability and increase resilience to climate change impact.
- In village Kaindul, potato crops grown between October – February were severely attacked at the soft root systems and at new leaf flushes by insect (not yet identified) soon after which the vegetative parts emerged causing huge economic loss. This may be attributed to frequently changing weather conditions etc.

## Assessment and Quantification of Defoliation by Insect Herbivore and its Impact on Regeneration and Population Dynamic of *Betula utilis* D. Don: A Key Stone Species of Timber Line Zone in Central Himalaya *(2013–2016, SERB, DST, New Delhi)*

*Betula utilis* D. Don (birch) locally known as 'Bhojpatra' forms treeline vegetation all along the central Himalaya, and huge forest stands of this species can be found on the northern shady slopes and ravines. It is the only broadleaved angiosperm tree species in the Himalaya which dominates an extensive area at subalpine altitudes. It shows a high freezing tolerance which enables it to form a treeline in the region. It is considered a keystone species of timberline zone and is considered sensitive to climate change. Defoliation of central Himalayan birch forests in timberline zone by insects herbivory is obviously the most important disturbance factor in these ecologically sensitive ecosystems. Recently it was reported that *Betula utilis* growing in association with *Abies pindrow, Rhododendron campanulatum,* and *Taxus baccata* between 3,300 to 3,600 m was damaged severely by defoliator moths (insects) and this is probably due to decrease in snowfall in the past 8 to 10 years and gradual increase in temperature. But, this kind of herbivore (moth) which is of serious concern for the population depletion and natural regeneration of this key stone species in timber line zone of the central Himalayan region has not yet been identified.

### Objectives

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

### Achievements

- The maximum total tree density (16.32 $m^2$) and total basal cover (67.39 $cm^2$/100 $m^2$) was found in mixed *Betula* forest in Tolma region (transition zone) of Nanda Devi Biosphere reserve as compared to another site Valley of flowers where maximum total tree density (13.88 $m^2$) was recorded in pure birch stand and maximum total basal cover (24.95 $cm^2$/100 $m^2$) in mixed Birch stand.
- Among the two sub-sites the dominance of *Betula utilis* in pure stand was found higher (99.88) as compared to mixed forest (28.74) and IVI was found higher (286.56) as compared to mixed forest (85.68) in Valley of Flowers whereas, in Tolma region IVI of *Betula utilis was* 217.31 in pure forest and 114.35 in mixed forest.
- Sapling density for *Betula utilis* was recorded maximum (14.92/100$m^2$) in Valley of Flowers as compared to Tolma region (9.32100$m^2$). *Rhododendron campanulatum* was another associate species having maximum density (3.56 & 3.2 sapling/100 $m^2$) in pure and mixed forest. In seedling layer, the total seedling density (42.48 seedlings/100 $m^2$) was found maximum in pure Birch forest in Tolma region compared to that in Valley of flowers (18.36 seedlings/100 $m^2$).

**Model Nursery Development of Valeriana Wallichii and Inula Racemosa under National Mission on Medicinal Plants *(2012–2015, HRDI/NMPB)***

The Himalayan region is a reservoir of large number of medicinal and aromatic plants (MAPs). This is largely because of the diverse ecological and climatic conditions existing in the area. Medicinal plants found in the Himalayan region include species of high ecological and economic potential (high value low volume crops). Though such species are known to have restricted habitat or distribution limits, the quality of active ingredients *i.e.*, medicine or aromatic compound varies with the environmental gradient in which they are found. A large proportion of medicinal plants are collected from the wild. The commercial demand for herbal drugs and dependence on produce harvested from the wild has led to rapid depletion of a number of MAPs from their natural habitats. Domestication and cultivation of MAPs is one of the viable options to meet the growing demands from the industries and reduce the extraction pressure on the natural habitats of MAPs. Cultivation of MAPs could provide an attractive opportunity to enhance incomes of people residing in harsh environments such as high elevation zones of Himalaya. The available data suggests that cultivation of MAPs can be economically more profitable for farmers compared to traditional crops being grown currently in such environments. Though there are no specific studies to support the ecological benefits of such interventions at present these are obvious as long as they are managed in the traditional cultivation systems. Cultivation of medicinal plants at present has limitations due to a number of factors. The most important among them is the availability of material at low prices due to large-scale collections from the wild with only collectors' labour as input. Other factors responsible for slow pace of technology adoption by the farmers include lack of appropriate agro-technology for the diverse mixtures preferred by the farmers as a contingency measure to ensure some returns even in the bad years, small & fragmented landholdings, shortage of desired planting materials, long gestation periods and lack of ensured marketing opportunities in the remote areas

Fig. 59: Various growth stages of *Valeriana wallichii* and *Inula racemosa* at nursery.

**Objectives**

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

**Achievements**

- Garhwal Unit of GBPIHED established a model nursery of *Valeriana wallichii* and *Inula racemosa in 2012* at village Majosi and Triyuginarayan, District Rudraprayag. About 1,50,000 seedlings of *Valeriana wallichii* and 25,000 of *Inula racemosa* were raised (Fig. 59).
- The seedlings of both species were grown under different microclimatic conditions e.g., Polyhouse, Polytunnel, Shadehouse and open conditions to develop appropriate package of agrotechnology for these MAPs for large scale cultivation. The seedlings of *Inula racemosa* brought from Lahaul-Spiti of Himanchal Pradesh were introduced in the Garhwal region for the first time on trial basis.

- Ironically, in the month of June 2013 due to torrential heavy rains, some part of Triyuginarayan nursery was damaged and a large number of seedlings of both species were damaged to cope with that situation, a small nursery of *Valeriana wallichii was developed at Garhwal Unit, Srinagar Garhwal where about 1 lakh seedlings were reised using various propagation methods.*

**Development of Opyimum Drying Condition for Selected Medicinal Plants of Indian Himalayan Region *(2012–2015, NMPB, AYUSH Dept., Ministry of Health, New Delhi)***

Medicinal plants play an important role in health care of majority of people all across the globe. India has one of the richest and most diverse cultural traditions associated with the cultivation and use of medicinal plants. Every step during raw herb collection, drying, storage, pre-processing, processing, storage and packing etc is important to decide the quality. It is estimated that as high as 30% of the raw material reaching the manufacturers is of low quality and is, therefore, rejected. Therefore, value addition is required to increase profitability and to reduce losses (Med herb green pages, 2009). Drying is the most common and fundamental method for post harvest preservation of medicinal plants because it allows quick protection of medicinal qualities of the plant material in an uncomplicated manner (Müller et al., 2006). Although drying accounts for 30–50% of the total cost in medicinal plant production (Qaas and Schiele, 2001), it is also essential for easy transportation; therefore, it is crucial to examine the effect and optimize the drying conditions so as to reduce the loss of active ingredients.

Quality of plant material is particularly influenced by moisture content of the produce along with relative humidity (RH) and temperature of the area where the materials are being dried. The effect of temperature and relative humidity on the sorption isotherm is of great importance as these parameters affect the mobility of the water molecules and the dynamic equilibrium between the vapour and adsorbed phases. These movements of moisture or water molecules can affect the quality of the plant materials during storage and packaging. To ascestain the exact behavior of plant material during drying, samples (rhizome) were dried in different conditions of temperatures and humidity using climate chamber. As the sorption isotherm is a characteristic property of the material, it has to be established for each individual plant species and even for separate plant organs by experiment. In the present project, five plants are under study. These are *Picrorrhiza kurrooa*, *Saussurea lappa*, *Aconitum heterophyllum*, *Swertia chirayita* and *Inula racemosa*. Out of these, two plants i.e. *Saussurea lappa* and *Inula racemosa* were selected for the second year study. Rhizomes of *Saussurea lappa* and *Inula racemosa* were procured from farmers in Ramni village (2522m), Chamoli and Samsha village (2888m), Lahul, respectively. (Fig. 60)

**Objectives**

- Collection of selected medicinal plants
- Identification of optimum drying conditions for selected medicinal plants
- Awareness workshops/ training programmes for farmers

**Achievements**

- Washed and surface dried materials (rhizomes) were processed (dried) in Climate chamber under controlled conditions of humidity and temperature. Temperature was varied from 30–50°C and RH from 30– 80%. Performance of rhizomes of selected medicinal plants during drying was studied in the form of drying curves and desorption isotherms through kinetics and thermodynamic studies.

Fig. 60: *Saussurea lappa* under cultivation in Shansha village, Lahul, Himachal Pradesh.

- Diffusion coefficients and activation energy were estimated which helped in optimizing drying phenomenon at commercial scale as well as for designing the driers. The effect of these drying conditions on medicinally important active ingredients of S. lappa plants was also studied (Fig. 61).
- The drying conditions were found to affect the costunolide and dehydrocostus lactone concentration; thermodynamic and kinetic studies of the drying data are under progress.

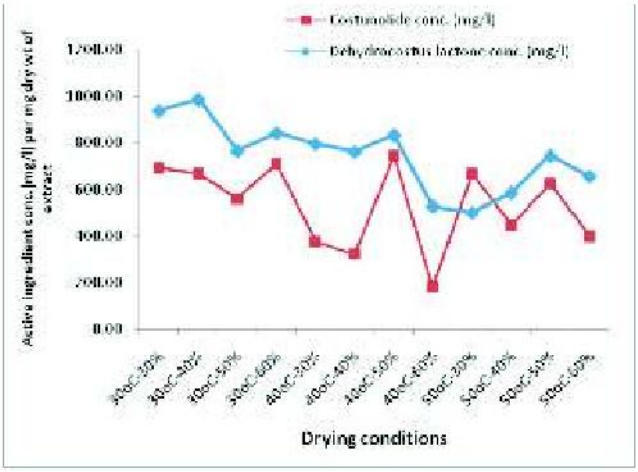



Fig. 61: Variation of costunolide and dehydrocostus lactone conc. in *Saussurea lappa* dried different drying conditions.

*Summary of Completed Project / Activity*

**Enhancement of the Livelihood Security through Sustaining Farming System and Related Farm Enterprises in North-West Himalaya** ***(2007-2014, NAIP-ICAR, New Delhi)***

Land degradation is a major environmental and socio-economic problem with negative effects on the livelihoods of two billion people, 90% of whom are living in developing countries. It is of utmost importance that local communities understand these threats and work towards broadly acceptable solutions. Restoration actions are increasingly being implemented throughout the world, supported by global policy commitments such as the Convention on Biological Diversity, the Kyoto Protocol, and the United Nations Framework Convention on Climate Change. Rehabilitation of degraded abandoned lands is important from regional, national and global dimensions of sustainable rural development. Though numerous land rehabilitation projects have been implemented in the Himalayan region, the impact has, by and large, been poor because of inappropriate technologies, policies and implementation mechanisms. Hence, there is a need to develop some potential interventions which not only combat the process of desertification, but also enhance the sustainable rural livelihoods of inhabitants of Himalayan regions. Uttarakhand has million acres of degraded/ wasteland, which is lying idle and can be brought under cultivation of fodder, fuel, timber, medicinal plants and orchard crops without curtailing the area under food crops. There is good scope in the Tehri Garhwal district for technology based improvement in the production of field crops, vegetables, fruits, fodder and other agriculture and allied livelihood activities. Realising this, three village clusters i.e. Jamnikhal, Manjgaon and Hadiya in Tehri Garhwal were identified to implement the Sustainable Rural Livelihood Security project under National Agriculture Innovation Project (NAIP). The project was implemented by the Garhwal Unit of G.B. Pant Institute of Himalayan Environment and Development, to demonstrate livelihood based approach to combat land degradation through the establishment of silvi-pasture and horticulture models.

The developed rehabilitation models of MPTs on village common degraded lands are playing a significant role in reducing drudgery of women by supplying fodder, fuel and grasses. These models also reduced the distance of traveling for women for collecting fuel wood and fodder to some extent and are saving their time that can be utilized in other household chores. These initiatives helped in demonstrating the value and potential of these rehabilitation models in terms of improving livelihoods as well as arresting land degradation. The degraded/wasteland converted into silvi-pastoral and horticulture orchards has helped in stabilizing soil, improving soil fertility and also enhancing carbon sequestration. Most importantly, the initiative has empowered the community in self management of resources. Villagers are now well aware of the basics of developing orchards. They have started to adopt and replicate horticulture models in their abandoned lands. Also, other people who are not part of this initiative are showing keen interest to take up horticulture. From the developed silvi-pastoral models, a total of 2134 kg/ha green fodder (grass) was harvested by the women folk which was assessed to be monetarily equivalent to Rs. 4268/ha at the prevailing rate in the local market. In case of horticulture models, women farmers harvested around 775 kgs of apricot, 1240 kgs of pear and 1640 kgs of plum from the entire land area with the total value of fruit harvest being estimated at Rs. 1,99,620. So far, these models have attained the age of 4-5 years. In addition, more than 500 horticulture plant seedlings were distributed to the interested farmers of three village clusters as an additional option of livelihood. Such activities are playing a catalytic role in making local communities to improve their livelihoods in a sustainable manner while harnessing the resources in ways that meet both short and long term needs

Theme

# R&D HIGHLIGHTS OF THE REGIONAL UNITS

## GARHWAL UNIT

- A detailed document on reconstruction and sustainable development of disaster-affected Kedar valley was developed and submitted to Shri Nitin Bhaduriya, IAS (the then Disaster Relief Commissioner, Govt of Uttarakhand), who has highly appreciated the efforts made by the Unit in this direction.
- Project staff working at RTC-Triyuginarayan extended great help during the Uttarakhand Disaster 2013 and provided shelter for 200 pilgrims at RTC, Triyuginarayan between 18–25 June, 2013.
- Successfully rehabilitated 25 ha of village common degraded land covering 8 prototypes under NAIP project (two restoration models (10 ha), five Horticulture models (13 ha) and one MAPs (2 ha) in three village clusters of Tehri Garhwal districts of Uttarakhand.
- Investigated the seasonal water scarcity and recorded the continuous water discharge data through integrated approach of isotope technique, remote sensing and GIS application.
- Initiated bioresource-based livelihood enhancement R&D activities and capacity building/skill development programmes in 12 disaster affected villages of upper Kedar valley for redevelopment/reconstruction.
- A total of 24 hectare village common degraded land was brought under development of different rehabilitation models (i.e. MPT models -10 ha, Horticulture -13 ha and MAPs -1.0 ha) and a *total of* 3900 seedlings of various horticultural crops i.e. Pear (Prunus persica) – 350, Apricot (Prunus armenica) - 1100, Walnut (Juglans regia) - 800, Apple (Malus sp) - 200 and Peach (Pyrus communis) - 400, and Plum (Prunus domestica) - 600, were planted in three village clusters .

## HIMACHAL UNIT

- For the Mohal Khad watershed some basic watershed maps were prepared. Three sites namely Khalyani, Khalogi and Pahnala in Kullu Valley were selected. Samples of garlic (*Allium sativum* L.), one of the important cash crops, along with top soil from different locations in Mohal Khad watershed were randomly collected. Soils were analysed for pH, electrical conductivity, available nitrogen (nitrate–nitrogen), total sodium, potassium and calcium, and garlic for number of leaves and roots; fresh and dry weights; roots, shoots and total length, bulb sizes and total sodium, potassium and calcium in roots, bulbs and leaves.
- Samples of *Brassica oleracea* L. var. *capitata*, *Brassica oleracea* L. var. *botrytis*, *Raphanus sativus* L. and *Lycopersicon esculentum* L. were collected from production and market sites in Kullu valley and analysed for Cu, Zn, Cd and Pb. The concentrations of Cu, Zn, Cd and Pb in water and soil collected from production sites during summer were found within the safe limits of Indian and FAO standards. The average concentrations of Cu and Pb in radish and cauliflower collected from production

areas during summer 2013 had exceeded safe limits of Indian, FAO/WHO and EU standards. The concentrations of Cd were found above the permissible limits of EU and FAO/WHO standards. Spinach and French bean were grown on soil amended with locally produced municipal solid waste composts (0–60%) and transfer factor of Zn, Cd and Pb exceeded its unit value in French beans, however the same was found less by a unit in spinach.

- The per cent germination and antioxidant activities in methanolic extracts of seeds of eight cultivars of pea (*Pisum sativum*) commonly grown in Kullu valley were studied. Per cent of seed germination was found highest in Early Giant, followed by Lincoln, GS-10, Ruchi, CM-Avtar, Saloni, Prachi and lowest in Anmol. Total phenolics was also found maximum in Early Giant, followed by Saloni, Ruchi, Lincoln, GS-10, CM-Avtar and Prachi, respectively. Total flavonoids were recorded highest in Ruchi, followed by Saloni, CM-Avtar, Prachi, Lincoln, GS-10 and Anmol, respectively. DPPH inhibition was shown highest by seeds of Early Giant, followed by Lincoln, CM-Avtar, Ruchi, GS-10, saloni, Anmol and Prachi, respectively.
- In Kanawar Wildlife Sanctuary of Himachal Pradesh 250 species of vascular plants, 106 economically important species and 10 forest tree communities were identified and soil samples were analysed for moisture content, pH, organic carbon and nitrogen.
- In Sainj valley of Himachal Pradesh 207 species of vascular plants 20 forest tree communities and 133 economically important species were recorded. Soil samples were collected and analysed for moisture content, pH, organic carbon and nitrogen.
- In Upper Beas Valley 250 species of vascular plants and 4 forest tree communities (i.e., *Pinus wallichiana*, *Cedrus deodara*, *Alnus nitida* and *Pinus roxburghii*) were recorded. Of the total species 49 species were bee flora, frequently visited by the bees for forage. Phenological observations were recorded on leaf fall, leaf bud initiation, flower bud initiation and leaf initiation and pink flower bud initiation, flower opening, fruit setting and fruit maturation in the marked Apple, Plum and Pear trees of the six selected orchards. The Participatory Rural Appraisal exercise and questionnaire surveys were conducted in eight villages to generate information on provisioning ecosystem services. The people use 39 plants for curing different ailments, 29 as wild edibles, 25 for fuel and 23 for fodder, etc.
- Total 16 sites representing 3 habitats and 6 aspects were surveyed and sampled between 2000–2135m in Rupasana Devi Sacred Forest (9 sites) and in Bhrighu Rishi Sacred Forest (7 sites). Total 148 species of vascular plants representing trees (13 spp.), shrubs (18spp.) and herbs (117spp.) were recorded. Both the Sacred Forests were dominated by *Cedrus deodara* community. Species were analysed for Species Diversity and Concentration of Dominance. Soil samples were analysed. Soil moisture in Rupasana Devi Sacred Forest ranged from 16.89 – 41.36%, total nitrogen, 2.24 – 2.51%; and organic carbon, 2.56 –2.51% and in Bhrighu Rishi Sacred Forest, soil moisture ranged from 11.38 – 23.57%, total nitrogen 1.87 – 2.45%, and organic carbon, 1.64 –6.17%.
- In Cold Desert Biosphere Reserve, 70 sites representing 12 habitats and 08 aspects were sampled. Total 360 species belonging to 60 families and 270 genera were identified. Among the identified species, 265 species (Angiosperms: 262; Gymnosperms: 02; and Pteridophytes: 01) of economically important plants were recorded. 32 plant communities (shrubs: 19 and herbs: 13) were identified. Species were analysed for Species Diversity (H′) and Concentration of Dominance (Cd). Soil samples were collected and analysed. Overall in the study sites, the soil moisture content ranged from 0.04–31.62%, pH, 5.48–8.09, total nitrogen (–) 0.07–1.33%, organic carbon 0.20–5.25% and organic matter, 0.34–9.05%.
- Total 60 populations, *Arnebia euchroma* (15 populations), *Dactylorhiza hatagirea* (2 populations), *Podophyllum hexandrum* (14 populations), *Angelica glauca* (12 populations), *Aconitum heterophyllum* (3 populations), *Picrorhiza kurrooa* (6 populations) and *Rheum australe* (8 populations) were studied between 2,096– 4,492m amsl in Himachal Pradesh. Seventy (70) distributional records, Bioclimatic, NDVI,

Physiographic, Topographic, Bathymetric and hydrology variables were utilized for the prediction of potential areas of *Arnebia euchroma, Angelica glauca and Podophyllum hexandrum* with the help of ecological niche modeling packages. The model test yielded satisfactory results for *Arnebia euchroma* (AUCtrain = 0.998 ± 0.055 and AUCtest= 0.978 ± 0.046), *Angelica glauca* (AUCtrain = 0.998 ± 0.215 and AUCtest= 0.941 ± 0.129) and *Podophyllum hexandrum* (AUCtrain = 0.983 ± 0.073 and AUCtest= 0.959 ± 0.048).

- Pollination Deficit Protocols (PDP) in Apple STEP sites for three consecutive years were successfully implemented. In case of apple, higher population density of *Apis cerana*, *Bombus* sp. and wild bees was revealing in orchards near natural habitats. Higher fruit set and fruit yield was observed in orchards supplemented with bee colonies irrespective of relative location of orchard with respect to natural habitat. Collection of key/native pollinators was made, so far over 50 insect visitors/pollinators were recorded from STEP site.
- Mapping of Cold Desert Biosphere Reserve in Himachal Pradesh was completed and GIS database created. The Land Use Land Cover of CDBR classified its total area into 10 classes. Each and every class was identified on the basis of signature and ground truthing. The LULC map shows that in CDBR, vegetation covers only an area of about 247.3 $km^2$ (3.19%) and all non-vegetation classes cover 7522.67 km2 (96.81%) area.
- Samples of *Withania somnifera* plants along with soils were collected from different populations of Kullu valley (Thalaut, Largi, Kolibehar, Matiana, Banala and Mohal) and total phenolics, and total favonoids contents, and antioxidant activities in methanol extracts of roots, stems, leaves and fruits were analysed using *in-vitro* assay namely DPPH,ABTS and FRAP. Maximum mean concentrations of total phenolics and flavonoids were found in fruits and stems. Mean DPPH, ABTS and FRAP activities were found in methanolic extracts of stems, roots and leaves, respectively.
- Total 9 populations of *Corylus jacquemontii*, 3 populations of *Carpinus viminea*, 2 populations of *Aconitum heterophyllum* and one population of *Buxus wallichiana* were assessed in the Kullu, Lahaul & Spiti and Chamba districts. Species were analysed for density, Species diversity and Concentration of dominance. Soil of the different populations was analysed for pH, total nitrogen, total organic carbon and C/N.
- Seed germination protocol for *Carpinus viminea* was developed. Treatment of *Carpinus viminea* seeds with GA3 35µM and $KNO_3$ 130mM increased the mean germination percentage to 76.67% as compared to 50% in control condition. High germination percentage was also observed in KNO3 170mM, KNO3 150mM, GA3 15µM, GA325µM and IAA 15µM.
- Samples of top soils from Seobag, Khaknal and Palchan apple orchards were collected during the early, mid and late dormant phases of apple growth, and were analysed for soil enzymes such as urease, dehydrogenase, alkaline and acid phosphatase.
- Nathpa-Jhakri (1500 MW), Shongthong (412 MW), Karchham-Wangtu (1000 MW), Shayang (2 MW), Tangling (3 MW), Baspa-II (300 MW) and Kashang (243 MW) HEPs in the Satluj basin were studied for the soil quality (i.e., nitrogen, phosphorus and potassium), background air quality (i.e., respirable particulate matter: PM10) and gaseous pollutants (i.e., nitrogen dioxide and sulphur dioxide). The mean highest values of PM10 at Shongtong showed 64.1±9.6 µg $m^{-3}$ and 27.5±4.9 µg $m^{-3}$ during post- monsoon and pre-monsoon periods, respectively. $NO_2$ during post-monsoon season was measured between 3 and 3.7 µg $m^{-3}$ at Shongtong and Rampur, respectively while the pre-monsoon $NO_2$ stood to be 3.4 and 4 µg $m^{-3}$ respectively at these places. $SO_2$ representing post-monsoon season stood to be from 4±0.5 to 4.5±0.5 µg $m^{-3}$ at Rampur and Shongtong HEPs, respectively and pre-monsoon season remained 3.3±0.3 and 3.7±0.4 µg $m^{-3}$ at Shongtong and Rampur HEPs respectively. The Mean N, P, and K content in soils adjacent to HEP affected areas were found to be 221, 19 and 312 kg $ha^{-1}$, respectively in the Satluj basin.
- Due to continuously increasing anthropogenic activities, solar attenuation in the form of aerosol optical depth (AOD) from 2006–2013 at 500 nm has been increasing at the rate of 0.02 per annum. On an

average, the solar flux due to atmospheric aerosols attenuated from forenoon to afternoon by 50% at 500 nm and 51% at all wavelengths (380–1025nm). Black carbon concentration (BCA) from 2009 to 2012 was found to be decreasing in a number of fire cases which stood to be 1902 during 2009–2010, 870 during 2010–2011 and 168 during 2011–2012. However, there was a slight increase in the number of fire cases (i.e., 1798) during 2012–2013 and as a result there was again a small increase in BCA in 2013. Study on Black carbon and other aerosols loading, and their impact on melting of the Parbati glacier has been initiated.

- Great Himalayan National Park was selected as a potential site for ecotourism development. The analyses of monthly profile of tourist inflow of Kullu district, which is mainly represented by tourist inflow to Manali, also indicates the pattern of demand for these services and hence provides clues for necessary provisions for hospitality, transport, etc., and scale of preparedness and management initiatives over the season periods. The examination of yearly inflow statistics suggests of 9.62 % growth in tourist inflow from 1546973 tourists in 2004 to 2886050 in 2013. The monthly distribution reveals a wavy pattern suggesting seasonality in tourism which is linked to pleasant climatic conditions during summer and autumn seasons, suggesting maximum consumer-ship for environmental amenity value based recreation/ leisure experience. The synthesis suggests average inflow of summer season i.e. April–June period around 42.88%, and the autumn period (Sept. –Oct.) around 18.49%.
- Arboretum, Herbal Gardens and Medicinal Plant Nurseries at Mohal, Doharanala and Kasol were strengthened through introduction of new accessions.
- For the promotion of Citizen Science Programme 3 Volunteer Programmes were organized jointly with Earthwatch Institute, India and involved the volunteers in the collection of data on different objectives of the project. Initially the volunteers were made aware about the project as a whole and the methodologies to be applied through LCD presentation. They they were trained practically in the field. The programmes were organized in four different modules; Module 1: Introduction of Participants, Organizations and Programme briefing; Module 2: Deliberations/Training; Module 3: Learning Sessions and Module 4: Field Surveys and Data Generations. The volunteers assisted the project research team in collection of data on qualitative and quantitative assessment of vegetation, Assessment of insect/pollinators diversity and density, phenological observation of the apple and associated crops; and different ecosystem services flowing from forest and agro-ecosystem to the inhabitants.
- Two One - Day Training Programmes on "Biodiversity Conservation and Management in Relation to Climate Change"; 01 week long on site Para-taxonomists training (June 26–30, 2013 in Apple STEP site); One day consultative meeting on "Ecotourism in Great Himalayan National Park: Status and Future Prospects"; A consultative meeting on "Present status and future prospects of farming systems under climate change regimes in Kullu valley; A One Day consultation meeting on "Watershed development and management in Kullu valley: issues and ways forward"; A One Day Consultative Meeting on – 'Implications of Climate Change for Recreational Services: Issues and Management Modalities'; and A consultative / interactve meeting on Strategic Environmental Assessment were organized. 15 exposure visits for the students, teachers and other stakeholders were also organized.
- Provided 167 seedlings of 08 medicinal plants and 29 seedlings of 04 trees to SSB, Shamshi for the Development of Campus; 73 plants of 07 species (40 ornamental; 20 hedge & 03 tree) to GSSS, Kais for Campus beautification; 45 plants of 03 species (01 medicinal, 20 hedge & 20 ornamental) to Cambridge International School, Mohal for Campus beautification; 15 plants of *Withania somnifera* to GSSS, Bajaura; and 85 plants of 12 medicinal plants, 64 plants of 11 tree species and 20 hedge plants of were provided to the inhabitants of Kullu valley.

## SIKKIM UNIT

- First time, exhaustive, ethnomedicinal study of Limbu tribe in Khangchendzonga Biosphere Reserve (Sikkim) was published.

- Development of seed germination protocol for *Aconitum ferox* was reported for the first time.
- The Khangchendzonga Sacred Landscape Yatra" – a programme under the aegis of Ministry of Environment & Forests, Govt. of India, with the support coming from FEWMD, RMDD, GBPIHED, WWF-India and KCC was successfully launched on 22 Feb 2014, which ceremoniously ended on 27 Feb 2014.
- Extensive surveys on various biodiversity conservation issues were made in five transition zone villages of Khangchendzonga Biosphere Reserve (Sikkim); 34 indicators of Biodiversity conservation and sustainability under 6 major groups were established and the data obtained was analysed.
- Priority index, based on the responses of inhabitants, were calculated for different individual indicators for each study village. For biodiversity conservation, average, forested area (76%), followed by native trees (62%) appeared at the top
- International project, 'Khangchendzonga Landscape Conservation and Development Initiative' (KLCDI, India) launched with National consultation, organized by GBPIHED, Sikkim unit (collaboration: ICIMOD, Nepal; convened: HK Badola) in Gangtok on 28–29 January 2014; proposed Khangchendzonga Landscape (India) delineated with Sikkim, and Darjeeling/Jalpaiguri districts (West Bengal). A core and two working groups formed, different partners and experts identified. 'KLCDI, India programme was apprised at high level in MoEF, Govt of India, and in the Directorate of Forests, Govt of West Bengal. Stakeholders workshop in West Bengal organized and various conservation and development issues emerged out for Feasibility Assessment of KL.
- Strengthening of *ex-situ* conservation efforts through: (i) improvement of seed germination of *Phoenix rupicola* and *Oroxylum indicum* (ii) development of *in vitro* propagation protocols for *Rhododendron niveum* (Sikkim State tree) and *Bergenia ciliata* (iii) field plantation of tissue culture and conventionally propagated plants of important Rhododendron spp. of Sikkim in 'Zoological Park', Gangtok.

**NORTH EAST UNIT**

- During the reporting year, Arunachal Pradesh Ecotourism Policy developed under the GOI-UNDP CCF-II Project entitled "Biodiversity conservation through Community Based Natural Resource Management in Arunachal Pradesh" by the Unit was followed up with the Govt. of Arunachal Pradesh for gazette notification. It is informed that the policy is at the stage of approval by the Govt. of Arunachal Pradesh.
- 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 (i.e. Arunachal Pradesh, Uttarakhand, Sikkim and Himachal Pradesh) were evaluated for their status in terms of arrival of tourists over a period, existing policies related to promotion of eco-tourism, institutional approaches to promote tourism, etc after a reconnaissance survey.
- Each site was assessed to develop as an ecotourism model integrating tourism with ecology, economy and culture and strengthening community conservation approaches to improve the quality of the product. An analysis of tourist arrivals in north eastern states revealed a positive trend in all the states over the period of 2000–2012 with Assam receiving maximum tourists while Arunachal Pradesh registered maximum percentage growth among other northeastern states.
- Data collection and analyses under the R&D project 'Monitoring and Inventorization of Biosphere Reserves (Dehang – Debang Biosphere, Arunachal Pradesh) in India using GIS and RS technology revealed that annual rainfall in DDBR varies from 2000mm to 3000mm and the peak rainy season is from the month of April to September. The temperature generally ranges from $0^0$ in winter to $30^0$ in summer.
- The vegetation of DDBR is broadly divided into 5 categories: (a) Tropical Zone which is found within an elevation of 500 – 900m, (b) Sub-tropical Zone which occurs within altitudes of 900–1800m, (c) Temperate Zone occurring at an elevation of 1800–3500m, (d) Sub-alpine Zone that extends upto 3500–4000m and is the timber line region and (e) Alpine Zone that occupies 4000–6000m

elevation extending above timber line up to snow line.

- The flora comprises of 1004 species of angiosperms, 16 species of Gymnosperms and 21 primitive plant species belonging to Angiosperms. The Faunal Resources are contributed by 133 species of butterfly, 180 species of mammals, 492 species of birds, 106 species of reptiles, 43 species of amphibians and 93 species of fishes.
- There are 21 villages within the BR with a population of about 1715 and 29 villages with a population of 8285 on the fringe area of the reserve.
- Data collection and analyses under the R&D project 'Strategic Environmental Assessment (SEA) of Hydropower Projects in the Indian Himalayan Region' revealed that Arunachal Pradesh receives enormous rainfall with annual rainfall varying from 1400 millimetres to as high as 6000 mm. Data on mean annual rainfall for last 177 years (1829–2006) showed that there is a decline in the annual rainfall in the NE Region. It was also further observed that water availability in the downstream reaches (particularly in Assam) seems to be the most important issue. The water availability includes environmental as well as social water requirements. The data on rainfall and temperature is also being recorded on daily basis in the study area.
- 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' datasets are being generated 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 sites in Lower Subansiri district in Arunachal Pradesh.
- During the survey, plant species of 18 wild edible, 8 aromatic plants and 34 medicinal plants have been identified. Herbaria of all these species have been made and are processed for herbarium preservation for future reference and study.
- During the reporting year, in the project entitled 'Wildlife management/Biodiversity conservation plan for Trans-Arunachal Highways' specific focus was given to biological study of road sites for flora and fauna, assessment of threats to flora and fauna and identification of biodiversity corridors zones and corridors of important mammals.
- The proposed highway is passing through rich biodiversity zones falling partly in the districts of Papumpare, Lowering Subansiri, Upper Subansiri, West Siang and East Siang Districts of Arunachal Pradesh. The major ethnic communities living along the forests of proposed segments of Trans-Arunachal Highway are *Nyishi, Apatani, Tagin, Galo* and the *Adi*, together known as *Abo Thani* tribes as they trace their origin from *Thani*, the mythical first human being. They follow an indigenous form of religion, which is known as *Donyi Poloism*. The road segment covers a total distance of about 386.94 kms connecting Lower Subansiri, Upper Subansiri, West Siang and western border of East Siang Districts of Arunachal Pradesh.
- About 859 species of plants were reported along the road sector. Besides, 52 animal species of prime ethnozoological significance were inventoried along the Trans-Arunachal Highway, which comprised 80% mammals, 12% birds and fish, and remaining 8% other species. Most animals were closely linked with indigenous faiths & beliefs.

Theme

# APPLICATION OF R & D OUTPUTS IN DEMONSTRATION AND DISSEMINATION

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

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

**Objectives**

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

**Achievements**

- Funds for 20 ongoing/completed projects were released to different organizations after careful examination of Utilization Certificates (UCs) and Statement of Expenditures (SEs).
- Annual Progress Reports (APRs) of 20 on-going projects were processed and referred to the subject experts for evaluation. Subsequently, the comments of the subject experts on the APRs were sent to the concerned PIs for follow-up action.
- Final Technical Reports (FTRs) of 7 completed projects were sent to various govt./user agencies for follow-up action on the recommendations of the project and also to the subject experts for their comments/suggestions.
- Eight IERP projects were on-going in 2 States (namely, Himachal Pradesh and Uttarakhand) of the Indian Himalayan region.
- Follow-up action on 65 project files (old/fresh/on-going/miscellaneous, etc.), excluding routine correspondences of about 381, was initiated/ completed during the year.

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

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

**Objectives**

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

**Achievements**

- Updated the available resource databases of Indian Himalayan states which were helpful to the user to access the relevant information at a single platform.
- Updated and compiled the State/district-wise information on forestry data (e.g., forest cover/forest area/tree cover, etc.) of different forest assessments (e.g., 1987–2011, etc.) of Indian Himalayan states for uploading in the website of the ENVIS Centre.
- Updated the databases on subject experts/Ph.D. theses/Medicinal Plants/RET Species, etc. for uploading in the website of the ENVIS Centre in 2013.
- About 75 research abstracts, related to the various aspects of Himalayan Ecology, were added on the Abstract Database of the ENVIS Centre. At present, this database contains 2060 abstracts.
- Collected around 85 news-clippings (Bilingual) on Himalayan environment related issues from various national and regional newspapers for the News and Views section of the ENVIS Bulletin (Vol. 21, pp. 1–124, 2013).
- ENVIS Bulletin (Volume 21) and ENVIS Newsletter (Volume 10) on Himalayan Ecology were prepared, published and made online through the website of the ENVIS Centre.
- Organized awareness workshop on "Environmental Awareness through ENVIS Centre" on 21 March 2014.
- About 80 queries of individuals/institutions related to Himalayan environment and development were responded to during the year 2013.
- All available information on various aspects of Himalayan Ecology, which was collected and compiled during the year, was disseminated to 325 stakeholders through electronic and print media.
- Electronic versions of all the ENVIS publications in CD formats were prepared and distributed to various stakeholders.
- All the publications of the ENVIS Centre, such as - ENVIS Bulletins, ENVIS Monographs and ENVIS Newsletters, which have been published so far, were uploaded (in PDF format) in the website of the ENVIS Centre.
- Website of the ENVIS Centre on Himalayan Ecology <http://gbpihedenvis.nic.in> was re-designed, maintained and upgraded at the headquarters of the Institute (GBPIHED).
- Online availability of all the ENVIS documents (21 Bulletins, 3 Monographs and 10 Newsletters) and databases on the website of the ENVIS Centre <http://gbpihedenvis.nic.in> has been made.

**Strengthening and Maintenance of the Central Library at HQ**

The Central Library of the Institute at its headquarters, had 16,301 books at the end of financial year 2013–2014. The library is subscribing a total of 90 periodicals (51 Foreign and 39 Indian). For the management of Library and Information Centre, a network version of the software PALMS developed by a 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 human resources. The Library of the Institute is accessible through the Institute's web site (http://gbpihed.gov.in).

During the reporting year, 794 new book titles were added to the Library. The R & D achievements of the Institute were disseminated through its regular in-house publications, namely Hima-Paryavaran – a biannual newsletter and the Institute Annual Report to various academic and scientific institutions, Government departments, NGOs, policymakers, planners and individuals working on various aspects of mountain environment and development

**Central Laboratory Facility**

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). For the quantification of aromatic and volatile compounds the institute is equipped with Gas Chromatography unit/ equipments/ apparatus (make- Chemito, Ceres 800$^{+}$). The Institute also provides facility of detection of C, H, N & S through CHNS-O analyser (make- Elementar, Vario EL-*III*) and UV-Vis spectrophotometer (make- UV 5704, Electronics corporation of India Ltd.) for soil, water & plant analysis. The Institute has extended these services to other organizations (NGO's and other Government Organizations) on payment basis. In the financial year 2013–14, Institute has recived Rs. 1.31 lakh as central laboratory service charge from 21 organizations (8 - Govt. Organization, 3- In-house, 2- External funded projects & 8 NGOs). Month wise collection of testing charges and service offered to other organizations is depicted below (Fig 62).

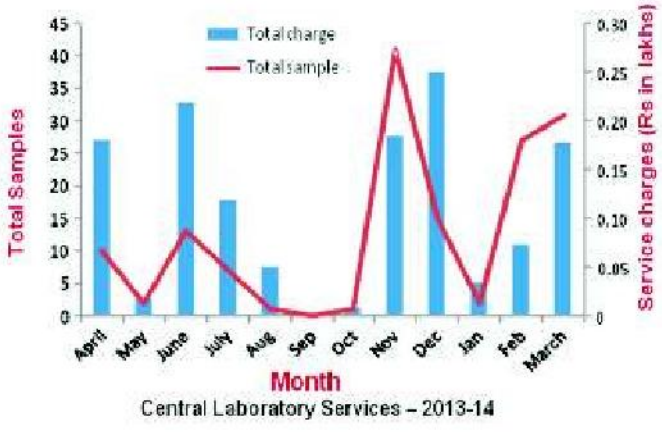
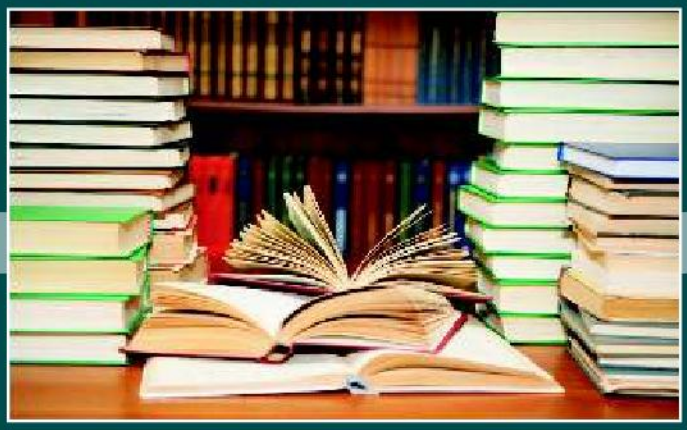



Fig. 62: Graphic representation showing total charge fee collected from Central Laboratory Services in 2013–14.



Theme

# MISCELLANEOUS ITEMS

## 1. SCIENTIFIC PUBLICATIONS

### (I) Scientific Journals

***National***


Dhyani, Shalini and R.K. Maikhuri (2013). Fodder banks can reduce women drudgery and anthropogenic pressure from forests of Western Himalaya, *Current Science,* 103(7): 763.

Chndra, A, Kandari, L S., Negi, V S., Maikhuri, R K and Rao K S (2013). Role of intercroping on production and land use efficiency in the central Himalaya, India, *Environ. We Int. H. Sci. Tech*. 8: 105-113.

Negi, V S., Maikhuri, R K., Rawat, L S, Chandra, A. (2013). Bioprospecting of Rhododendron arboreum for livelihood enhancement in central Himalaya, India *Environ. We Int. H. Sci. Tech* 8: 61-70.

Maikhuri, R K, Negi, V S, Rawat, L S and Maleth, A (2014). Sustainable development of disaster-affected rural landscape of Kedar valley (Uttarakhand) through simple technological interventions. *Current Science* 106 (7): 915-16.

Kholia, B.S., R. Joshi and Richa Punetha (2013). Extended distribution of *Cyathea spinulosa* Wall. Ex Hook. in Uttarakhand Himalaya with a note on distribution and diversification of Himalayan ferns in relation to recent climate change. *NeBio* 4(2): 40-45.

Negi, G.C.S., R.S. Rawal, S. Sharma, K. Kumar and P.P. Dhyani (2014). Need for strengthening mountain-specific research. *Current Science* 106 (5): 659-661.

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Rangini, N., M.S. Lodhi, P.K. Samal, S. Sharma and P.P. Dhyani (2013). Review of Fauna of Dehang-Debang Biosphere Reserve, Arunachal Pradesh (India). *Nature and Science* 11 (9): 8-13.

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Kuniyal, C.P., V. Purohit, J.S. Butola, and R.C. Sundriyal (2013). Do the seed pulp and storage time affects seedling emergence in the Indian Bay leaf (Cinnamomum tamala)? *National Academy of Sciences Letters* 36(3): 331-334.

Majumadar, K., Abhik Gupta and Prasanna K. Samal (2014). Documentation of avifauna in proposed Tsangyang Gyasto biosphere reserve, Western Arunachal Pradesh, India. Cibtech Journal of Zoology, 3(1): 74-85. ISSN: 2319-3883.

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Gyasto biosphere reserve, Western Arunachal Pradesh. CZoo's Print, XXIX(4): 3-7.

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Saha, D. and R.C. Sundriyal (2013). Perspectives of tribal communities on NTFP resource use in a global hotspot: Implications for adaptive management. *Journal of Natural Science Research* 3(4): 125-169.

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**(II) Chapter in Books/Proceedings**

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## 2. AWARDS AND HONOURS

Bharat Shiksha Ratan Award 2013 by Global Society for Health and Educational Growth, New Delhi for outstanding contribution in the field of Information and Communication Technology (R.K. Singh)

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

Award of Honor during District Level Children Science Congress- 2013 on October 26, 2013 at GSSS, Mohal organized by Department of Elementary Education, Kullu, Himachal Pradesh in collaboration with State Council for Science, Technology and Environment, Himachal Pradesh, Shimla from 24th -26th October, 2013. (S.S. Samant)

**Participation of Institute Faculty/Project Staff in Different Events:**

| Events | HQs | Units | | | | *Total* |
|---|---|---|---|---|---|---|
| | | NE | Sikkim | Garhwal | HP | |
| ***National*** | | | | | | |
| • Conferences / Workshops | 31 | 09 | 32 | 23 | 28 | **123** |
| • Training Courses | 20 | 03 | 15 | 08 | 15 | **61** |
| • Meetings | 45 | 08 | 39 | 12 | 37 | **141** |
| • Participation as Resource Persons | 26 | 05 | 53 | 45 | 56 | **185** |
| • Others | 00 | 00 | 08 | 07 | 21 | **36** |
| ***International*** | 06 | 03 | 05 | 04 | 01 | **19** |

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# INDEPENDENT AUDITOR'S REPORT

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

We have audited the attached Balance Sheet of G.B. PANT INSTITUTE OF HIMALAYAN ENVIRONMENT AND DEVELOPMENT (A Institute of Govind Ballabh Pant Himalayan Paryavaran Evam Vikas Sansthan) which comprise the Balance Sheet as at March 31, 2014, and the Income and Expenditure Account, Receipt & Payment account for the year then ended and a summary of significant accounting policies.

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

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

**Opinion**

In our opinion and to the best of our information and according to the explanations given to us, the financial statements of G.B. PANT INSTITUTE OF HIMALAYAN ENVIRONMENT AND DEVELOPMENT for the year ended March 31, 2014 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 2014.**

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

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

**Emphasis of Matter**

*We Draw attention to*

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

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

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

*Our opinion is not qualified in respect of this matter.*

**Report on Other Legal and Regulatory Requirements**

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

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

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

**Date :** 04.08.2014

**Place : Almora**

**Date :** 04.08.2014

**Place : Almora**

**For Daver Karnatak And Associates**
**(Chartered accountants)**

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

**G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT**
**KATARMAL, KOSI | ALMORA | UTTARAKHAND**
**INCOME & EXPENDITURE A/C FOR THE YEAR ENDED 31ST MARCH 2014.**

| PARTICULARS | SCHEDULE | CURRENT YEAR (₹) | PREVIOUS YEAR (₹) |
|---|---|---|---|
| **INCOME** | | | |
| Income from Sales/Services | 12 | 60583.74 | 46385.00 |
| Grants/Subsidies(net off exp) | 13 | 151735964.00 | 132461372.8 |
| Fees/Subscriptions | 14 | 0.00 | 0.00 |
| Income tfr from Fixed Assets fund | - | 23267360.35 | 22022987.18 |
| (to the extent of depreciation & WDV of asset sold) | | 0.00 | 0.00 |
| Income from Royalty, Income from Inv. Publication etc. | 16 | 275.00 | 0.00 |
| Interest Earned | 17 | 2124907.00 | 1786052.00 |
| Other Income | 18 | 5876511.00 | 2670694.00 |
| Increase (decrease) in stock of Finished goods and work in progress) | 19 | 0.00 | 0.00 |
| **T O T A L (A)** | | **183065601.09** | **158987490.98** |
| **EXPENDITURE** | | | |
| Establishment Expenses: a) Institute | 20 | 78319286.00 | 59322516.00 |
| b) Projects | | 10908350.00 | 11259043.00 |
| c) F.C (Projects) | | 3407623.00 | 2285739.00 |
| Administrative Expenses :a) Institute | 21 | 37159797.00 | 32729460.00 |
| b) Projects (As per Annexure) | | 12022310.00 | 20199228.00 |
| c) F.C (Projects)(As per Annexure) | | 5713473.00 | 2240316.80 |
| Expenditure on Grants, Subsidies etc. | 22 | 4205125.00 | 4425070.00 |
| Interest | | | 0.00 |
| Depreciation (Net Total at the year-end-as per Sch. 8) | | 23267360.35 | 22022987.18 |
| **T O T A L (B)** | | **175003324.35** | **154484359.98** |
| **Balance being excess of Income over Expenditure (A - B)** | | | 0.00 |
| Transfer to special Reserve | | | **0.00** |
| Transfer to/ from General Reserve | | | **0.00** |
| **BAL.BEING SURPLUS TRF.TO CORPUS/CAPITAL FUND** | | **8062276.74** | **4503131.00** |
| SIGNIFICANT ACCOUNTING POLICIES | 24 | | |
| CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS | 25 | | |

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

04/08/2014

**(DR. P.P. DHYANI)**
**DIRECTOR**

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

04/8/14

**(SURYA KANT)**
**ACCOUNTS OFFICER**

**(Sanjay Karnatak)**
**PARTNER**
**M.NO.0501670**

**DATED : 04.08.2014**
**PLACE :ALMORA**

**G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT**
**KATARMAL, KOSI ( ALMORA ) UTTARAKHAND**
**BALANCE SHEET AS ON 31ST MARCH 2014**

| PARTICULARS | SCHEDULE | CURRENT YEAR (₹) | PREVIOUS YEAR (₹) |
|---|---|---|---|
| **LIABILITIES** | | | |
| CORPUS / CAPITAL FUND | 1 | 95836449.46 | 80649841.81 |
| RESERVE AND SURPLUS | 2 | 408340285.60 | 403036300.96 |
| 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 | 93674666.07 | 63691178.64 |
| **TOTAL** | | **597851401.13** | **547377321.41** |
| **ASSETS** | | | |
| FIXED ASSETS | 8 | 408340285.60 | 403036300.96 |
| INVEST. FROM EARMARKED/ENDOWMENT FUND | 9 | 87774172.72 | 76146710.81 |
| INVEST. OTHERS | 10 | 0.00 | 0.00 |
| CURRENT ASSETS , LOANS, ADVANCES ETC. | 11 | 101736942.81 | 68194309.64 |
| MISCELLANEOUS EXPENDITURE | | | |
| **TOTAL** | | **597851401.13** | **547377321.41** |
| SIGNIFICANT ACCOUNTING POLICIES | 24 | | |
| CONTINGENT LIABILITIES & NOTES ON ACCOUNTS | 25 | | |

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

**(Sanjay Karnatak)**
**PARTNER**
**M.NO.0501670**

**DATED : 04.08.2014**
**PLACE :ALMORA**

04/08/2014

**(DR. P.P. DHYANI)**
**DIRECTOR**

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

04/8/14

**(SURYA KANT)**
**ACCOUNTS OFFICER**

**G.B PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT**
**KATARMAL, KOSI ( ALMORA ) UTTARAKHAND**
**RECEIPTS & PAYMENTS A/C FOR THE YEAR ENDED 31ST MARCH 2014**

| RECEIPTS | CURRENT YEAR | PREVIOUS YEAR | PAYMENTS | CURRENT YEAR | PREVIOUS YEAR |
|---|---|---|---|---|---|
| **I. Opening Balances** | | | **I. EXPENSES** | | |
| a) Cash in hand | 38644.53 | 177496.63 | **a) Establishment Expenses** | 55079973.00 | 34588069.79 |
| | | | **I) Institute** | | |
| b) Bank Balances | | | **b) Administrative expenses** | | |
| | | | a) Institute | 23571315.00 | 19016367.00 |
| i) In current accounts | 0.00 | 0.00 | b) R&D( Rev) expenses | 16923090.00 | 12933430.00 |
| ii) In deposit accounts ( Corpus Fund) | 31666.81 | 498215.71 | c) Payments for current liabilities/gratuity/leave | 4359819.00 | 918058.00 |
| iii) Savings accounts | 3331886.60 | 25200003.44 | **C. Capital expenditure** | | |
| c) Advances & Others | 104283937.01 | 89823209.43 | a) Purchase of Fixed Assets | 18440765.00 | 12758348.00 |
| (As per annexure Attached) | | | b)Expenditure on Capital Work in Progress | 3300000.00 | 2612000.00 |
| **F.C. ACCOUNT** | | | c) Acquirement of land (Lease money) | | 0.00 |
| A) Cash in hand | 9004.33 | 18975.33 | **II Payments made against funds for various proj.** | | |
| b) Cash at bank | 2110183.93 | 1007474.07 | **Expenditure State govt. projects** | | |
| c)FC Advances | 2850181.67 | | a) Capital | 3379904.00 | 3382195.00 |
| **II. Grants Received** | | | b) Revenue: | | |
| a) From Government of India | 140000000.00 | 119500000.00 | Establishment exp | 18700428.00 | 11396207.00 |
| i) Institute & IERP | | | Administration exp | 11535846.00 | 20199298.00 |
| | | 0.00 | **Expenditure FC projects** | | |
| b) From Other agencies | 34473479.00 | 30121558.00 | **a) Capital** | 1480567.00 | 0.00 |
| c) From other sources [from FC] | 27192252.43 | 5458037.14 | **b) Revenue:** | | |
| **III. Income on Investments from** | | | Establishment exp | 3297585.00 | 2272441.00 |
| a) Corpus Fund(Received from Institute) | 4503131.00 | 3329033.10 | Administration exp | 5713473.00 | 2210315.80 |
| **IV. Interest Received** | | | **IERP grant released** | 4285125.00 | 4495000.00 |
| a) On Bank deposits savings a/c | 2088120.00 | 1666168.00 | **III Investments and deposits made** | | |
| b)On term deposits a/c | 5336875.00 | 6656804.00 | Corpus Fund | 9475000.00 | 3850000.00 |
| c) Loans, Advances etc. | 553638.00 | 173409.00 | **IV Refund of surplus money/Loans** | | |
| | | | a) To the Government of India | 800033.00 | 217158.00 |
| **V. Other Income** | | | b)To Others/ security/ caution money | 341000.00 | 0.00 |
| (As per annexure Attached) | 593094.74 | 2770779.00 | **V Other payments** | | |
| **VI. Amount Borrowed** | | 0.00 | Other Payment to inst. FC Proj | 287437.00 | 11236.00 |
| **VII. Any other receipts.** | | 0.00 | Current liabilities | | 0.00 |
| | | | Fund transfer to Corpus fund | 4503131.00 | |
| b) Other Receipt FC a/c | 1448.30 | 0.00 | **VI Closing balances** | | |
| c) receipts current liabilities | 119036.00 | 3707452.95 | **a) Cash in hand** | 38540.53 | 38644.53 |
| d) IERP grants refunded by grantee Org. | | 0.00 | **b) Bank Balance** | | |
| e)Construction Fund | | 0.00 | i) In Current account | | 0.00 |
| f) Corpus Fund FDRS | 249027306.00 | 0.00 | ii) In deposit accounts ( Corpus Fund ) | 94804.81 | 31666.81 |
| g) Caution Money | 3580.00 | 7000.00 | iii) In savings accounts | 47808329.74 | 33318861.60 |
| h) Security Deposit | | 30000.00 | | | |
| i) EMD | | 68250.00 | **C) Advances and others** | 22890993.84 | 104283937.01 |
| j) Royalty | 275.00 | | **FC Project** | | |
| k) Sales Tax / VAT | 2991.00 | | a) Cash in hand | 930.33 | 9004.33 |
| | | | b) Bank Balance | 16086723.36 | 2110183.93 |
| | | | c) Advances and others | 5459808.67 | |
| | | | Adjustment of previous year closing Advances | 83280872.77 | |
| TOTAL | 387709383.03 | 290100859.80 | TOTAL | 387709383.03 | 290100859.80 |

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

(Sanjay Karnatak)
PARTNER
M.NO.501670
DATED : 04.08.2014
PLACE :ALMORA

(Dr. P.P. DHYANI)
DIRECTOR

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

(SURYA KANT)
ACCOUNTS OFFICER

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

**STATEMENT OF OPENING & CLOSING BALANCES**

| PARTICULARS | OPENING AMOUNT | CLOSING AMOUNT |
|---|---|---|
| **Cash & Bank Balances** | | |
| **Cash In Hand :** | | |
| Srinagar | 461.85 | 0.00 |
| Sikkim | 861.00 | 0.00 |
| Kullu | 690.40 | 0.00 |
| Itanagar | 29895.56 | 0.00 |
| Grant in aid in transit (Biotech-XIII) | 184000.00 | 184000.00 |
| Cheque in transit: (HP Unit ) | 0.00 | 125000.00 |
| Cheque in transit: (G Unit ) | 760274.74 | 0.00 |
| Cheque in transit: (Sk Unit ) | 0.00 | 200000.00 |
| Cheque in transit: (N.E. Unit ) | 0.00 | 277465.56 |
| **Cash at Bank Balances** | | |
| SBI Almora A/c No.10861378091 | 31666.81 | 0.00 |
| SBI Tadong A/c No 11226047758 | 541576.85 | 0.00 |
| SBI Kullu A/c NO. 10792147561 | 1747314.78 | 0.00 |
| SBI Itanagar A/c No 10940060114 | 633276.58 | 0.00 |
| SBI Srinagar A/c No 10972182864 | 1334286.27 | 0.00 |
| **Advances** | | |
| Electrecity Charges Recoverable | 0.00 | 4575.00 |
| House Building Advance | 2307997.00 | 1669351.00 |
| Motor cycle/Car Advance | 103975.00 | 103975.00 |
| Festival Advance | 40500.00 | 38625.00 |
| Computer Advance | 21000.00 | 9000.00 |
| Income tax deducted at source | 191498.00 | 191498.00 |
| **Units of Institute:** | | |
| Sikkim Unit | -43427.83 | -49630.83 |
| HP Unit | 8721.00 | -63896.00 |
| Garhwal Unit | 46115.00 | 0.00 |
| NE Unit | 0.00 | 160.78 |
| **Fixed deposit** | | |
| Corpus Fund FDRs | 69558240.00 | 0.00 |
| Interest accrued on Corpus Fund FDRs | 6556804.00 | 0.00 |
| **FDR (Margin Money/LC A/C)** | | |
| Institute | 500000.00 | 0.00 |
| ISRO-JCK-EO (HP Unit) | 1035000.00 | 0.00 |
| TOTAL: | **85590727.01** | **2690123.51** |

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

| | | |
|---|---|---|
| **Brought forward** | **85590727.01** | **2690123.51** |
| **Due Staff/ other IC A/c** | | |
| Dr. B. S. Majila | 0.00 | 0.00 |
| Dr. A. K. Sahani (T.T.A) | 0.00 | 65000.00 |
| Dr. R. C. Prasad (L.T.C) | 0.00 | 100800.00 |
| Dr. S. C. Ram (L.T.C) | 0.00 | 71145.00 |
| Receivable from Sikkim Unit | 800.00 | 0.00 |
| STUP Consultant | (7435.00) | (7435.00) |
| M/S International Trade Links, Mumbai | 34328.00 | 34328.00 |
| LICOR INC USA | 54460.00 | 54460.00 |
| Tuder Rose UK (Instt.) | 88535.00 | 88535.00 |
| S.K. Diesel Sales (Instt.) | 66538.00 | 66538.00 |
| Wipro GE Health Care (Instt.) | 296534.00 | 296534.00 |
| Elemonter Analyser (Instt.) | 0.00 | 0.00 |
| VPKAS Almora (Instt.) | 26560.00 | 26560.00 |
| Saveer Biotech New Delhi | 0.00 | 0.00 |
| Adv. to NIH Roorkee | 100000.00 | 100000.00 |
| Post Master G.P.O Almora | 40566.00 | 40566.00 |
| Employment News | 48287.00 | 48287.00 |
| Sigma Aldrich Chemicals | 10590.00 | 10590.00 |
| Siltap Chemicals Ltd (Biotech -III) | 408.00 | 408.00 |
| DST (LMS) ILTP NRSA Hyderabad | 48000.00 | 48000.00 |
| NRSA Hyderabad | 35300.00 | 35300.00 |
| R.K.Nanda & Sons | 28517.00 | 28517.00 |
| NICSI New Delhi | 35106.00 | 35106.00 |
| Security Deposit CET Sikkim Unit | 11000.00 | 11000.00 |
| NRSA Hyderabad (NNRMS Proj.) | 234000.00 | 222000.00 |
| NRSA Hyderabad- Grant in Aid (NNRMS Proj.) | 458441.00 | 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 |
| NCADMS, Itanagar (MOE&F CC-II) | 0.00 | 0.00 |
| N.E. Regional Institute, Itanagar (MOE&F UNDP CCF) | 213403.00 | 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 |
| Director State Forest Research Institute ( UNDP-CEF-GOL) NE Un | 193.00 | 0.00 |
| E E R.E.S. Almora (IIRDI I.D.B. Project) | 59000.00 | 59000.00 |
| Adv. a/c of Chief Secretry Nagaland (Mountain Division) | 0.00 | 1500000.00 |
| Adv. a/c of Meteorological Department | 0.00 | 8000.00 |
| Adv. a/c of Chief Coservator Eco Tourism D. Dun (Mountain Divisi | 0.00 | 500000.00 |
| Adv. a/c of NRSC Hydrabad (Project No. 04) | 0.00 | 48000.00 |
| Adv. a/c of of FRI Dehradun MoE&F (NNRMS) | 0.00 | 805000.00 |
| Adv. a/c of Contrution Division II Pay Jal Nigam (MoE&F B G RSF | 0.00 | 1495800.00 |
| **TOTAL** | **104283937.01** | **22590993.84** |

G.B.PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT
KATARMAL, KOSI | ALMORA | UTTARAKHAND
SCHEDULE FORMING PART OF BALANCE SHEET AS ON 31ST MARCH 2014.

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 | 400902.00 | 135634.00 | 0.00 | 542536.00 | 3526490.00 | 3668124.00 |
| 2 | BUILDING: | | | | | | | | | | |
| | a) On Freehold Land | 214731986.00 | 0.00 | 0.00 | 214731986.00 | 35688631.61 | 8880457.40 | 0.00 | 44569089.01 | 170162896.99 | 179043354.39 |
| 3 | PLANT MACHINERY & EQUIPMENT | | | | | | | | | | |
| | a) Scientific Equipments | 178250686.11 | 8497737.00 | 0.00 | 186748423.11 | 88882234.91 | 8846901.91 | 0.00 | 97729136.82 | 89019286.29 | 89368450.21 |
| 4 | VEHICLES | 9493269.30 | 631371.00 | 0.00 | 10124640.30 | 7358048.49 | 1031424.06 | 0.00 | 8389270.57 | 1735369.73 | 2135220.81 |
| 5 | FURNITURE FIXTURES | 26863411.40 | 2182417.00 | 0.00 | 28383828.40 | 17462530.09 | 1787139.04 | 0.00 | 19249668.12 | 8953160.28 | 9400881.32 |
| 6 | OFFICE EQUIPMENT | 27197791.35 | 2797321.00 | 0.00 | 29995112.25 | 14651636.85 | 2849525.67 | 0.00 | 17501162.50 | 12493949.85 | 12546154.52 |
| 7 | COMPUTER/PHERIPHEARLS | 0.00 | 1174435.00 | 0.00 | 1174435.00 | 0.00 | 43324.79 | 0.00 | 43324.79 | 1131110.21 | 0.00 |
| 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 | 50962.00 | 0.00 | 0.00 | 50962.00 | 49226.83 | 2895.72 | 0.00 | 52122.55 | 8839.45 | 11735.16 |
| 9 | LIBRARY BOOKS | 59561601.50 | 3003423.00 | 0.00 | 107565216.50 | 44148530.87 | 5109352.53 | 0.00 | 49257883.40 | 58307430.10 | 55416157.64 |
| 10 | TUBE WELLS & W. SUPPLY | | | | | | | | | | |
| 11 | OTHER FIXED ASSETS | | | | | | | | | | |
| | CLASS / NET HOUSE | 3911549.00 | 0.00 | 0.00 | 3911549.00 | 3094595.43 | 160995.23 | 0.00 | 3255591.65 | 655957.34 | 810953.57 |
| | TOTAL OF CURRENT YEAR | 560426012.89 | 23284106.00 | 0.00 | 583710118.89 | 213737138.07 | 28267350.35 | 0.00 | 237004498.42 | 346692859.60 | 346688874.96 |
| | PREVIOUS YEAR | 543804364.89 | 16621648.00 | 0.00 | 560426012.89 | 191649308.48 | 22022987.18 | 64842.32 | 213531040.69 | 346688874.96 | 352155056.46 |
| | B. CAPITAL W I P | | | | | | | | | | |
| | Requirement of land (Lease money) | 0 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | CCU Delhi | 56347426.00 | 5000000.00 | 0.00 | 61647426.00 | 0.00 | 0.00 | 0.00 | 0.00 | 61647426.00 | 56347426.00 |
| | 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 | 616773438.89 | 28284106.00 | 0.00 | 645357544.89 | 213737138.07 | 28267350.35 | 0.00 | 237004498.42 | 408340285.60 | 403036300.96 |

## INSTITUTE SUPPORTING STAFF

### HEAD QUARTERS

| | |
|---|---|
| Mr. Anil Kumar Yadav | Administrative Officer |
| Surya Kant Langayan | Accounts Officer |
| L.M.S. Negi | Office Superintendent (Admn.) |
| Sanjeev Higgins | |
| Preeti Tiwari | Technical Gr. – IV(1) |
| Sarita Bagdwal | Stenographer |
| Jagdish Kumar | Stenographer |
| Mamta Higgins | U.D.C. |
| Heera Singh | U.D.C. |
| K.K. Pant | U.D.C. |
| Hema Pandey | U.D.C. |
| S.K. Gururani | L.D.C. |
| Suraj Lal | L.D.C. |
| Jagdish Singh Bisht | Technical Gr. – II(1) |
| R.C.Bhatt | Driver |
| Chandra Lal | Driver |
| K.N.Pathak | Technical Gr. – I(3) |
| Pan Singh | Peon |
| G.D. Kandpal | Peon/Mali |
| Nathu Ram | Peon/Mali |
| Ganga Joshi | Peon |
| Kanshi Ram | Peon/Mali |

### GARHWAL UNIT

| | |
|---|---|
| D.P. Kumeri | L.D.C. |
| M.P. Nautiyal | Driver |
| J.M.S. Rawat | Driver |
| R.C. Nainwal | Field Assistant |
| R.P. Sati | Peon |

### HIMACHAL UNIT

| | |
|---|---|
| S.P. Maikhuri | Office Superintendent |
| Daulat Ram | Peon |

### SIKKIM UNIT

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

## INSTITUTE FACULTY

### HEAD QUARTERS

| | | |
|---|---|---|
| P.P.Dhyani | Director | Plant Physiology; Restoration Ecology |
| Kireet Kumar | Scientist-G | Environmental Engineering; Hydrology |
| S.K. Nandi | Scientist-G | Plant Physiology; Biochemistry |
| R.C. Sundriyal | Scientist-F | Plant Ecology; Rural Ecosystems |
| Anita Pandey | Scientist-F | Microbiology |
| S.C.R. Vishvakarma | Scientist-F | Plant Ecology; Rural Ecosystems |
| B.P. Kothyari | Scientist-F | Plant Pathology; Restoration Ecology |
| D.S. Rawat | Scientist-F | Settlement Geography; Rural Ecosystems |
| R.S. Rawal | Scientist-F | High Altitude Ecology; Conservation Biology |
| R.C. Prasad | Scientist-F | Library & Documentation |
| G.C.S. Negi | Scientist-E | Forest Ecology; Watershed Management; EIA |
| Subrat Sharma | Scientist-D | Agroecology; Remote Sensing / GIS |
| Paromita Ghosh | Scientist-D | Plant Science; Soil Science |
| I.D. Bhatt | Scientist-D | Plant Physiology; Phytochemistry |
| R.K. Singh | Scientist-D | Information Technology |
| Ranjan Joshi | Scientist-D | Ecology Economics; Resource Valuation |
| Rajesh Joshi | Scientist-D | Mathematical Modeling |
| K.C. Sekar | Scientist-D | Plant Taxonomy; Animal Taxonomy |
| Shilpi Paul | Scientist-D | Molecular Biology; Plant Biotechnology |
| Vasudha Agnihotri | Scientist-C | Soil Science; Plant Analysis; Instrumentation |
| Sandipan Mukherjee | Scientist-C | Climate Change; Ecosystem Services |
| B.S. Majila | Tech. Grade IV (3) | Forest Ecology; Restoration Ecology |
| Subodh Airi | Tech. Grade IV (2) | Forest Ecology; Biotechnology |

### HIMACHAL UNIT

| | | |
|---|---|---|
| S.S. Samant | Scientist-F & In-charge | Plant Taxonomy; Conservation Biology |
| J.C. Kuniyal | Scientist-E | Development Geography; Waste Management |
| R.K. Sharma | Scientist-D | Policy Analysis; Environmental Management |
| Sarla Shashni | Scientist-C | Rural Entrepreneurship and Small Business |
| Vaibhav Eknath Gosavi | Scientist-B | Hydrology; Watershed Management |

### SIKKIM UNIT

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|---|---|---|
| H.K. Badola | Scientist-F & In-charge | Morphoanatomy; Conservation Biology |
| K.K. Singh | Scientist-F | Plant Physiology; Stress Physiology |
| S.C. Joshi | 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

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|---|---|---|
| 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

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|---|---|---|
| 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 |