ANNUAL REPORT

2016-2017

गोविन्द बल्लभ पंत हिमालय पर्यावरण एवं विकास संस्थान

G.B. Pant Institute of Himalayan Environment & Development

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

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ANNUAL REPORT

2016-2017

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Director, Botanical Survey of India
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Member Secretary

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

CONTENTS

FOREWORD

The Institute with its 28 years of existence has created a special niche among national and international research and development (R&D) communities. The progression has been multidirectional and the Institute through its R&D activities catered to the needs of the multiple stakeholders ranging from indigenous communities to the policy makers. The Institute has also fulfilled its commitments to ensure time bound delivery of R&D based solutions on the key issues of conservation and development in the Indian Himalayan Region (IHR).

During the reporting period, i.e. Year 2016-17, the Institute made significant strides in achieving its R&D targets. During this period, Institute looked into critical mountain issues more holistically. In this context, to bring mountain perspective in plans and policies, the fifth unit of the Institute has been established as Mountain Division at MoEF&CC, New Delhi. Also, the efforts were made to upgrade the Institute into a National Institute.

Some of the major achievements of the reporting year include: (i) addressing the key issues of water scarcity in IHR hills by using WEAP model; (ii) geodynamic and hydrochemical studies of Gangotri glacier system in Garhwal Himalaya; (iii) operation of permanent and campaign mode GPS stations for quantification of tectonic deformation field in Himalaya; (iv) understanding impacts of changing climate on hill farming systems; (v) development of long-term data base on aerosols climatology, radiative forcing and temperature rise in the Kullu valley (Himachal Pradesh); (vi) strategic Environmental Assessment (SEA) of hydropower projects in river Sutlej basin (Himachal Pradesh) and Ranganadi (Arunachal Pradesh); and (vii) studies of cold tolerant microbial inoculants and their uses for biological hardening and bioremediation of heavy metal contaminated soils, etc. In addition, the Institute organized several training programmers for the stakeholders through its Rural Technology Center (RTC) at Headquarters and Units for promoting outreach to the society. Also, onsite training programmes, orientation courses and exposure visits on biodiversity conservation, natural resource management, disaster management, etc., remained regular activities in the Institute. For improved outreach, various consultative meetings, workshops, and side events at national and International forum were organized. Among others, organization of a Himalayan Parliamentarian meet for policy advocacy on sustainable development of IHR was a major achievement. The Institute, through network projects, continued to undertake collaborative national and international researches. All these endeavors have helped in putting forth the Institute's perspective and sharing its expertise and infrastructure for mutual benefits.

As the Director of this premier Institute, it has been my endeavour to promote and strengthen R & D activities to achieve its mandate. All through reporting period, the guidance and support received from the Scientific Advisory Committee (SAC), the Governing Body (GB), and the Society, has been outstanding. I am sure, with the efforts of colleagues in the Institute and well wishers outsides, the Institute shall succeed in achieving its long term vision of ensuring ecological and economic security of IHR.

(P.P. Dhyani)
Director

MAJOR ACHIEVEMENTS
(2016-2017)

1. Towards addressing the issue of water scarcity in IHR hills and to ensure its availability for different uses, water evaluation and planning studies using WEAP model were successfully carried out at Mohal Khad watershed in Kullu, Himachal Pradesh.
2. The successful completion of the study on 'Geodynamics and hydrochemical studies of Gangotri glacier system Garhwal Himalaya' provided new insights on glacier system dynamics, glacier retreat, and methodological suitability for short and long term studies. The study revealed that Gangotri and Chaturangi glaciers are retreating with variable rates at 10.26±0.05 m/yr and 22.84±0.04 m/yr, respectively.
3. To understand responses of farming systems under changing climate scenario, the GML model performances were used for prediction of yield estimates of rice, wheat and mandua crops and delineated the impacts of rise in temperature and rainfall conditions.
4. The study on - Operation of permanent and campaign mode GPS stations for quantification of tectonic deformation field in Himalayan terrain' added information to the existing database in the field generated through various projects with GBPIHED as collaborative partner. The results of study are in terms of understanding of build-up of dynamic strain field in the region, hazard contexts and potentials, and for creating a Minimum Risk Land Use Plan in and around the selected urban centers of IHR.
5. Study on phenological responses has exhibited that among the dominant forest tree species of western Himalaya, mean date of peak leafing and leafdrop has advanced by 1-2 weeks due to rise in ambient temperature (0.005 °C/yr) and decline in rainfall (3.3 mm/yr) during the past over two decades, hence overall length of growing season did not increased due to climate change, as has been reported in the temperate latitudes of the world.
6. A strategy for policy guidelines was designed to determine the number of hydropower projects according to carrying capacity of a river basin under Strategic Environmental Assessment (SEA) of hydropower projects in river Sutlej basin of Himachal Pradesh and Ranganadi in Arunachal Pradesh.
7. Long-term data base generated to understand the aerosols climatology, radiative forcing and temperature rise in the Kullu valley of Himachal Pradesh. Database on surface ozone and its precursors at high altitude station- Kothi (2500 m) was created under Atmospheric Chemistry, Transport and Modelling (AT-CTM).
8. Cold tolerant microbial inoculants (such as *Bacillus subtilis* and *Psuedomonas putida)* and their uses in propagation and conservation of plants, biological hardening of micropropagated plants and bioremediation of heavy metal contaminated soils were identified.
9. The Institute contributed through National Mission for Sustaining Himalayan Ecosystem, as a nodal organization for implementing Task Force 3: Forest resources and plant biodiversity and also a network partner for Task Force 5: Traditional Knowledge System. Also provided inputs in (i) technical committee of National Water Mission, and (ii) preparing State Specific Action Plan for Water Resources (SSAP) for Uttarakhand.
10. Towards improving its outreach, Institute organized various consultative meetings, workshops, and side events (i.e. during CoP 13 CBD in Mexico and CoP 22 of UNFCC in Morocco) and celebrated important days such as International Biological Diversity Day (May 22), Environment Day (June 5), Annual day (September 10), Wildlife Week (October 1-7), Mountain Day (December 11), etc. Third meet of Himalayan Parlamentarian was organized for policy advocacy on sustainable development of the Indian Himalayan Region (August 10, 2016).

Publications

1. Peer Reviewed Scientific Journals		
National	-	***20***
International	-	***48***
2. Chapters in Books/Proceedings	-	***30***
3. Authored/Edited Books/Booklets/Bulletins/Monographs	-	***13***
4. Popular Articles	-	***16***

EXECUTIVE SUMMARY

The institute with a strong commitment for sustainable development of the Indian Himalayan Region (IHR) is the only institute of its kind which addresses physical, biological, social and economic issues of the region and its people in an integrated manner. The R&D mandate of the Institute is broad and covers all the facets of environment and development. Towards achieving this, multi-disciplinary approach and integration are the guiding principles. The emphasis on interlinking of natural and social sciences is the major thrust of all the programmes in the Institute. In this effort, special attention is placed on the intricate balance between fragility of mountains, indigenous knowledge and sustainable use of natural resources. Design and implementation of R&D activities on priority environmental problems, development and demonstration of best practices, technology packages and delivery systems for improved livelihood of the people is the core issues covered under most programmes conducted by the Institute. A conscious effort is made to mobilize a variety of stakeholders (students, researchers, academicians, farmers, citizens, policy makers, and others) together with the development processes through different initiatives. Therefore, training, education and awareness of a variety of stakeholders are the essential components of all the R&D programmes. A brief summary of R&D activities of the Institute during the reporting year 2016–17 is as follows.

WATERSHED PROCESSES AND MANAGEMENT (WPM)

The year saw the completion of the externally funded projects on Glacier dynamics and recession, and tectonic deformation studies of geologically fragile Himalaya; it was also the last year of the In-house projects initiated during the ongoing planning period. The studies on Glaciers, and the Tectonic Deformation Fields, added to the existing knowledge base in respect of glacier recession/ dynamics/hydrological functioning, etc. and provided valuable learning cues towards understanding the role of tributary glaciers in glacial melt and discharge, hitherto a very less explored segment under the glacier study. The tectonic deformation study provided a general understanding of relative movements of Eurasian Plate in IHR vis-a-vis Indian Plate with respect to selected references, and a micro view at regional scale in IHR measured through continuous monitoring at some selected towns and local scale movement by frequent revisit of identified locations and frequent GPS campaigns.

Under the study 'Ecological, social and policy implications of changing water scenario in the Indian Himalayan Context' the grasp of water scenario in IHR was obtained thru micro-level studies in Kosi-watershed Almora in the Kumaun region and the Mohal Khad watershed in Kullu (Himachal Pradesh). Hydrological assessments, inventorization of water resources, human perceptions, field observations, climatic records, water demands, and use patterns, etc. were recorded for the purpose. In Uttarakhand the water problem is evident in the form of decline in numbers of springs/ streams, their reduced flow, shifting of dependence from springs/streams to rivers and bore-wells, drying of seasonal resources, and perennial surface resources becoming seasonal, etc. The survey of selected water demand sites in Kosi watershed reveals the annual and seasonal water stress and scarcity situation in that area. In Mohal Khad watershed WEAP model was used to understand water scarcity impacts with respect to water demand/ deficit, runoff, available water supply, etc. and identification of critical ecosystem elements. Using the model, the water management strategy was framed for efficient water allocation in the watershed.

In the project 'Farming systems and changing climate regime: impact of biophysical and social drivers on farm yields in Central Himalaya' - the rainfed yields of 3 major crops i.e. wheat, madua, and rice were examined with respect to identified measurable physical, social, and biological drivers/ factors. The district level time series data of these crops for the period 1990 to 2010 were statistically analyzed for co-linearity amongst different drivers, impact of individual factors, and GML model based future yield estimates. The yield response of these crops for six set of scenarios were projected; the GML performances revealed 30-40% enhancement of rice yield from average yield of 1990-2000 due to increase in both temperature & rainfall from benchmark values, and 28-31% in rice and 68-75% in wheat due to temperature effect

only. Similar GML estimates for 'madua' indicate a rise of 25-30% in yield due to increase in temperature and a decline of 5% yield due to 10% increase in rainfall.

During the year a new project- 'Investigation of alternative boundary layer scaling properties over the complex terrains of Himalaya' funded by MoES was initiated wherein impact of surface in-homogeneity to turbulance properties for summer & winter period is being investigated, and relationship between temperature fluctuations and turbulance parameters explored for best-fit by optimization of constants. During the period necessary instrumentation for the study including installation of one 3-D for Sonic Anemometer, and 1-CO_2/H_2O Gas Analyzer was done and high frequency meteorological data from one slope site obtained.

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

During the reporting period this theme focused on data-base strengthening throughc inventorization and prioritization of biodiversity (flora and fauna component including soil mycorrhiza), field work based data collection on population status of RET category of species, assessment of threat on biodiversity due to biotic interference (particularly hydro-power projects), resource use, invasion of weeds, forest fire, etc. Activities on biodiversity assessment encompass major ecosystems of the IHR such as forests, cold deserts, wetlands and aquatic systems, arboreal habitats, etc. Efforts were made to capture data set on the above mentioned aspects across Himachal Pradesh, Uttarakhand, Sikkim and North-East. To come up with suitable conservation strategies case studies based on participatory approaches were conducted on indigenous knowledge on biodiversity conservation and sustainable management of biodiversity across selected locations in the region. *Ex-situ* and *in-situ* conservation approaches were followed for certain plants of conservation importance. Realizing the fact that climate change is a powerful driver of response of plants and biodiversity elements (species and populations) efforts were made to undertake R&D activities using advance methodologies/techniques across the representative vegetation types/landscapes. Quantification and valuation of ES emanating from ecosystem/landscape scale was another major thrust to develop mechanisms for biodiversity conservation across several localities in the IHR. Climate change impact on selected tree species across low and high altitude forests was monitored for different phenophases. In this effort citizens science was also used as a novel approach to generate large data set. Equal efforts were placed on compilation of knowledge products on biodiversity conservation and management to strengthen science-policy-practice linkages; and raise awareness and capacity building of a range of stakeholders for participatory conservation both within and outside the region.

CLIMATE CHANGE (CC)

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

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

Today, our existing resources are scarce but there are ample demands of the growing population. The scientific and judicious use of available resources with the ever increasing demand needs to be rationalised and balanced. So there is a need to establish a balance between conservation of resources and their consumption patterns. Otherwise, there would be adverse impacts on the natural components of the environment. Haphazard development in case of power projects and unplanned economic activities like mass tourism or any other activity beyond carrying capacity for economic gains would lead to environmental loss to a greater extent. This will result in many environmental problems and continue to increase pollution loads in different forms, e.g., deforestation, soil erosion, flash floods, air pollution, waste problem, etc. So it has become a need of the hour to minimise ecological

threats, maximise resource use availability and capacity with some alternatives for achieving ecological and economic sustainability in context to the Indian Himalayan Region (IHR). The Environmental Assessment and Management, and Environmental Governance and Policy (EAM & EGP) Themes take into account such important issues in-depth and therefore stand as a backbone of the Institute's other programmes. Developmental interventions in the area of energy sector such as hydropower development based on carrying capacity of a basin, environmental flow, water use pattern, public involvement and their participation level have been notable issues of the in-house activities. In addition, anthropogenic impacts in the surrounding environment in various forms evolve. These could be ambient air pollution (gaseous, particulate, black carbon, etc.), columnar aerosols and influence of local meteorology on atmospheric pollution, glaciers melting, wetland deterioration, climate change impact and their mitigation measures. These efforts are being carried out with the support of external funding agencies such as ISRO GBP, ISRO AT-CTM Environmental Observatory, DST, NMSHE and NMHS.

SOCIO - ECONOMIC DEVELOPMENT (SED)

The mountain communities are largely dependent the surrounding bioresources for their sustenance. Therefore, documenting traditional knowledge related to bioresource use and management is critical for devising sustainable development strategies. In the reporting year under the SED theme, the work continued to assess the efficacy of indigenous land use systems, customary management of bioresource, and documentation of traditional healthcare system of communities in the northeast and northwest regions. The work was undertaken under National Mission for sustaining the Himalayan ecosystems (NMSHE) as 'Network programme on the convergence of traditional knowledge system for sustainable development of Indian Himalaya region'. To increase community livelihoods and income on-farm demonstration of technology models, such as protected cultivation, integrated fish farming, cash crop cultivation, horticulture, vermicomposting, integrated poultry farming etc. were undertaken in selected village clusters; a total of 35 such models were established. One of the main causative factors to enhance forest fire is the accumulation of chirpine leaf litter at forest floor during pre-summer months. A 'Chirpine needle processing unit' was established to use such litter for productive use, such as papermaking. Also, a model of wasteland rehabilitation in the form of 'Nandavan' was established in Almora with the help of local administration. The findings are reported in the form of major achievements.

BIOTECHNOLOGICAL APPLICATIONS (BTA)

The theme Biotechnological Applications focuses on the utilization of biotechnological methods for improving the productivity, developing propagation protocols for mass multiplication, assessing biochemical attributes of high value plants, and identification and characterization of microbial diversity with respect to their biotechnological applications and conservation. A psychrotolerant strain of Pseudomonas sp., isolated from cold desert site in IHR, was investigated for the production of cold active lipase. The bacteria was identified as *Pseudomonas proteolytica* by 16S rDNA sequencing. Lipase production by the bacterium was confirmed by qualitative assay using tributyrin and rhodamine-B agar plate method. The bacterium produced maximum lipase at 25 ºC followed by production at 15 ºC while utilizing olive, corn, as well as soybean oil as substrate in lipase production broth. Enzyme produced by bacteria was partially purified using ammonium sulphate fractionation. The bacterium showed aggregation behaviour which was confirmed using several techniques including gel filtration chromatography, dynamic light scattering, and native PAGE. The enzyme showed stability in wide range of pH from 5-11 and temperature up to 50 ºC. The stability of enzyme was not affected with methanol while it retained more than 75% activity when incubated with ethanol, acetone, and hexane. The bacterium is likely to be a potential source for production of cold active lipase with efficient applicability under multiple conditions.

ENVIRONMENTAL PHYSIOLOGY AND BIOCHEMISTRY (EPB)

The theme Environmental Physiology and Biochemistry is focusing on the understanding the mechanism of adapation under changing environmental perturbations and developing strategies for conservation and sustainable utilization of Himalayan bioresources. During the reporting year, the theme focused on the development of *in vitro* production of secondary metabolites in *Nardostachys jatamansi*, propagation protocols of *Bergenia ligulata*, *Aconitum ferox*, *A. heterophyllum*, *Trillium govanianum*, *Rhododendron* spp., *Paris polyphylla*, *Pittosporum eriocarpum*, *Corylus jacquemontii, Swertia chirayita*, *Michelia excelsa*, *Spondias axillaris,* etc., assessing nutritional and

antinutritional properties of *Berberis asiatica, B. jaeschkeana, Paeonia emodi*; antioxidant proprties of Astavarga plants, morphological and physiological responses of tissue culture raised *Valeriana jatamansi*, etc. In addition, utilization of ecological niche modeling for prediction of suitable habitat and reintroduction of threatened plant species in Himalayan region is ongoing process. The theme is also working on the investigation of nutritional propeties of traditional crops and its impact on the schedule caste of the region. Establishment of different demonstrations and experimental plots of threatened and high value plants for their future use is also initiated. Various trainings workshops and exposure visits are being carried out throughout the year to sensitize the diverse group of stakeholders towards sustainable utilization of Himalayan bioresources.

KNOWLEDGE PRODUCT AND CAPACITY BUILDING (KCB)

Translating evidence-based knowledge on resource management into knowledge products and converting it into a formal and well-structured training programme is a huge gap. The theme addresses such gap by transforming knowledge into practical solutions and empowering communities through training to enhance their technical capabilities so as to address the issues of local livelihood and environmental management at the village and regional levels. During the reporting year through RTCs at Institute HQs (Almora), Triyuginarayan (Garhwal), and Pangthang (Sikkim Unit) a total of 41 simple & cost effective technologies were demonstrated and disseminated. Besides, a total of 170 training programmes were organized benefiting 7109 persons (3480 female and 3629 males) covering 14 districts and 736 villages in Uttarakhand and Sikkim. Further details of the training, demonstration, and technology models are provided.

1. INTRODUCTION

During the year 2016-17, various R&D activities were executed by the Institute at different locations of the Indian Himalaya Region (IHR) 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). More recently to look into mountain issues holistically and bring in mountain perspective in plans and policies, the fifth unit of the Institute has been established at MoEF&CC, New Delhi. Over the years, the Institute has taken significant strides in identifying problems, developing region-specific approaches, demonstrating their efficacy in the field and disseminating information to various stakeholders. The diverse problems thus addressed were related to ecology, resource conservation, traditional practices, livelihood opportunities, land restoration, propagation protocol development, biotechnological interventions, etc. The Institute implements its activities through core funds provided by the Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt of India, and the projects financed by external funding agencies (National and International). The Institute also supports activities of various partner Institutions situated in different Himalayan states through Integrated Eco-development Research Programme (IERP). The Science Advisory Committee (SAC) of the Institute reviews the progress of existing projects and provides guidance to develop new R&D programmes. All the projects fall under 10 identified thematic categories such as (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); (6) Knowledge Product and Capacity Building (KCB); (7) Environment Governance and Policy (EGP); (8) Ecosystem Services (ES); (9) Climate Change (CC); and (10) Environmental Physiology and Biochemistry (EPB). All these themes have been grouped under 4 different groups. These include, (1) Watershed Processes and Management, Environmental Assessment and Management and Environment Governance and Policy (WPM, EAM & EGP); (2) Biodiversity Conservation and Management, Ecosystem Services and Climate Change (BCM, ES & CC); (3) Socio-economic Development and Knowledge Product and Capacity Building (SED&KCB); and (4) Biotechnological Applications and Environmental Physiology and Biochemistry (BTA & EPB).

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 were published and made available for the public. The progress made during the year 2016–2017 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 the quantum and quality of outputs of various R&D activities.

2. MILESTONE EVENTS

Citizen's Science Programme

The GBPIHED Himachal Unit, in collaboration with Earth Watch International organized a Citizen's Science Programme for the Volunteers of the Public/Corporate (Shell) teams from abroad during April 11-29, 2016. The programme trained and used the participating trainees for recording of observations and field data, data synthesis, and report work for the GBPIHED-EWI Himalayan Ecosystems Service Research project 'Scientific Research on Changing Climate and its impact on Floral Diversity and Ecosystem Services (Pollination) at Kullu region of IHR – a Citizen Science initiative'. The volunteer groups generated information on qualitative and quantitative assessment of biodiversity, density and diversity of pollinators and their preferential foraging plants, phenology, etc.

Consultation Workshop on Climate Change Adaptation

GBPIHED Himachal Unit in collaboration of State Council for Science, Technology & Environment Himachal Pradesh, CTRAN Bhubaneshwar, and IHCAP-SDC India Office (New Delhi) organized a Consultation Workshop on 'Developing Adaptation Concepts for Kullu District' at GBPIHED, Mohal-Kullu. Dr M A Khan, the Team Leader IHCAP described the background of the workshop and underlining the urgency for expeditious planning and implementation of adaptation action. Dr A K Lal, Director, Department of Environment, Science & Technology, Himachal Pradesh delivered the Key Note Address describing the threats of cloud bursts, global warming, forest fire, melting of glaciers, natural disasters and the environmental degradation. Dr. Nadine Salzmann, University of Fribourg, Switzerland in her address discussed adaptation to climate change in different mountain regions of the world, and shared the findings of her work in Grindelwald Glacier (Alps), Laguna 513 (Andes) and Beas River (Kullu) on glacial hazards, debris flow and flash floods. During the workshop the 'Synthesis Report' of IHCAP project on "Climate Vulnerability, Hazards and Risk: An integrated pilot study in Kullu District, Himachal Pradesh" was launched. Shri Hans Raj Chauhan, Deputy Commissioner Kullu and the Chief Guest highly applauded the efforts made towards climate change adaptation under IHCAP studies, and emphasized on the involvement of community and common people to combat climate disasters and protection of vulnerable environment of Kullu and sustainable management of natural resources. Mr A K Singha, MD, CTRAN Consultancy Ltd. gave an overview of the NAFCC process and climate financing criteria, etc. It was recommended that there is need of systematic long-term monitoring networks for obtaining robust scientific data for successful and sustainable CCA and DRR.

International Day for Biological Diversity Day

The International Day for Biological Diversity was celebrated at GBPIHED Headquarters and its regional units. At the Institute headquarters, a discussion session on the year's theme 'Mainstreaming Biodiversity: Sustaining People and their Livelihood' was organized to pick-up cues for fine-tuning the activities of 'Biodiversity Conservation and Management, Ecosystem Services, and Climate Change (BCM-ES-CC)' group of the institute in the context of global happenings. The day was also celebrated in different schools of Kailsh Sacred Landscape sites in order to promote awareness among students and teachers. In Himachal Unit, an orientation lecture on the above theme was delivered and the students were exposed to various facilities such as environmental observatory, arboretum, herbal gardens, and the waste management demonstration site at the unit campus. In Sikkim unit, an interactive and discussion session with scientific staff and researchers of the unit was conducted.

World Environment Day

The World Environment Day (June 5, 2016) was organized at the Institute and its units with great deal of enthusiasm and fanfare. In Garhwal unit a workshop on this year's theme "Go Wild for Life: Zero Tolerance for Illegal Wildlife Trade" was organized at the unit premises in Srinagar. Students from HNB Garhwal University, local NGOs, and senior citizens of the region participated in the programme. The programme concluded with the pledge for wildlife conservation. In Northeast unit at Itanagar, a brainstorming session on Environment Day was organized with the students and teachers of Garden Dew Public School (Itanagar). The students were sensitized about the

history and genesis of Environment Day and the Theme of the year, which was followed by a discussion on environment, biodiversity, and wildlife conservation. In Himachal Unit at Kullu, the day was celebrated at Govt Senior Secondary School, Bajaura, wherein nearly 300 participants including 250 students and teachers from different schools and colleges of Kullu valley and 50 research scholars, staff, and faculty members of the Himachal unit attended the function. A rally of participants in the Bajaura area with Slogans on awareness about the environment was also organized, and the tree plantation in the School Campus was carried out.

Union Environment Ministers Meeting

The Union Minister of State (Independent Charge) for 'Environment, Forest and Climate Change' Hon'ble Sri Prakash Javdekar, during his visit to Almora (Uttarakhand) convened a review meeting of 'G. B Pant National Institute of Himalayan Environment and Sustainable Development' at Circuit-House, Almora; the meeting was attended by the director, scientists, and other officials of the institute. Sri Ajay Tamta, Member of Parliament (Almora-Pithoragarh constituency) was also present in the meeting. The minister was extremely pleased with the progress of the Institute; he congratulated the staff on the institute's up-gradation to a national level, named as 'G B Pant Institute of Himalayan Environment and Sustainable Development', and encouraged the staff to gear-up for its transformation into an International level Institute. Underlining the importance of Himalayan Eco-system and its fragility concerns, he emphasized that the Institute needs a team of quality researchers. The minister released the mission document on 'National Mission for Himalayan Studies'.

High Power Sub-Committee Meeting for Institute's Upgradation

A high powered sub-committee constituted by MoEFCC visited the Institute and took a meeting of staff and scientific faculty of GBPIHED on June 27, 2016 to discuss the structure, R&D programmes, manpower, and functions and funding modalities of the institute in context of its upgradation to national level institute named as 'G. B. Pant National Institute of Himalayan Environment and Sustainable Development'. Prof S P Singh, the Ex-Vice Chancellor (HNB Garhwal University) and the Member Governing Body and Chairman, Institute's Scientific Advisory Committee, chaired the meeting; Dr Suneesh Buxy, IFS, DIG - Forest (MoEFCC New Delhi), Prof D M Banerjee (Emeritus Professor of Geology and INSA Honorary Scientist), Dr T Chandni (Scientist-G/Adviser, MoEF&CC New Delhi), and Dr P P Dhyani (Director GBPIHED) were the other members of the committee.

National Consultation on Khangchendzonga Land scape Conservation & Development Initiative

As a follow up of the then on-going extended phase of KLCDI in India, a national consultation of stakeholders on the '*Khangchendzonga Landscape Conservation and Development Initiative (KLCDI)*' India held in Chumbi Residency, Tibet Road, Gangtok on 15th May 2016. The G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Sikkim Unit (Pangthang-Gangtok), in collaboration of ICIMOD-Nepal and with cooperation of state forest departments of both Sikkim and West Bengal, organized this interactive meeting, which intends sharing the progress of programme so far and further sharing Natural Resource Management Plans for three pilot sites in KL-India. Over 45 participants representing high level government and non-government officials from Sikkim, West Bengal and Nepal, including ICIMOD (Nepal), scientific and academic institutes like Sikkim University, BSI, IBSD, , GBPIHED, etc, local NGOs and other organization from Sikkim (TMI, ECOSS, ATREE, NABARD, etc) and West Bengal (HNAF, PRERNA, etc), and community /Panchayat representatives from pilot sites, and researchers, intensively interacted in the consultation and shared their views.

Scientific Advisory Meeting

The 22nd Meeting of Scientific Advisory Committee (SAC) of GBPIHED was held on 26-27 August 2016 at the Institute HQs. Prof. S.P. Singh, Chairman; Dr. D.C. Upreti, Dr. Paramjit Singh, Director BSI, Member; Er. Kireet Kumar, Dr. H.K. Badola, Dr. J.C. Kuniyal (GBPIHED Nominee Member); Dr. J.K. Bisht, VPKAS, Almora (Special Invitee), Dr. P.P. Dhyani, Director GBPIHED attended the meeting. Prof. D.M. Banerjee, Dr. Arun K. Sharma and Director, Wadia Institute of Himalayan Geology could not attend the meeting. The Chairman, Prof S. P. Singh, in his opening remarks mentioned that over last three years the Institute has improved its outreach by way of engaging with diverse stakeholders. Institute's engagement with peoples' representatives and through widening of network of young researchers has brought in more visibility to the Institute across Himalaya. SAC unanimously appreciated the dynamism of R&D that has been brought in recent years by way of excellent academic leadership. SAC further appreciated the efforts made by the Institute in: (i) obtaining/strengthening international

partnerships like full membership of Himalayan University Consortium, (ii) undertaking R&D beyond boundaries in collaboration with ICIMOD, (iii) achieving scientific excellence through quality publications, (iv) engaging with diverse stakeholders through 8 new initiatives, and (v) generating adequate funds for R&D from external funding agencies (national and international) and thereby strongly moving on the path of self sustenance.

Annual Day and Pant Memorial Lecture

The Institute at its HQs Kosi-Katarmal, Almora and all the regional units (Garhwal Unit, Srinagar; HP unit, Kullu; Sikkim unit, Pangthang; NE Unit, Itanagar; Mountain division, New Delhi) celebrated its foundation day and organized 22nd G B Pant Memorial Lecture on 10th September 2016. At HQs Dr. Vijay Raghvan, Secretary Department of Biotechnology, Government of India was the speaker of 22nd G.B. Pant Memorial lecture. While deliberating on the lecture, he stressed on the use of biotechnology in the day to day problems and requested all to focus their research towards solving the problems. He indicated that such efforts will lead towards achieving the sustainable development goal. On this occasion, Mr. Ajay Tamta, Minister of State for Textiles; Prof. A.N. Purohit and Prof. S.P. Singh, Ex Vice Chancellor, HNB Garhwal University; Secretary and Additional Secretary, MoEF&CC Govt. of India; dignitaries from various organizations, scientist and staff of the Institute participated. At Garhwal Unit, 3rd Himalayan Popular Lecture entitled "Impacts of service sectors on natural ecosystem and Natural Resource management" was delivered by Mr. Bharat Jhunjunwala. The event was attended by around 145 participants comprising of students from Govt. Polytechnic College Srinagar, Scholars and Professors from HAPPRC and Garhwal University, NGOs and other stakeholders. In Sikkim unit, a popular lecture on "*Knowing the Sikkim Environment and Culture- My experiences" was delivered* by Shri S. G. Tashi, Vice Chancellor ICFAI University-Gangtok. He talked about the changing agricultural systems in the Himalayan region. Shri Omkar Singh, PCCF & Principal Secretary, Govt. of Arunachal Pradesh delivered a popular lecture at NE Unit on the topic "Status of Biodiversity in the Forests of Arunachal Pradesh".

Swachh Bharat Mission Campaign

The Institute at its HQs and all the regional units organized Swachh Bharat Abhiyan in line with the National campaign by the Government of India to clean the streets, roads and villages of the country. In Sikkim Unit cleanliness drive was organized on 27th September, 2016. About 29 unit staff, field assistant and researchers participated in these events. In NE unit, the campaign was organized through posting/installation of banners, slogans and messages, awareness campaigns with the village community, and conducting cleanliness drives at different occasions in the villages. As part of the programme, the NE Unit conducted an awareness and cleanliness drive on August 27, 2016 at Nompu village.

Awareness Programme on High Altitude Wetlands

An education cum awareness program on "Conservation of Floral Biodiversity of High Altitude Wetlands with Special Reference to Climate Change" was organized by the NE Unit for students, teachers of Govt. residential school (Taktsang) and local communities under SERB, DST funded project on October 09, 2016 at a very remote Taktsang village, Zemithang Circle, Tawang district of Arunachal Pradesh. The significance of high altitude wetlands, biodiversity and impact of climate change in high altitude ecosystem was discussed with the participants.

International Conference

An international conference (ICBCS-2016) was jointly organized by Rajiv Gandhi University, Arunachal Pradesh and the North East Unit, GBPIHED from October 15-18, 2016 at Rajiv Gandhi University campus, Arunachal Pradesh wherein the researchers and global think tanks working in the area of Biodiversity, Climate Change and Sustainable Development presented their research work in technical session and took active participation in side events. The NE Unit showcased the activities through a display stall/exhibit during the side events of conference. Er. M.S. Lodhi, Incharge, NE Unit was the Joint Organizing Secretary; he also chaired one technical session during the conference.

National Seminar

A National Seminar was jointly organized by Department of Economics, DN College, Itanagar and NE Unit, on October 22&23, 2016 at Dera Natung Government College, Itanagar and sponsored by UGC (NERO). The NE Unit provided technical and logistic support in organizing the National Seminar. Er. M.S. Lodhi, Scientist Incharge delivered a special lecture on "Environmental degradation in Indian Himalayan region" during the opening day of the seminar. Several research

papers were presented by the researchers of the NE Unit who also took active role.

Exposure visit cum training

An exposure cum training on Bamboo value chain development for the local communities of Landscape Initiative for the Far-Eastern Himalayas (Hi-LIFE) project area was jointly organized by G. B. Pant National Institute of Himalayan Environment and Sustainable Development and Rain Forest Research Institute (RFRI), Jorhat, Assam at RFRI, Jorhat from 10th to 14th November, 2016. The training program was sponsored by International Center for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal. Twenty-eight participants from Hi-LIFE India project area i.e. Miao, Changlang district, participated in the above exposure visit cum training. The main aim of the training was to give first-hand experience to local people on usefulness of bamboo, and bamboo based value chain for improving the livelihood opportunities of local communities at pilot sites of Hi-LIFE India. The Programme was inaugurated by Dr. R.S.C. Jayaraj (Director, RFRI Jorhat) who spoke about the importance of bamboo for rural economy of the people of Assam. Dr. K.S. Kanwal, Scientist, GBPIHED welcomed all the participants of the training program and provided a detailed overview of Hi-LIFE Initiative, objectives and expected outcome of the program. He appraised about the richness, uniqueness and significance of the Far Eastern Himalayan Region. He highlighted that linking of ecosystem service with livelihoods will help in participatory resource management for equitable growth and development of the region. Dr. R.K. Kalita, Scientist RFRI appraised the purpose and structure of exposure visit cum training program. Dr. T.C. Bhuyan, Former faculty of RFRI and resource person of the training gave a presentation on Overview of Bamboos in the Country-Choice of species for Arunachal Pradesh. A trip was organized to visit Nagaland Bamboo Resources Centre (NBRC) at Dimapur, Nagaland which is about 170 km from Jorhat, Assam.

National workshop on Forest Resources and Plant Biodiversity

A National workshop on "Forest Resources and Plant Biodiversity" was organized at the Institute HQs in Kosi Katarmal, Almora from November 16-18, 2016 under the DST funded National Mission for Sustaining the Himalayan Ecosystem (Task Force-3). The objective of the workshop was to validate, refine and finalize the common methodology, to identify and discuss various thematic gap areas, and to establish project partnership and develop mechanism of knowledge and data sharing. The workshop began with an overview of different activities of the project by Dr. S.K. Nandi (PI, GBPIHED), which was followed by a presentation of progress, session objectives, and discussion points by Dr. R.C. Sundriyal (GBPIHED). The workshop provided a platform to exchange scientific ideas which were helpful in developing, standardizing and validating methodology for various components of the project. Identification of climate change indicators and vulnerability assessment framework, developing monitoring protocols were some of the outcomes in this Workshop. Several experts namely, Prof. S.P. Singh, Dr. A. Pattanayak, Prof. S.P.S. Kushwaha, Prof. M.L. Khan, Dr. D.K. Upreti, Dr. Amalava Bhattacharya, Dr. C.S. Jha were present and provided valuable inputs. The workshop was attended by over 120 participants representing 20 Institutes and universities all across the country.

Workshop on Sustainable Livelihood Development

A day long workshop was organized by GBPIHED, North East Unit and Himalayan Environmental Studies and Conservation Organisation (HESCO), Dehradun, Uttarakhand on November 28, 2016 at Itanagar, Arunachal Pradesh. The main objectives of the workshop were to understand the issues and challenges related to sustainable livelihood options of ethnic communities in Arunachal Pradesh and preparing a future roadmap, and build popular opinion for common roadmap by involving community and research institutes for sustainable livelihood development. The programme was started with a formal welcome speech and felicitation to the Chief Guest Shri Omkar Singh PCCF&PS, Padmashree Dr. Anil P. Joshi (HESCO, Dehradun), special guest Dr. V.K. Sharma (SIRD, Itanagar) and Er. M.S. Lodhi, Incharge NE Unit. Shri Omkar Singh highlighted the importance of the workshop and congratulated the organizers for organizing such an important event. He mentioned that Padmashree Dr. Anil Joshi has played significant role in rural development in Uttarakhand state and he is amongst the real heroes working for the Himalaya. Er. M.S. Lodhi in his opening remarks discussed the background of the workshop and stressed upon the importance of rural livelihood development in the state of Arunachal Pradesh.

International Mountain Day

Towards celebrating International Mountain Day, a workshop on "Mountain Cultures: Celebrating Diversity and Strengthening Identity" was organized at the Institute HQs, Kosi-Katarmal, Almora on December 11, 2016.

Similarly, Sikkim Unit and Integrated Mountain Initiative (IMI)-Sikkim chapter, jointly organized an interactive meeting. One day meeting was organized in collaboration with Forest, Environment and Wildlife Management Department, Govt of Sikkim at Range office of Fambonglho Wildlife Sanctuary, Pangthang, East Sikkim. Over 40 participants representing various Government and NGOs, including the Sikkim Forest department, Sikkim University, The Mountain Institute of India, ATREE-Sikkim, GRADE-Sikkim, Department of Justice-Sikkim, EIECOS-Sikkim, MLAS-Dzongu, Echostream, WWF India (Gangtok), Taktse International School, ECOSS and GBPIHED, Sikkim Unit and others, intensively interacted upon the theme. In NE unit the day was celebrated at Museum Hall of Mother's Home, Suluya Village. Members of Achu-Kuru Welfare Society, Mother's Home, Members of Biodiversity Management Committees, Representatives from Forest Department and Local Community and Students from Dutta Middle School, Ziro, Arunachal Pradesh attended the celebration. Garhwal Unit celebrated the day at Sadharmyam Meeting Hall, Upper Bhaktiyana, Srinagar Garhwal. About 70 participants comprising students from cultural and folk department of HNBGU Srinagar Garhwal, local entrepreneurs engaged in crafting artisans, and handloom, and NGOs participated in the event. Chief Guest of the programme Prof. J. P. Pachauri, Department of Sociology and Social work has stressed on development of local artisans and handicrafts based economy through improvement in technical skills. Prof. D.R. Purohit, department of English, HNBGU Srinagar Garhwal pointed out about improvement in local instruments developed by the community since antiquity and promoting these instruments to give them due recognition and value. Dr. R. K. Maikhuri, highlighted the issues and challenges faced by the mountain communities and emphasized on skill development and training to the people.

Workshop on Cultural diversity

The Institute organized a three days workshop (December 28-30, 2016) on 'Diversity - Our Identity Our Heritage' in order to raise the awareness towards understanding the bio and cultural diversity under Kailash Sacred Landscape Conservation and Development Initiative project at Gangolihat, Pithoragarh during 28-30 December 2016. In this event cultural diversity of Kumaun region was exhibited and celebrated. The cultural groups included Shauka, Rang, Johar, Gangola, Vanraji, and others who avtively participated. Around 400 participants from diverse group of stakeholders participated in this 3-day event.

Side event on Himalayan Ecosystem

The Institute organized a side event on "Impact of climate change on the Himalayan Ecosystem" at CoP 22 - Twenty second meeting of the Conference of the Parties to the UNFCC at Marrakech, Morocco during November 7 - 18, 2016. Also a side event on "Himalayan Biodiversity & Climate Change" at CoP 13 - Thirteenth meeting of the Conference of the Parties to the Convention on Biological Diversity at Cancun, Mexico during December 4 - 17, 2016.

Environmental awareness cum plantation campaign

A one-day programme on environmental awareness was observed along with plantation of elite plant species at Lindok, 8th mile, East Sikkim (altitude 1200 m a.s.l.) on 17th Feb, 2017. A total of 40 participants from the village including the local farmers, the panchayat and staff of GBPIHED, Sikkim unit participated in the programme. The program was conducted on the Panchayat premises with support from Panchyat and villagers. Around 100 plants were planted on the Lindok area and the species selected were habitat specific e.g. *Phoenix rupicola*, *Spondias axillaris*, *Eriolobus indica*. Some selected plants are threatened and vulnerable and some are economically important of the region and plantation of such species will not only socially benefit the local people but also help in conservation of the species. The programme concluded with discussion session where the effectiveness of the programme was discussed and suggestions were noted.

Training and capacity building programme on Value addition and marketing

A one day training and capacity building programme on Value addition and marketing of agro-products through organic farming was organised by Garhwal Unit of GBPIHED on 7 March 2017 at village Loyal, Tehri Garhwal. The major objectives of the training programme were to interact, share experiences and knowledge with stakeholders about the value addition of agro-products which they are growing in their farming systems and role of government institutions and developmental programmes in strengthening agricultural sector. The focus was on organic farming and marketing, to understand and analyse the major factors responsible for change, governments (state and central level) action and response to provide amicable solution and to understand the stakeholders perception, and response about climate variability/change and its impact on agro- products and farming system

including local adaptation measures/strategies, if any. A total of 70 participants attended the training programme. The programme identified the need for capacity building programmes for farming communities with regards to enhance the quality of agro-products by integrating these products with organic farming so as to fetch premium price at national and international market. Value chain to reduce the risk in price controlling of the products and timely selling as identified one of the critical step to be taken to bridge the gap between producers and buyers.

Rural Technology Strengthening for Clean Environment at Lingdok

On March 8th 2017, a meeting/training-cum-interactive session on rural technology strengthening for clean environment was organized by Sikkim unit of GBPIHED in Lingdok, East Sikkim, under Swachh Bharat Mission. The program was intended to aware the villagers and the school kids about waste management and to teach them various technique of composting the degradable wastes. After a brief speech by Dr. Y.K. Rai (Coordinator of this programme) and other respected guests, the participants were divided into two groups, who started cleaning the village area, including the school grounds, roadways, places around shops etc. A group of 70 people including farmers, SHGs, panchayat members, students, and teachers actively participated in this event. Plastic wastes and degradable wastes were collected separately. A large volume of plastic wastes were collected which included plastic bottles and chocolate wrappers mainly from the school areas. The procedure of making compost from the wastes by adding forest humus, leaf litter and water was demonstrated involving the villagers themselves. Mainly the school kids focused on awareness but were also involved in the cleaning work along with other adult villagers. Dustbins made using local bamboos were distributed by the institute. Bins were coloured distinctly, those coloured in green were for degradable wastes and those in red were for plastic wastes.

Workshop on Hydropower Project

A brainstorming workshop on “Hydropower Project and Environmental Impact Assessment (EIA)” was organized under in-house project-3 entitled 'Strategic Environmental Assessment (SEA) of Hydropower Projects in the Indian Himalayan Region' at Lakhimpur Girls' College, North Lakhimpur, Assam on March 12, 2017. The workshop objectives were to bring experts, researchers, administrator civil society group working on the issue of dams with special reference to upcoming hydropower project in the North-Eastern India. The workshop helped in sharing and learning experiences with other participants. including representatives from line departments. A total 60 participants attended the workshop. Dr. Surajit Bhuyan, Principal of Lakhimpur Girls' College inaugurated the workshop and discussed about the basic concept of hydropower project and EIA. Er. M.S Lodhi, SIC of NE Unit discussed about the process of EIA and its role in hydropower development. He also highlighted the major hurdles viz. Land acquisition, road connectivity, displacement or resettlement and other environmental issues in hydropower development in the region. Dr. L.P Hazarika gave a presentation on critical analysis on EIA environmental decision making machinery. He suggested that the quality of EIA reports needs to be improved for realistic assessment of impact of hydropower development. Dr. K.S. Kanwal discussed the impact of hydropower projects on biodiversity of Arunachal Pradesh. All the experts and other stakeholders, in one voice, suggested that strategic environment and social planning is urgently needed with the participation of local communities for sustainable development of hydropower projects in the North-East Himalayan region.

Training cum awareness programme

A training cum awareness programme on 'Community Based Ecotourism for Biodiversity Conservation and Sustainable Livelihood Development' was organized by the North East Unit, Itanagar under In-house project-1 entitled “Eco-tourism as a potential tool for biodiversity conservation and sustainable livelihood in Indian Himalayan Region” at Mother's Home of Achukuru Welfare Society, Ziro on March 18, 2017. The programme aimed at creating awareness about community based ecotourism for strengthening capacity of local communities for sustainable livelihood development and conservation of biodiversity. During the programme, GBPIHED Scientist, Dr. K.S. Kanwal gave a detailed presentation on the community based ecotourism as a potential tool for biodiversity conservation and sustainable livelihood development, and discussed the potential and prospects of community based ecotourism in the state. Speaking as resource person, Lower Subansiri District Tourism Officer, Shri Dikchu Raji appraised the participants about various ongoing schemes of government for development and promotion of tourism in the state. Range Forest Officer, Shri NyilyangTachang highlighted the importance of wildlife for tourism and said that community participation can play a key role in

conservation of biodiversity and development of tourism in the region. Chairman of NgunuZiro, a local NGO, Shri HibuTatu informed the participants about the concept of homestays, roles and responsibilities of homestay owners, and positive as well as negative aspects of homestays. Ms. Tailyang Shanti, Chairman of Achukuru Welfare Society thanked the G.B. Pant Institute for organizing the training program at Mother's Home, Ziro. She hoped that each participant would be benefitted by this training cum awareness programme.

Training programme on eco-tourism

Under the project "Eco-tourism as a potential tool for biodiversity conservation and sustainable livelihood in Indian Himalayan Region" two days training program was organized at Tiwargaon, Tehri Garhwal on 25th and 26th March 2017 where 28 stakeholders were participated and learnt different tools, methods and techniques of eco-tourism activities. The training was provided by Mr. Jeevan Lal Verma, who is a successful eco-tourism entrepreneur from Sonargaon, Bageshwar, Uttarakhand. The programme was graced by Mr. Sobat Singh Jeena, Tourist officer, Tehri Garhwal. Drs A.K. Sahani (PI), Arun Jugran, L.S Rawat, Prakash Phondni, Yetish Bahuguna from the Garhwal Unit also delivered lectures on various livelihood options through integrated Eco-tourism.

Training and capacity building programme on Livelihood enhancement

A two days training and capacity building programme on livelihood enhancement through skill development and sustainable management of natural resources in rural areas was organized by Garhwal unit of GBPIHED at Village Jammu, district Rudraprayag between 27-28 March, 2017. The workshop provided an umbrella for sharing experience and ideas among wider stakeholders such as scientists, officials of state government line departments, villagers, NGOs, and students in the context of skill development for sustainable natural resources management and linking this with livelihood options to the stakeholders. The technical skill in field of various livelihood options like promotion of organic cultivation, horticulture plantation, value addition in local bioresources, honey bee rearing, mushroom cultivation, seasonal and off-seasonal vegetables cultivation through introducing protected cultivation technology to enhance the production and improve quality of the products and climate resilient technologies to cope the adverse impact of climate change. About 130 participants from different sections of the society participated in the programme. The participants were motivated and encouraged to adopt simple eco-friendly technologies for livelihood enhancement. Shri A. N. Shukla, Incharge, Horticulture Unit, Guptakshi, briefed about preparation methods of different value added products from edible fruit species of the region to the participants. Dr. R K Maikhuri, Convener of the programme, addressed different wild edible fruit species and their medicinal and marketing potential if harnessed sustainably and motivated participants to conserve these resources through sustainable harvesting.

Capacity Building Workshop on Long Term Monitoring of Himalayan Biodiversity

Two day national capacity building workshop was organized on "*Long term monitoring of Himalayan Biodiversity for Stakeholders of Himalayan region*" jointly by the G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Sikkim Unit; Zoological Survey of India, Kolkota and Botanical Survey of India, Kolkata as part of the National Mission of Himalayan Studies (NMHS) programme of the Ministry of Environment, Forest and Climate Change, Government of India during 29-30 March 2017. This two days capacity building workshop was held at Hotel Chumbi Residency, Tibet Road, Gangtok. Stakeholders from state forest department, central and state government officials and NGOs as well as students and researchers of various universities and institutes concerning Biodiversity and its conservation, participated in this workshop. Dr. Kailash Chandra, Director, ZSI briefed about the Long term monitoring of Himalayan biodiversity in Himalayan region and jointly carried out by ZSI, BSI and GBPIHED in both eastern and western Himalayan region. Shri Vineet Kumar, PCCF of Himachal Pradesh attended the workshop as the Chief Guest and in his inaugural address emphasized on the importance of long term monitoring of Himalayan biodiversity in the context of climate change. Dr. Thomas Chandy, PCCF, Sikkim Forest department, Dr. H. K. Badola, Scientist In-charge of GBPIHED, Sikkim Unit, Dr. Bipin Sinha, Scientist-F, BSI, Kolkata and Dr. Usha Lachungpa, Principal Research Officer of Sikkim Biodiversity Board were also present during the inaugural session. During this two days programme, Scientists from the ZSI, BSI and GBPIHED presented their studies and familiarized the participants belonging to different backgrounds about the modern research techniques and tools in the field of Himalayan biodiversity.

Interactive Meeting on Biodiversity Conservation

In an effort to generate awareness on biodiversity issues and conservation measures, a one-day interactive meeting on biodiversity conservation was organized by GBPIHED, Sikkim Unit on 30th March 2017. Over 35 students, teachers and scientists participated in the programme. At the outset, Dr. H.K. Badola, Scientist In-Charge of the Institute enlightened the participants about biodiversity by explaining them the importance of biodiversity which consists of important flora and fauna having great purpose. He also spoke about endangered species and their conservation through *ex situ* and *in situ* techniques and on cultural diversity of communities of Sikkim focusing on the age old ways used by them for conservation of biotic life. Dr. Mithilesh Singh, highlighted different causes of biodiversity loss and also explained why conservation of biodiversity is necessary. She focused on biotechnological interventions that can be used to conserve important plant species of the Sikkim Himalaya. After that, all the students participated in painting competition whose theme was "Biodiversity conservation". Students of two schools from Bojhogari and Penangla actively participated in this competition. After prize distribution, teachers of each school were felicitated with khadas and small gifts. Each and every student were given small consolation prize to keep their spirits up and inculcate the feeling of good competition.

3. RESEARCH AND DEVELOPMENT PROGRAMMES

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

The overall mission of SED & KCB Group is to promote ecological and economic security, and sustainable development in the Indian Himalayan Region (IHR), which is characterised by diverse, unequal and often varied socio-economic realities. The Socio-economic Development (SED) theme works for promoting innovative, knowledge-rich, cost-effective and eco-efficient economy, so as to provide better livelihood and employment in IHR. It supports research in a range of disciplines that focus to understand social and economic dynamics and patterns, such as population density, growth, poverty and migration, status of natural resources and community dependence, key temporal and spatial trends influencing these factors, and impacts of natural and human risks and hazards on socio-ecological systems. Investigations are done to understand the complex interactions and interdependencies between the social, economic, physical and natural environments so as to identify socio-economic risks, vulnerabilities and coping capacities of different communities in IHR.

There is enormous knowledge being generated on various subjects within and outside the institute, however the challenge is how to harness this knowledge in a coherent and productive way so that it could be used for the benefit of the Himalayan society. The Knowledge Products & Capacity Building (KCB) theme compiles new knowledge generated on diverse discipline, devises/ designs suitable products, strategies, plans, approaches, and services so as to take appropriate actions. The theme works with communities, take interdisciplinary R&D investigations, develop location/problem specific demonstrations and skill development programs, facilitate linkages between knowledge providers, knowledge seekers and users to effectively utilize available knowledge resource/products, and undertake policy advocacy on NRM and sustainable development issues of IHR. Thus SED & KCB Group and its R&D efforts greatly contributes to regions and communities, and by working with network of partners at local, regional and national level, facilitates communities becoming more resilient and adaptive to global change.

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

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

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

The importance of biological resources for human sustenance and welfare is tremendous and beyond question since immemorial. With increasing human population and demand for bioresources, its sustainable and judicious use is essential for the long-time survival of the mankind. This holds extremely important in the IHR, which covers a total geographical area of approximately 591,000 km^2 (18% of

India) and is inhabited by about 3.7% of the total population of the country. This region harbours a variety of flora and fauna, and is considered a "hot-spot" of biodiversity. It also contributes significantly to livelihood and contributes to the economic well-being of the people. However, in the changing world scenario there is an increasing emphasis on the need for increasing food production, pharmaceutical and other products, along with industrialization, which has compelled biologists to contemplate on issues like conservation of biodiversity, climate change, ecosystem service, etc. The group focuses on aspects of biodiversity conservation and management, ecosystem services and climate change perturbations in the IHR.

Group: Biotechnology Applications (BTA) & Environmental Physiology & Biochemistry (EPB)

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

THEME

WATERSHED PROCESSES & MANAGEMENT (WPM)

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

Objectives

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

Ecological, social and policy implications of chaining water resource scenario in Indian Himalayan context (In house, 2012-17)

IHR, recognized as one of the most diverse and versatile mountain system in the world due to its distinctive attributes. At the same time, it is considered as one of the most vulnerable eco-system by climate change and other manifestation of global environmental changes. Recent developments in industries, booming urbanization altered the land use/land cover that increased the demand of water in manifolds, exerting extreme pressure on mountain water

resources. In this fragile mountain ecosystems of Himalaya, changes in the timing and volume of available water for rural water supply and irrigation can threaten water security and agriculture production, also creating water use conflicts in the area. With established facts of severe water scarcity in hills for agriculture as well as for domestic and industrial use, the water demand-supply assessment studies still lack in this regions. With the aim of closing the gaps between water management and catchment hydrology by addressing both bio-physical factors influencing the river and socio-economic factors affecting the level of domestic, agriculture and industrial demand; the Water Evaluation and Planning (WEAP) study has been carried out in Kosi and Mohal khad watershed for evaluating the water demand status of the area and water allocation strategy is formed.

Objectives

- To identify, analyze and assess potential indicators depicting changes in water resource scenario under changing climate regime and its interaction with different ecosystem components and society at basin scale.
- To investigate the implications of changing water resource scenario and delineate the critical ecosystem components susceptible to change.
- Analyses of the consequences of the changing water regime 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

1. WEAP model is customized for Mohal khad (Kullu) watershed and using its outputs possible impacts on water scarcity is demonstrated. For present WEAP modeling, we set year 2015 as a current year for which inputs (various primary and secondary datasets) were given to the model and future projection has been carried till 2030 with respect to water demand, unmet water demand, runoff, available water supply etc. for the Mohal khad watershed (Fig. 1). Rainfall-Runoff method (simplified coefficient method) was used in WEAP among the other three method based on scope of the present project.

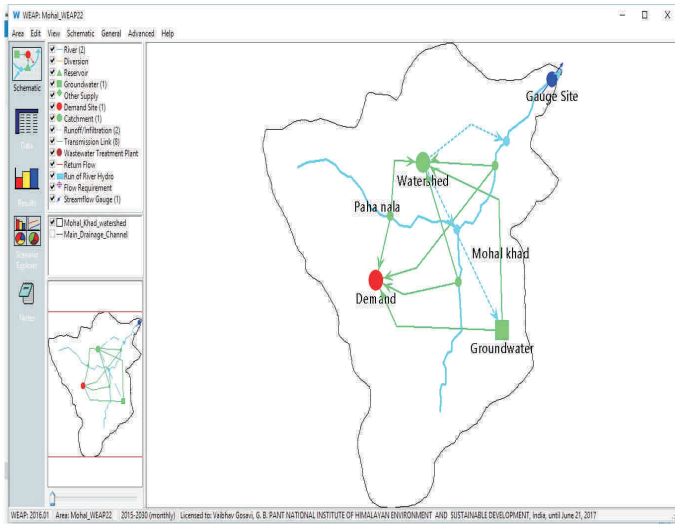


Fig. 1 WEAP Schematic for Mohal khad watershed

2. Average monthly surface runoff in WEAP is calculated by inbuilt Curve Number (CN) method. Runoff is highest in the month of July. Due to hilly topography huge amount of runoff mostly occurred in monsoon season in the watershed. Therefore, rain water harvesting is highly desired for meeting out unmet water demand of the watershed. Further forest area is expecting to experience highest runoff, this is due to fact that the watershed is mostly forested watershed with the area shared by the forest is about 65% of the total area (Fig. 2).

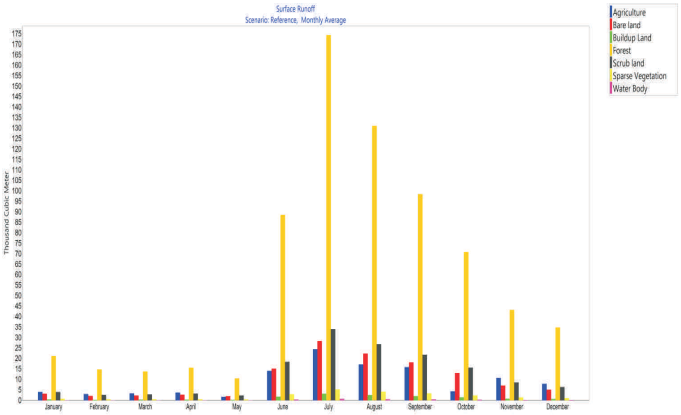


Fig. 2 Average monthly surface runoff from the watershed

3. Based on the study, critical eco-system components which are susceptible to change were identified - water quantity (mostly surface runoff and rainfall), land use changes, watershed characteristics that govern the soil infiltration. Based on WEAP modeling, water allocation strategy was framed for effective water management in the study area.

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

The Indian Himalayan Region (IHR) is a distinct and eco-sensitive geographical region where about 70% of the population lives in rural areas. This segment of the population in the Himalaya is dependent mainly on agriculture, horticulture and animal husbandry and, about 85% of the total agriculture of the central Himalayan region comes under rain fed category. Although in recent past, a decreasing trend in the yield of major crops (such as rice, wheat and madua) of this region has been observed with increasing trend in the cash crop or fruit production (such as soyabean, walnut etc.); socio-economy, agropractise, landholding, governmental policy along with changes in few environmental and climatological parameters are presumed to be responsible for this change. Moreover, quite often, changes in the climatic parameters reducing farm yields are over emphasized without any numerical assessment of actual impact of climate change on farm yield of this region. Again, knowledge of accurate and significant environmental and socio-economical drivers controlling farm yield of major crops and their degree of influence on changes of the yields is also ambiguous. Therefore, identification and quantification of drivers affecting crop yields of this region is of superior importance and requires multiplicity of approaches with detail knowledge of the system. Therefore, a study assessing impact of biophysical and social drivers on the farm yields was carried out in the Almora district of Uttarakhand state using district level impact assessment of changing environmental and socio-economical parameters affecting farm yields of rice, wheat and madua.

Objectives

- To quantify biophysical and socio-economical drivers/parameters controlling rainfed yields of rice, wheat and madua of a central Himalayan district.
- Sensitivity study of crop yields of rice, wheat and madua with respect to systematic changes in the identified climatic drivers using numerical models in view of expected future changes of climatic parameters.

Achievements

HQs Kosi-Katarmal

1. In order to identify significant drivers affecting rain fed agricultural yields of rice, wheat and madua of Almora district, drivers of agro-productivity were broadly categorized into three parts: (i) Physical drivers, (ii) Biological drivers and (iii) Social drivers. Each driver was further categorized into different parameters, such as monsoon and winter seasonal total rainfall and average temperature, soil pH, soil volumetric water fraction, cropping area, no of cultivators and no. of livestock. Individual parameters were selected based on expert opinion of agricultural scientists, cultivators and local government representatives of the region. Few other very significant parameters, such as human-animal conflict, implication of national policies, out migration etc., were also identified, however, such variables could not be included in the modeling exercise either due to qualitative nature of the parameter or due to lack of long term database.
2. The baseline data of agricultural yields and their drivers were collected as an annual time series for the period of 1990-2010 with very few missing values. Gaps in time series data were filled using simple linear trend. Details of the individual data are provided in Table 1.

Table 1: Description of drivers used in this study

S. No.	Parameters	Descriptions and sources
1	Total rainfall	Seasonal total rainfall of June -September of 1990 -2010 for rice and madua, and total rainfall of November - December for wheat. Data source: APHRODITE by Yatagai et al. (2009).
2	Average temperature	Seasonal average temperature of June -September of 1990 -2010 for rice and madua, and November - December for wheat. Data source: APHRODITE by Yatagai et al. (2009).
3	Volumetric soil moisture content	Data was obtained from NCEP Reanalysis products for 1990-2010.
4	Average soil pH	Soil pH of agricultural fields was used from published sources. Missing data were filled by plotting linear trends during study period and average rate was added or subtracted from previous year. Field observations during 2013-14 were also used to validate the trend. Data duration 1990-2010.
5	Total cropping area	Total annual cropping area of 1990 -2010 was available from Uttarakhand district statistical handbook.
6	No of livestock	Five yearly livestock population was available from Uttarakhand district statistical handbook. All livestock were converted into the cattle unit following Swarup (1991).

3. In order to assess impact of climate change on the district level yield of rice, wheat and madua collinearity amongst different drivers/parameters responsible for controlling yields were estimated. The condition indices of collinearity for each drivers of each crop are provided in Fig. 3. Any condition index from the collinearity analysis having value less than 10 shows weak degree of collinearity whereas, 10 < condition index < 30 shows moderate degree of collinearity amongst variables. It is eminent from Figure 1, that except for moderate collinearity of `No of livestock' for all three crops and `soil pH' for wheat, degree on collinearity amongst other drivers were negligible. Subsequently all of these drivers were used

to develop the GLM for future yield Prediction under three climate change cases.

4. The GLM model performances during training and validation period of rice and madua yield were evaluated using statistical measure of r^2-values and rmse. The rmse values during training and validations were found to be: 247.8 and 694.6.0 Mt for rice, 456.0 and 815.0 Mt for wheat. The same for madua were found to be: 225.0 and 675.0 Mt with r^2-values for rice wheat and madua of [0.9, 0.7], [0.88, 0.66] and [0.7, 0.68] for training and validation, respectively, inferring a satisfactory performance by the model. Finally, impact of changing climate on the yields of rice, wheat and madua was assessed using three different cases and six simulations. It was found that increase in both temperature and total rainfall from the baseline values of 29.1°C and 831.1 mm were expected to enhance the district level yield of rice by 30% and 40%, respectively, of the average yield between 1990-2010 values. Furthermore, enhancement only of average temperature was found to significantly increase yield of both rice and wheat by 28-31% and 68-75% from the average yield values of 1990-2010, respectively.

Garhwal Unit, Srinagar

1. The farmer's perceptions and indigenous knowledge related to pests and pest management within a broader perspective of agro-biodiversity and farming system in the central Himalayan region were documented.

2. In the hills, several factors are influencing agriculture and some of them are: (i) poor ecosystem health, (ii) lack of community involvement in the conservation and management of common resource pool viz. land, forests, water and traditional crops, (iii) youth moving away from the subsistence agriculture-due to high educational levels, and better prospects in other vocations, (iv) extensive damage being caused by wild animals and inconvenience to communities caused by wild life conservation laws, preventing farmers from taking any action to protect their crops, (v) market and socio-economic forces raising demand for different products.

3. Impact of climate change/variability in farming system were critically analyzed while involving 1020 households of 54 villages across an elevational gradient between 500 to 3000 masl in the central Himalaya and it was observed that farming communities adapting with traditional knowledge and their own innovations to fight against climate change impacts. This study explores perceptions of rural communities of Uttarakhand on climate change using gender–aware participatory rural appraisal methods (PRA), focus group discussion and interviews. During PRA, the following three indicators were used to collect information on the impacts of climate-change: (i) Seasonal weather variations (iii) Seasonal activity calendar and (iv) Resource availability chart.

4. Farmer's indigenous knowledge with regard to classification of drought resistance rainfed paddy landraces into three categories for cultivation based on their various climate stress situation such as severe drought (no rainfall), moderate drought (less rainfall) and normal weather conditions were documented and evaluated.

5. In recent years, several agricultural and horticultural support services have been implemented in the region (e.g. Horticulture Mission, Livelihood Programme, Agriculture Technology Management Agency (ATMA) and Uttarakhand Decentralized Watershed Development Project (GRAMYA). However, few have managed to reach their intended target/user groups. Extension services and support remain weak and inadequate for the traditional farming system. A strong commitment is required to address the complex social, economic, environmental and policy issues affecting smallholders and their farming systems in the region.

6. The farming systems in the region are challenged by political marginalization, limited access to markets, insufficient infrastructure and technological interventions, and poor quality of social services. All these factors combine to limit the options available to the farming communities, driving them further into poverty, which leads to migration of the male members to the plains to seek off-farm jobs. Breaking this vicious cycle of poverty requires robust institutions, fair policies, larger incentives, pragmatic multidisciplinary research approach, a renewed focus on science, appropriate technology and innovations. A strong political commitment is required to address the complex issues affecting the farming system in the region and its evolving needs.

7. Organized four capacity building/skill development programme at Randhar, Kandara, Silkakhal and Loyal

villages cluster in Garhwal region on "Promoting organic farming for reducing vulnerability to climate change impact in rural landscape and about 195 progressive farmers and majority of them were women to whom training on climate friendly suitable technologies, best practices related to agriculture and value addition in the traditional crops etc., were imparted for livelihood enhancement and income generation.

Investigation of alternative boundary layer scaling properties over the complex terrains of Himalaya (Ministry of Earth Sciences, Govt. of India, 2016-2019)

Exchange properties of energy within the convective boundary layer have been traditionally addressed with the statistical fluid mechanical (SFM) approach of Reynold's averaged Navier Stokes Equation. Following this framework, the dimensional analyses of Monin-Obukhov (MO) and Deardroff similarity theory have provided the conceptual and practical foundations for almost all modeling of the convective boundary layer (CBL) during the last few decades. However, with extensive and thorough experiments of CBL energy exchange processes, it has been realized that neither MO theory nor the Deardroff similarity theory is conclusive and dynamically efficient in explaining the CBL energy exchanges. As an alternative to this framework, a chaotic dynamical system (CDS) approach has been put forward by McNaughton et al. (2004, 2006) where the fundamental energy exchange processes in a CBL are assumed to be due to interaction of different types of eddies. This new CDS approach, unlike the SFM approach, describes the turbulence processes with few nonlocal parameters. These newly developed nonlocal scaling parameters of the CDS approach are found to be satisfactorily collapse the energy, momentum and tracer spectra in a wavenumber axis when turbulence is measured over a flat terrain. However, the model is yet to be tested over a complex terrain and over the flat terrains of India before its ubiquitous acceptance. Therefore, this project is aimed at extending this CDS approach of spectral analysis of CBL turbulence over two sites (on ridge-top and on-slope) of the Central Himalayan region where few new scaling properties will be investigated along with the traditional local scaling parameters.

Objectives

- The work element for 2016-17 is aimed at verifying MO theory based relationships of gradients and universal functions of surface layer for measurements made over a complex terrain during convective periods associated to dominant wind sectors and stability classes of summer and winter period. Within this broader framework, the particular objectives are:
- To verify the impact of surface inhomogeneity to turbulence properties for summer and winter period of 2016
- To compare normalized velocity and temperature fluctuations with existing models, and establish numerical relationships between integral turbulence parameters and stability parameter (z/L) by optimizing constants of two generic formulae for best fitting using data from summer and winter period of 2016.

Achievement

1. Data presented in the study were obtained from the on-slope site for the period of 01 February 2016 0000 hrs - 31March 2016 2330 hrs, considered as Summer season, and 01 December 2016 0000 hrs - 22 December 2016 2330 hrs Indian standard time (IST), considered as Winter season.

2. To investigate the impact of surface inhomogeneity in turbulence intensities, detail turbulent statistics for dominant wind sector runs for both summer and winter periods were estimated. Results of the study were compared to the observations made by Bradley (1980), Al-Jiboori et al. (2001) and Katurji et al. (2011) over complex terrain in different parts of the world. Following Miyake et al. (1970), it is known for a flow over a flat terrain would follow $\sigma u > s v > s w$. Average values of $s u$, $s v$ and $s w$ for the summer and winter period northwesterlies (270-350° and 260-340°) of this study indicate that the underlying terrain along the sector is much smoother than the other two sectors.

3. The transverse components of turbulence (σ_v / σ_u) for the same wind sector was also found to be 0.89 and 0.77, respectively, representing flow properties over a flat terrain; whereas the average (σ_v / σ_u) value for the southeasterlies (120-225° and 120-160°) of present study was found to be 1.0 and 1.0, respectively, corroborating well with some of the earlier results for flows over complex terrain (Bradley 1980, Al-Jiboori et al. 2001 and Katurji et al. 2011).

Summary of Completed Project / Activity

Geodynamics and hydrochemical studies of Gangotri glacier system Garhwal Himalaya (DST Funded)

The Himalayas contain largest concentration of snow and glaciers other than the polar region. According to the various reports, a number of mountain glaciers are retreating due to climate change and global warming. During years 2013-16, the work was concentrated on snout mapping, measuring discharge and suspended sediment, stake establishment to determine the velocity of the glacier using GPS survey etc., around the snout area. The main purpose of this current study was to understand the dynamic nature of the Gangotri glacier system through ground based methods using the Differential Global Positioning System (DGPS). In addition the hydro-chemical study for temporal and spatial solute dynamics of glacier was also carried out. Some of the findings are presented below.

1. The Gangotri and Chaturangi glacier are retreating with variable rate 10.26±0.05 m/yr and 22.84±0.04 m/yr, respectively. This variation in retreating rate is not only due to change in local climatic conditions but also governed by glacier characteristics and morphological factors.
2. This study concluded that the satellite imagery method is suitable for long term study while kinematic GPS is more appropriate for the annual monitoring of retreating rate and trend. In addition for establishing cause effect relationship, between glacier retreat and other physical or local parameters, annual monitoring using DGPS is required. This study also suggested that monitoring and mapping of all the tributary glaciers is necessary in order to assess the overall changes in the main glacier system and its health.
3. The average surface velocity of the Gangotri glacier was around 2.58±0.13 m/month. The velocity was varied from margin towards centre, due to which several longitudinal and transverse crevasses were formed on the glacier surface.
4. The suspended sediment concentration 93.99×10^4 ton was measured in the year 2015 and 128.26×10^4 ton was measured in year 2016 from Gangotri glacier meltwater stream. This indicates that the erosion rate was higher in the year 2016 as compared to 2015 possibly due to high meltwater discharge volume 354.42×10^6 m^3 (May to September) in 2015 and 382.83×10^6 m^3 (June to September) in 2016.
5. The suspended sediment concentration 61.31×10^4 ton was measured in the year 2015 and 87.16×10^4 ton was measured in year 2016 from Chaturangi glacier meltwater stream. This indicates that the erosion rate was higher in the year 2016 as compared to 2015 possibly due to high meltwater discharge volume 193.41×10^6 m^3 (May to September) in 2015 and 237.23×10^6 m^3 (June to September) in 2016.
6. The atmospheric CO_2 level of Gangotri and Chaturangi glacier valley was around 270 ppm and 260 ppm respectively in 2014 and 286 ppm and 272 ppm respectively in 2016. This indicates that the atmospheric CO_2 level in both the valleys is slightly increasing with consistent rate.
7. The hydrochemical analysis of Gangotri and Chaturangi glaciers indicate that the Sulphate is the most dominant anion followed by Bicarbonate and Calcium is the dominant cation followed by Magnesium in both the glacier's meltwater.
8. The ions which were present in the meltwater also support the mineralogy of the nearby rocks, which indicates that weathering of surrounding rocks is the dominant mechanism controlling the hydrochemistry of drainage basin.
9. The relatively high contribution of (Ca+Mg) to the total cation (TZ^+) and high (Ca+Mg)/(Na+K) ratio (1.10±0.6) in year 2014, (1.12±0.8) in year 2015 and (1.21±0.21) in year 2016 indicates that carbonate weathering is a major source for the dissolve ions in meltwater of Gangotri glacier

Summary of Completed Project / Activity

Operation of permanent and campaign mode GPS stations for quantification of tectonic deformation field in Himalayan terrain (MoES funded)

1. The results of the present study throw light on the present rate of tectonic deformations and strain rates using continuously permanent operating GPS receivers in the urban towns in central and eastern sector of the Himalayan arc, i.e., Nainital and Almora in Kumaun Himalaya, Srinagar in Garhwal Himalaya, Kullu in Himanchal Pradesh, Ziro in Arunachal Pradesh and Gangtok in Sikkim. The results obtained from this study has also yielded helpful information in terms of the dynamic strain field in the region, should illuminate more definitively the hazard contexts and potentials of those already identified (as per Geological Survey of India) for creating a Minimum-Risk Land Use Plan in and around these urban centers.

2. The Himalayan region is under compressional regime due to collision between Indian and Eurasian plates. The velocity vector of all permanent GPS stations and two IGS stations (IISC and HYDE) concluded that an average convergence rate of Indian plate 47.89±0.99 mm/yr to Eurasian plate towards NE direction. The results as expected reveal a compressional tectonic environment in the Himalaya and the compressional strain is dominated in this region.

3. The strain rate interpretation through baseline change between permanent GPS stations revealed that the maximum strain is accumulated in the central part of the Himalaya between the MBT and MCT, which is lowering towards the E-W direction. It also explains that central part is most vulnerable for future earthquakes. However, the campaign site which are close to or within the Great Himalaya show significant annual convergence.

4. The results obtained from the six permanent GPS stations and campaign sites all along the Himalayan arc from E-W reveal that the central Himalaya, a part of central seismic gap shows an average ITRF08 velocity of 45.82±1.13 mm/yr. Based on the station velocities, we interpret that presently the detachment under the Lesser Himalaya (GBPK, GBNL) is locked with the Indian plate and show less amount of deformation which might be due to local thrust and faults.

5. The deformation rates derived from the limited period data (ranging from 2-5 years 2010-16) of permanent stations indicate that the magnitude and direction of velocity vector marginally varies from west to east and from one station to other. The velocity results indicate that no statistically significant changes occur in velocities of permanent stations during study period and the baseline changes between the station showed that the maximum expansion of crust along

THEME

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

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

Understanding biodiversity patterns and processes under changing resource use and climate scenario in Indian Himalaya – ecological and social implications (2012 - 2017; In-house)

The biodiversity of Indian Himalayan ecosystems is depleting gradually 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 IHR one of the most vulnerable ecosystems among the mountain landscapes of the world. Therefore, it calls for immediate actions towards assessing status, changing patterns and processes of biodiversity components of the temperate, sub-alpine and alpine landscapes and their conservation and socio-economic values; evaluating and comparing ecological integrity, stability and resilience of representative ecosystems and their components; analyzing impacts of climate and resource use changes on the biodiversity components, and assessing its socio-economic consequences so as to draw realistic and widely accepted action agenda for the conservation and sustainable use of its biological diversity under changing climate and land use. Keeping in view the importance of biodiversity of the temperate, sub-alpine and alpine regions

and its vulnerability to the global climate change, the study has been initiated in the temperate, subalpine and alpine landscapes of Himachal Pradesh in the North Western Himalayan biogeography province. Establishment of long-term monitoring sites to ensure uninterrupted flow of information, identification of most resilient habitat and formulation of Himalayan biodiversity and climate change network (HBCC-KN) are among major outcome of the study.

Objectives

- To assess status, changing patterns and processes of biodiversity components of the temperate, sub-alpine and alpine landscapes of Himachal Pradesh in North Western Himalaya
- To assess conservation and socio-economic values of biodiversity of the temperate, sub-alpine and alpine landscapes
- To evaluate and compare ecological integrity, stability and resilience of representative ecosystems and their components in the target landscapes
- To analyze impacts of climate and resource use changes on the biodiversity components, and assess its socio-economic consequences
- To establish Himalayan Biodiversity and Climate Change Knowledge Network (HBCC-KN) to build on existing knowledge and enhance information generation, and develop management and sustainable use plans with policy briefs

Achievements

Himachal Pradesh: Kanawar Wildlife Sanctuary

- Among 5 identified plant communities 12 sites were sampled between 2,711-3,392 m altitude (31.92584°-31.95103°N lat. and 77.34949°-77.36466°E long.). Soil moisture content of studied sites ranged from 15.48-65.52%; pH 5.47-7.18; total nitrogen 0.05-1.21% and organic carbon 1.95-7.49%.
- Among these communities, tree density ranged from 32.0-998.0 ind. ha^{-1}; total basal area 3.095-27.472 m^2 ha^{-1}; sapling density 160.0-470.0 ind. ha^{-1}; seedling density 83.0-1160.0 ind. ha^{-1} and shrub density 235.0-843.0 ind. ha^{-1} and herb density 30.60-75.45 ind. m^{-1}. Species diversity index (H') for trees ranged between 0.129-1.281, saplings, 0.14-1.08, seedlings, 0.27-0.94, shrubs 0.69-1.99; and herbs 2.41-3.56. Concentration of dominance of trees ranged between 0.02-0.952, saplings, 0.34-0.76, seedlings, 0.21-0.56 shrubs, 0.16-0.50; and herbs 0.04-0.10.
- Total 209 species (Angiosperms: 198; Gymnosperms: 07; and Pteridophytes: 04) were economically important and used as medicine (88 spp.), wild edible/food (27 spp.), fodder (40 spp.), fuel (27 spp.), timber (5 spp.), religious (05 spp.), fibre (07 spp.), making agricultural tools (06 spp.) and some other purposes (09 spp.).
- The inhabitants of Gharan, Thunja, New Kasol and Old Kasol villages were dependent for fuel and fodder resources on six forest tree communities namely, *Quercus floribunda, Quercus floribunda- Pinus wallichiana* mixed, *Pinus wallichiana, Celtis australis-Toona serrata* mixed, and *Picea smithiana* communities. The lopping intensity in different communities is presented in Fig. 3.

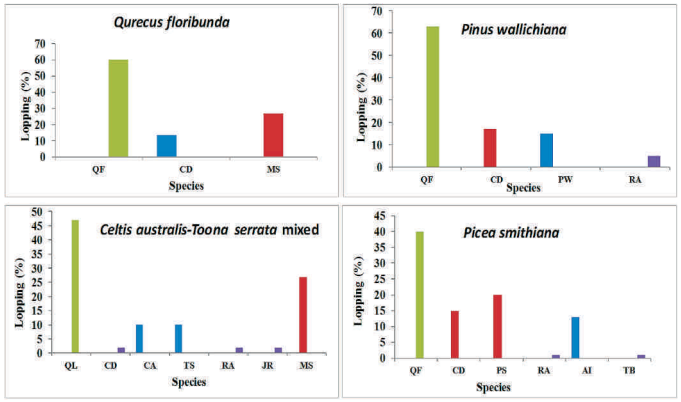


Fig.3. Lopping intensity of tree species within different forest communities

Abbreviations used: AI=*Aesculus indica,* CA=*Celtis australis,* CD=*Cedrus deodara, MS=Morus serrata,* PW=*Pinus wallichiana,* PS=*Picea smithiana,* QF=*Qurecus floribunda,* QL=*Quercus leucotrichophora,* RA=*Rhododendron arboreum, JR= Juglans regia, TB=Taxus baccata* ssp. *wallichiana,* and TS=*Toona serrata*

Uttarakhand: Hat-Kalika Watershed and Byans valley

- In Hat-Kalika watersheds, based on reconnaissance of the entire watershed, a total of 9 villages were identified, 3 villages each at three different altitudinal zones (i.e. low altitude 800-1200 m Jarmal, Kanara, Bhandari Goan. mid altitude 1200 to 1600 m Kothera, Simalkot, Jajut and high altitude > 1600 m Chitgal, Futsil, Uprada). A total of 34 woody species (27 trees, 7 shrubs) representing 22 families were recorded for ethno-botanical purposes. Among these, Rosaceae was observed as the major family with a total of 5

species followed by Fabaceae (4 spp.), Tiliaceae (2 spp.), Meliaceae (2 spp.) and remaining families were represented by one species.

- The plant use value index range (0.01-0.13) was determined in whole watershed. In upper zone *Quercus leucotrichophora* (0.10), *Q. lanata* (0.10), *Grewia optiva* (0.10), *Cedrus deodara* (0.10), *Pinus roxburghii* (0.06) having high use value were recorded. In mid altitude *P. roxburghii (0.10), Q. leucotrichophora* (0.06), *Q. glauca* (0.06) *and G. optiva* (0.10) *were recorded.* In lower altitude zone *Shorea robusta* (0.13), *P. roxburghii* (0.06), *Mallotus philippensis* (0.06), *Bauhinia variegata, Ougeinia oojeinensis and G. optiva* had similar use value (0.10).
- In Byans valley, a total of 17 fuelwood species (3 trees and 14 shrubs) were recorded. The fuel wood collection ranges from 3200-3840 kg/hh/year and consumption ranges from 3.3-5.5 kg/capita/day. Near Gunji, *A. pindrow* community had 'good' regeneration. *Berberis jaeschkeana* was the most dominant shrub mainly found in undergrowth of *A. pindrow* community. Out of 17 species, 6 species fall in 'Least Concern' categories and 3 species namely, *B, jaeschkeana*, *B. umbellata*, *Rhododendron anthopogon* were found 'Vulnerable'.
- Floristic diversity analysis of 2nd GLORIA site was completed. A total of 63 species belonging to 51 genera and 25 families were recorded. Maximum species richness was found in Shyang (42 spp.) followed by Chaga (40 spp.), Kuti (38 spp.) and Eurong (25 spp.) summit areas.

Sikkim: Kanchendzonga Biosphere Reserve

- Total 105 (98 species identified) woody species recorded within fourteen major sites. Out of 98 woody species of 33 families, 33% shrub species and 67% tree species were recorded in Yuksom-Black Kabru transect. Ericaceae emerged as the most dominant family, followed by Rosaceae, Lauraceae and Fagaceae. Maximum number of adult individuals were recorded at 4000 m (2070 ind./ha), followed by 1530 ind./ha at 3600 m and 1360 ind./ha at 3400 m.
- Maximum basal cover of adult woody species was recorded at 2000 m (1023.2 m^2/ha), followed by 49.0 m^2/ha at 2600 m and 344.83 m^2/ha at 3400 m Negative correlation between species richness and altitude (r=-0.863, p<0.01; Fig. 4) was found in Yuksom-Black Kabru transect. Dominant forest communities of the study area were identified based on Importance Value Index by taking relative frequency, relative dominance and relative density of each study site.

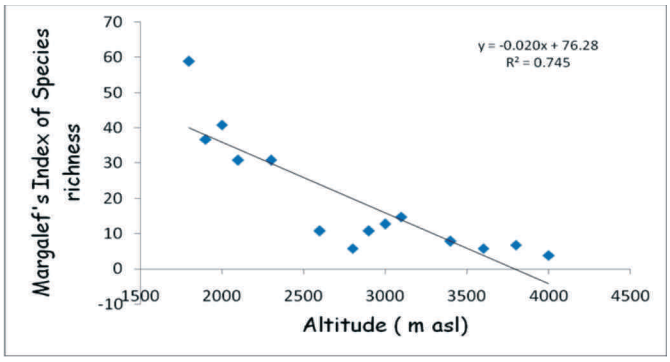


Fig.4. Woody species richness and altitudes of study sites in Yuksom- Black Kabur transect in Khangchendzonga Biosphere Reserve (west Sikkim)

- From Kusong-Panch Pokhri (North Sikkim, KBR) transect between 1800 m- 3800 m a total of 91 woody species (59% trees and 41% shrubs) were recorded. Maximum number of adult individulas were recorded at 2000 m (1260 ind./ha), followed by 1090 ind./ha at 3000 m, 1090 ind./ha at 3000 m and 1070 ind./ha at 2800 m. A good cover of adult woody species was recorded at 2800 m (3257.92 m^2/ha), followed by 3176.26 m^2/ha at 2200 m and 2034.92 m^2/ ha at 2400 m.
- Quantitative assessment of vegetation was made using standard protocol for Tholung- Kisong transact (1780-4810 m) in Khangchendzonga Biosphere Reserve (KBR), west Sikkim. Six sites were investigated along 2400 - 4200 m. Out of 50 woody species (37 trees and 13 shrubs) recorded maximum number of individuals (seedlings+saplings+adults) was recorded at 3000 m. (21300 ind./ha), followed by 17490 ind./ha at 4200 m and minumum 5310 ind./ha were recorded at 2800 m.
- A good basal cover of woody species (seedling+ sapling+adult ind.) in the transect was recorded at 2400 m (391 m^2/ha), followed by 368.7 m^2/ ha at 3000 m. The minimum basal area of woody species was recorded at 4200 m (1.8 m^2/ha). Negative correlation between species richness and altitude (r=-0.934, p<0.01) was found for Tholung-Kisong transect.

North-East: Ziro Valley of Lower Subansiri

- Field surveys were conducted in Hakhe Tari forest in Ziro valley of Lower Subansiri District, Arunachal Pradesh. Total 14 sites selected and surveyed for the assessment of plant diversity were represented by shady, moist and dry habitats. A total of 49 species

were found in all the 14 sites. Among the sites, species richness ranged from 5-10, density (150-430 ind./ha), and species diversity (H') 1.49-2.26. Among habitats, the species richness ranged from 23-30, density (245-306.7 ind./ha), and species diversity (H' = 2.80 to 3.08).

- A total of 14 communities were found across the 14 sites in the Hakhe Tari forest area. Among these communities the species richness was ranged from 5-10 and found maximum 10 in *Alstonia scholaris - Cinnamomum bejolghota - Castanopsis hystrix - Alnus napalensis - Betula alnoides* mixed community followed by 9 in *Quercus* sp.- *Phoebe goalparensis - Litsea cubeba-Eurya indica* mixed community. Among communities, the density ranged from (150-430 ind./ha) and species diversity (H'= 1.49 to 2.26) (Table 2).
- A total of 41 species of wild edibles and medicinal plants (15 herbs, 3 shrubs, 5 climbers, 17 trees) belonging to 33 families were recorded from these sites. Among the medicinal plants, fruits of *Terminalia bellirica* were used for Diarrhea, piles and dropsy; leaves of *Cinnamomum tamala* used for cough, headache and dizziness; boiled leaves of *Plantago erosa* used for constipation; rhizome of *Acorus calamus* used for cut, wounds and skin diseases; stem of *Berberis aristata* used for cold, fever and malaria; and rhizome of *Costus speciosus* used for cough, catarrhal fever, dyspepsia, skin diseases and worm infections.

Table2. Community wise distribution of species richness, density, species diversity in Hakhe Tari forests, Ziro

Site	Community type	Site representation	Species richness	Density (ind./ha)	Species Diversity (H')
1	*Alstonia scholaris-Cinnamomum bejolghota-Castanopsis hystrix-Alnus nepalensis-Betula alnoides* mixed	1 (Site 14)	10	340.00	2.26
2	*Brassaiopsis sp-Betula alnoides-Calophyllum polyanthum* mixed	1 (Site 2)	6	150.00	1.75
3	*Castanopsis hystrix-Alnus nepalensis-Lithocarpus elegans* mixed	1 (Site 1)	5	220.00	1.59
4	*Eurya sps.-Eurya acuminata-Macropanax dispermus* mixed	1 (Site 3)	7	160.00	1.79
5	*Magnolia champaca-Phoebe goalparensis-Litsea cubeba* mixed	1 (Site 12)	7	350.00	1.89
6	*Pinus wallichiana-Castanopsis indica* mixed	1 (Site 6)	6	240.00	1.69
7	*Pinus wallichiana-Castanopsis indica-Eurya acuminata* mixed	1 (Site 10)	8	280.00	1.84
8	*Pinus wallichiana-Engelhardia spicata-Cyathea spinulosa* mixed	1 (Site 5)	8	290.00	2.01
9	*Pinus wallichiana-Phoebe sp.* mixed	1 (Site 8)	5	270.00	1.49
10	*Pinus wallichiana-Quercus griffithii-Castanopsis indica* mixed	1 (Site 4)	8	310.00	1.97
11	*Pinus wallichiana-Quercus sps.-Castanopsis indica-Magnolia oblong* mixed	1 (Site 11)	8	390.00	2.04
12	*Pinus wallichiana-Saurauia sps.* mixed	1 (Site 9)	5	250.00	1.49
13	*Quercus sp.-Phoebe goalparensis-Litsea cubeba-Eurya indica* mixed	1 (Site 13)	9	430.00	2.18
14	*Rhus semialata-Trevesia sp.-Pyrus griffithii* mixed	1 (Site 7)	8	210.00	1.95

Study on the impact of Sainj Hydro-Electric Project on the Great Himalayan National Park (GHNP) in general and flora and fauna of the local area in particular (2012-2017; Himachal Pradesh Power Corporation Limited)

The increasing human and livestock population, and developmental activities such as construction of roads, initiation of a large number of hydropower projects in biodiversity rich areas, establishment of forest based industries, etc. have created a tremendous pressure on the biodiversity in the IHR. This has resulted in decreased population of many ecologically and economically important species. A large number of hydro-electric projects (HEPs) have been constructed, under construction and proposed for construction on the rivers originating from the Himalaya. The Sainj HEP (100 MW), a run-of-the-river project at Neuly on river Sainj, a tributary of river Beas in Kullu district is under construction. It is located in the periphery of Great Himalayan National Park. The adjacent areas in the GHNP of the Sainj HEP are very rich in flora and fauna that requires impact studies on flora and fauna for conservation and management planning.

Objectives

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

Achievements

- 30 sites were surveyed between 1,385–2,070 m and $31^0$45.431'-$31^0$47.046' N lat. and $77^0$19.813'-$77^0$25.083' E for the quantitative assessment of floristic diversity. Seventeen (17) trees communities and (01) shrub community were recorded. Within the communities, total tree density ranged from 90.00-350.00 ind./ha; total basal area 0.27-38.16 m^2 ha^{-1}; total shrub density 450.00 - 1330.00 ind./ha; total herb density 36.30-80.58 ind. m^{-2}; total sapling density 150.00-510.00 ind. ha^{-1} and total seeding density 13000-410.00 ind. ha^{-1}.
- 260 species of vascular plants were recorded; among these 225 species were used as medicinal; 35 as fodder; 19 as edible; 20 as fuel; 11 as religious; 09 as timber; 05 as dye; 03 as fiber; 05 as agricultural tools and 11 as miscellaneous uses.
- Dominant families were Asteraceae (33 spp.), Lamiaceae (22 spp.), Rosaceae (17 spp.), Poaceae (16 spp.), and Polygonaceae (09 spp.), and dominant genera were *Artemisia* and *Polygonum* (05 spp. each), *Anaphalis*, *Elsholtzia*, *Nepeta*, *Rubus*, *Rosa* (04 spp. each), *Anaphalis*, *Bidens*, *Berberis*, *Cynoglossum* (03 spp. each), *Acer*, *Arisaema*, *Aster*, *Gnaphalium*, *Senecio*, *Berberis*, *Impatiens*, *Desmodium*, *Polygonatum*, *Quercus*, *Geranium*, *Plectranthus*, *Oplismenus*, *Thalictrum*, *Rhamnus*, *Galium* (02 spp., each). 87 species were native to the Himalayan Region; 173 species non-native and 13 species near endemic to the IHR.

Population assessment, standardization of propagation protocols and establishment (*ex situ* and *in situ*) of selected species as a part of biodiversity conservation plan under Sainj Hydro Electric Project in Himachal Pradesh (2014-2019; Sainj Hydro-Electric Project, Himachal Pradesh Power Corporation Ltd., Sarabai)

The IHR with its unique topography, diverse habitats and varied altitudinal range (200-8000 m) supports representative, natural, unique and socio-economically important floristic diversity. The IHR harbours about 18,440 plant species, of which 1748 species of medicinal plants, 675 wild edibles, 960 orchids and 155 sacred plants. The high anthropogenic pressures coupled with changing environmental conditions have resulted in rapid depletion of economically important species in the region. Along with this large number of HEPs have been constructed, under construction and proposed for construction on the rivers originating from the Himalaya. The Sainj HEP (100 MW), a run of the river project on river Sainj, a tributary of river Beas in Kullu district is under construction and located at Neuly, in the periphery of Great Himalayan National Park, Sainj valley. The adjacent areas towards the GHNP of the Sainj HEP are very rich in flora and fauna including threatened species. Constructions of HEPs have adversely affected the habitats and sustenance/security of inhabitants. Considering the high rate of habit degradation and population depletion of economically important species in their natural habitats, it becomes essential to adopt *in situ* and *ex situ* conservation measures. Therefore, the present study has been proposed for conservation of some selected species namely *Desmodium gangeticum*, *Delphinium denudatum* and *Polygonatum verticillatum* by

doing population assessment, standardization of propagation protocols, promoting mass multiplication, hardening and establishment of seedlings and plantlets of these species *in situ* and *ex situ* conditions.

Objectives

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

Achievements

1 22 populations were sampled for the assessment of *P. verticillatum, and D. denudatum* species between 31°45.757' N to 31°76.897' N and 77°18.378' E to 77°38.49' E. and 1,565 – 2,230 m in surrounding areas of Sainj HEP. In *D. denudatum* populations (Fig. 5a), species richness of shrubs ranged from 1-9 and herbs, 9-29; total shrubs density 10-1680 ind. ha^{-1} and total herb density, 11.70-65.30 ind. m^{-2}; and relative density (%) of *D. denudatum* 0.49-21.37%, and *P. verticillatum* populations (Fig. 5b). Species richness of shrubs ranged from 1-8 and herbs, 12-30; total shrub density 40-830 ind. ha^{-1} and total herb density, 21.80-91.95 ind. m^{-2}; and relative density (%) of *P. verticillatum* 0.30-8.49 %. Soil pH, organic carbon and nitrogen have been presented (Fig. 5c).

Fig. 5a. *Delphinium denudatum*

Fig. 5b. *P. verticillatum*

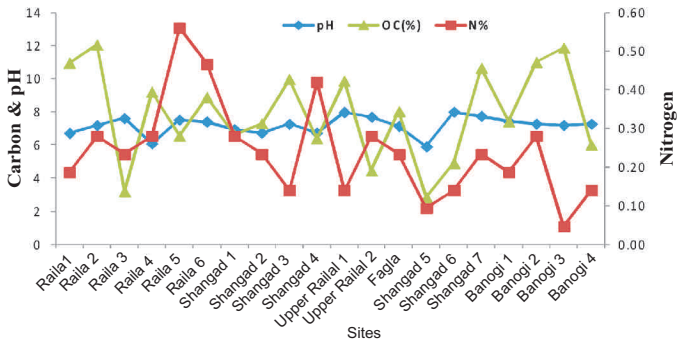


Fig. 5c. Soil characteristics of various studied populations

2 Young plantlets of *P. verticillatum* and seeds of *D. denudatum* were collected for re-introduction in their natural habitats. Seed germination trials for *D. denudatum* resulted 80% in BOD at controlled temperature, 23 C in 6 days, reduced mean germination time (Fig. 6 a,b). Seed germination trials for *P. verticillatum* have been initiated; 20% germination percentage was recorded (Fig. 6 c,d).

Fig. 6a&b. Propagation of *Delphinium denudatum* using conventional and tissue culture technique

Fig.6c & d. Propagation of *Polygonatum verticillatum* using conventional and tissue culture technique conventional and tissue culture technique

3 Plant tissue culture studies for *P. verticillatum* and *D. denudatum* using leaves, root, tuber and young shoots as explant on Murashige and Skoog Medium (MS-Medium) has been initiated. Callus induction was observed when stem explant of *P. verticillatum* was cultured in MS Medium with BAP 0.3mg/l and shoot induction observed when cultured in MS medium with BAP (0.5 mg/l). And In *D. denudatum*, callus induction was observed when leaf explant of *D. denudatum* was cultured in MS media with IAA & BAP (0.2 mg/l). While 70% shoot induction was observed when the same was cultured in MS medium with (BAP 0.3 mg/l).

Assessing the floristic diversity and ecosystem values of selected high altitude wetlands of Indian Trans Himalaya (2015-2018, Ministry of Environment, Forest and Climate Change, New Delhi)

High Altitude Wetlands (HAWs) of Trans Himalaya act as a unique ecosystem that holds great importance for the endemic / threatened species of plants, migratory birds, wild animals and for the people living in and around the region. High altitude mountain lake ecosystems play an important role as water sources for communities at lower altitude and also sustain rich biodiversity. In recent years, these HAWs are under high anthropogenic pressure, such as overgrazing of vegetation in and around the wetland area, creating pollution in soil and water, unplanned developmental activities and increasing tourist pressure putting adverse impacts on these very fragile ecosystems. For any conservation and management initiative of high altitude wetlands, the biodiversity analysis and ecosystem values are prerequisite and play essential role to implement the conservation programme. Considering the above, in this project Chandra Tal, Suraj Tal in Lahul Spiti (Himachal Pradesh), and Tso Moriri and Pangong Tso in Leh (Jammu & Kashmir) HAWs located in Trans Himalayan Region of India were studied. Among these wetlands Chandra Tal and Tso Moriri are notified under Ramsar Site in 2002.

Objectives

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

Achievements

1. A total of 75 species were recorded (22 Families, 60 Genera) from Chandra Tal (Fig. 7), including one species of gymnosperm (*Ephedra intermedia)*. Seventy nine percent of these plants belong to 10 dominant families, and Asteraceae was the largest family. More than 42% species were used for different medicinal purposes including leaves (>32%). A total of 64 tourists visited this site per day during July. A total of 1246 (sheep and goat) and 46 (horses, donkey and mule) forage at this site during summer.

2. A total of 63 species were recorded (20 families, 43 genera) from Suraj Tal (Fig. 7), including one species of gymnosperm (*E. intermedia)*. Ninety percent of these plants belong to 15 dominant families, and Asteraceae was the largest family. Around 51% species were used for different medicinal purposes, and leaves, flowers were commonly (>38%) used for medicinal uses. A total of 623 (sheep and goat) and 22 (horses, donkey and mule) forage at this site during summer.

3. A total of 109 species belonging to 81 genera and 28 families were recorded from Pangong Tso site (Fig. 7), including one species of gymnosperm (*E. intermedia*). Eighty nine percent of the total flora belongs to 17 dominant families, and Asteraceae is the largest family represented by 21 species. A total of 55 species (15 families) are used for different ailments (ethno-medicinal purpose) and family Asteraceae was dominant among them.

4. A total of 78 tourists visited this lake per day during the month of August. A total of 1,227 livestock population, 24 wild animals visit this site for foraging during summer. Pangong Tso is an important breeding ground for a number of migratory birds like Black necked cranes (vulnerable), Brahmani Ducks, Common Hoopoe, Indian cuckoo and Black redstart, all of them except one belong to 'Least concern' category.

5. A total of 113 plant species belonging to 72 genera and 27 families were recorded from the Tso Moriri site (Fig. 7), represented by herb (106 spp.), shrub (6 spp.) and climber (1 spp.). Eighty eight percent of the total flora belongs to 14 dominant families, and Asteraceae is the largest family represented by 19 species. While analyzing the diversity of medicinal plants, a total of 51 species (45%) are used for different ailments, and leaves are highly utilized for medicinal purposes by local people. A total of 1,326 livestock population and 30 wild animals depend on this wetland for foraging during summer. Tso Moriri is an important breeding ground for a large variety of migratory birds like black necked cranes (VU) and Bar-headed Goose (LC).

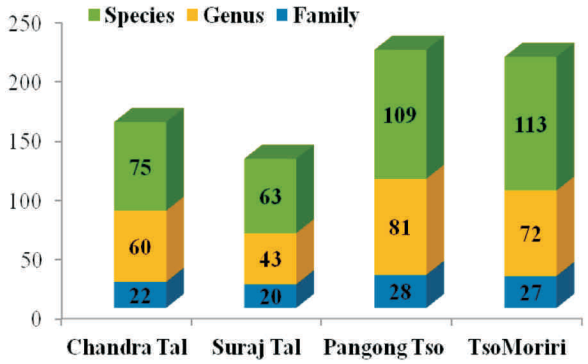


Fig. 7. Floristic diversity of targeted wetlands

Multidisciplinary studies in floristic assessment, ecological analysis, ecosystem services, conservation and sustainable management of selected National Parks in Western Himalaya (2016-2019, National Mission on Himalayan Studies, MOEF&CC, New Delhi)

The Article 8 of the Convention of Biodiversity stresses *in-situ* conservation of biota in a holistic manner and to fulfil this mandate for conservation of biodiversity, rehabilitation and restoration of degraded ecosystems and conservation of threatened taxa, a Protected Area Network (PAN) has been established that covers approximately 5% geographical area of India. In this project the Valley of Flowers and Great Himalayan National Park PAs were targeted. The Valley of Flower is located in Chamoli District of Uttarakhand, Western Himalaya. It was declared as a National Park in 1982 and now covered under the UNESCO World Network of Biosphere Reserves since 2004, and World Heritage Site of MAB. The Great Himalayan National Park was established in 1984, and in June 2014 it was added to the UNESCO list of World Heritage Sites. Both the PAs are largest centre of endemism of plant diversity in Western Himalaya. Due to scenic beauty, diversity of colourful flowering and presence of several endangered animals (i.e., Asiatic black bear, snow leopard, musk deer, brown bear, red fox, blue sheep, monal pheasant and other high altitude birds, etc.) inflow of tourists has increased manifold in these pristine PAs. Recent climate change and natural disasters in Uttarakhand and Himachal Pradesh has also affected the fragile ecosystem of these alpine pastures. Thus, changing vegetation patterns in the changing scenario of climate change and human use of these PAs has become essential to formulate conservation strategies.

Objectives

- Ecological assessment of floristic diversity of the National Parks
- Status assessment of plant diversity, including endemic, threatened and medicinal plants in the target region
- Analyzing floristic changes in the Park area
- Analyzing possible loss of plants in relation to climate and anthropogenic aspects
- Providing awareness training about the plant diversity and sustainable plant utilization

Achievements

1. A total of 78 specimens were collected and 51 specimens were identified (23 families, 42 genera and 50 species) from the Valley of Flowers National Park. For ecological assessment, five threatened species namely *Polygonatum verticillatum* (L.) Alloni

(1.71±0.41 ind./m^2), *Dactylorhiza hatagirea* (D. Don) Soo. (1.76 ± 0.38 ind./m^2), *Fritillaria roylei* Hook. (0.42 ± 0.8 ind/m^2), *Podophylum hexandrum* Royle (0.78 ±0.02 ind./m^2) and *Malaxis muscifera (Lindl.) Kuntze* (1.00 ± 0.02 ind./m^2) were assessed and compared with earlier records to define the floristic changes.

2. There was a massive decrease in the density of *D. hatagirea, F. roylei, P. verticillatum, P. hexandrum,* while the density of *Malaxis muscifera* increased than the earlier reports. The diversity of *P. polystachyum* Wallich ex Meissn. (2.49 ± 062 ind./m^2) was found higher compared to the past as it is a major invasive plant in the valley.

3. During the ecological assessment, we recorded one sapling of *Pinus wallichiana* A.B. Jackson at an altitude of 3527 m (lat. 30^0 43' 40.4" N, long. 79^0 36' 07.7" E), which is a new addition to Valley of Flowers National Park. Further, towards strengthening datasets on lower group of plants, a total of 49 species of lichens belonging to 32 genera and 17 families were recorded from the Park.

Summary of the completed project

Threat assessment and conservation of Himalayan silver birch (*Betula utilis* D.Don): A keystone species in timberline zone of Central Himalaya, Uttrakhand (funded by DST-SERB, New Delhi)

Achievements

1. A total of 278 plant species belonging to 66 families and 166 genera were recorded. Of these, 52 families and 149 genera belongs to angiosperms, 4 families and 5 genera of gymnosperms and 10 families and 13 genera of pteridophytes were recorded between 3000-4200 m from valley of flower National Park and Nanda Devi National Park of NDBR. Among the flowering plants (angiosperm and gymnosperms), the life forms were recorded as 4.6% trees, 18.77% shrubs and remaining 76.63% herbs and forbs.

2. The total tree density in pure *Betula utilis* forest was found higher (1388 ind ha^{-1}) at Valley of Flower National Park (VoF-NP) as compared to mixed *Betula* forest (1116 ind ha^{-1}) whereas in Nanda Devi National Park (ND-NP) the reverse trend was observed where mixed *B. utilis* forest showed maximum tree density (1632 ind ha^{-1}) as compared to the pure *Betula* forest (1536 ind ha^{-1}). However, overall tree density in pure & mixed forest was recorded higher at ND-NP as compared to VoF-NP.

3. In the pure *B. utilis* forest at the south aspect of VoF-NP, *B. utilis* and *R. campanulatum* had 'fair regeneration' while *A. pindrow* and *A. caesium* had 'good regeneration'. However, at north aspect *R. campanulatum*, *A. pindrow* and *S. sikkimensis* had 'good regeneration' and *B. utilis* showed 'fair regeneration' pattern. However, ND-NP out of four species, *R. campanulatum* showed 'good regeneration' and rest three species viz., *B. utilis*, *A. pindrow* and *T. baccata* exhibited 'fair regeneration' at south aspect. while in the north aspect two species viz., *R. campanulatum* and *A. pindrow* exhibited 'good regeneration', and *B. utilis* and *S. foliolosa* recorded 'fair' and 'poor' regeneration, respectively.

4. Satellite imageries and field observations showed increasing number of seedlings and sapling recruitment and growth of *Betula utilis* above the timberline in both sites whereas density of other tree species decreased with increase in altitude. The higher number of seedlings of *Betula utilis* was recorded in pure forest (3600-4100 m) and ranged between 19.33 to 33.50 seedlings/$100m^2$ and 7.83 to 30.00 seedlings/$100m^2$ for north and south aspects of VoF-NP and ND-NP at timberline, respectively.

5. The fuelwood consumption was ranged between 2.60 to 8.84 Kg/capita/Day while per capita fodder consumption was found between 8.23 to 31.30 Kg/capita/day in the Niti valley, NDBR. The per capita fuelwood consumption of *B. utilis* was recorded 2.52 kg/capita/day at timberline area particularly by the people involved in *Cordyceps* collection during the month of May and June.

6. The study exhibited that the area of mixed and pure *B. utilis* forest has increased over last 23 year time period. In 1990, the proportion of pure *B. utilis* forest increased about 761 ha while mixed forest about 883 ha, however, digitizated satellite imagery data indicates that the forest area has enhanced about 1029 and 1107 ha during 2013. The total of about 268 ha and 224 ha area of pure and mixed *B. utilis* forest increased between 1990 and 2013 in Nanda Devi national park of NDBR, respectively.

THEME

ECOSYSTEM SERVICES

Millennium Ecosystem Assessment (2006), defined ecosystem services (ES) as "the benefits people obtain from ecosystems", and delineated the ES among four categories - supporting, provisioning, regulating and cultural. The MEA highlighted the dependence of humans on ecosystems, and stressed the need to better describe, quantify and value (ecologically, culturally and economically) the ecosystem goods and services. In spite of the crucial ecological, cultural and economic importance of these ES, ecosystems are continually deteriorating worldwide as the value of ecosystems to human welfare is still underestimated and the ES are not, or only partly, captured in conventional market economics. Therefore, understanding of functions and values of these ecosystems considering the direct, indirect and existence benefits is crucial for long-term conservation and sustainable development imperatives. Himalayan mountain ecosystem services are of critical importance not only to the people of this region, but also to a significant proportion of the global population. Therefore, efforts are also required for quantification and valuation of ecosystem services for natural resource accounting and mainstreaming in decision making for environment-friendly development. The objectives envisaged for ES theme are: (i) Quantification and valuation of ES emanating from ecosystem/landscapes to sensitize the stakeholders for taking informed decisions for biodiversity and natural resource conservation for enhancement of ES; (ii) Valuation of ES for integration into national and state accounting system and developing payment for ecosystem services (PES) mechanisms for forests and natural resource conservation; (iii) Identification of drivers of change impacting natural capital that influence ES; (iv) Hypothesis testing on biodiversity vis-à-vis ES enhancement and develop participatory approaches for biodiversity conservation; and (v) Disseminate knowledge to different stakeholders through various mechanisms and publication of knowledge products.

Climate change impacts on ecosystem services in the Indian Himalayan region (2012-2017; In-House)

Climate change has wide ranging implications for the global environment and ecosystems; hence, on the set of services that emanate from these ecosystems. Himalaya is most vulnerable to climate change, and climate impacts are becoming evident in the form of uneven distribution of rainfall, glacial retreat, extreme events of drought and floods, etc. The Himalayan region is important on account of its unique topography, micro-climatic conditions and strategic location, and represents one of the "Global Biodiversity Hotspots". The richness of endemic flora and fauna with restricted distribution and life support values (ecosystem goods and services) of this region are highly valuable for the global community in general, and for the regional inhabitants (both highland-lowland), in particular. However, in the recent decades under the changing climate the forest ecosystem services such as provisioning of NTFPs to support the local livelihoods, biological diversity, C-sequestration potential etc. have altered due to climate change (CC). Protection of the forests to boost natural regeneration and planting forest blanks with suitable mix of species would restore them and also generate ES in longer run. Also, the recreational services of Himalayan environment which are mainly availed in different variants of tourism and adventure sports are likely to be affected as a result of CC. Limited development opportunities in Himalaya warrant that such activity be sustained. Realizing the above, the present project was undertaken across an altitudinal gradient (300 – 2100 m) on major forest ecosystems of Kumaun Himalaya (*Shorea robusta, Pinus roxburghii, Quercus leucotrichophora and*

Quercus floribunda forests) for selected life cycle phases (phenophases) of eight species to relate the timing of these events with weather patterns and CC. This project integrates all these aspects to improve understanding on the impacts of CC on mountain forest ecosystems and come up with certain mitigating mechanisms. In these efforts people's perception of CC adaptation and mitigation measures would be helpful to devise strategies to cope up with the CC impacts.

Objectives

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

Achievements

1. In the 8 selected forest dominant tree species (Table 3) phenophases were found to have response to increase in ambient temperature (0.005 °C/yr) and decline in rainfall (3.3 mm/yr) over the past over two decades in the study area. In each of the species leafing and flowering was recorded earlier at south aspect than at the north aspect. Also, a greater leaf area, leaf mass and relative growth rate of leaves at the S aspect was recorded than at the N aspect indicating that atmospheric warming will benefit the S aspects in terms of carbon gain in the eventuality of climate change.

2. A syntheses of phenological data compared with the past similar data set revealed that during the intervening 30 yrs period (1985-87 to 2014-16) mean date of peak leafing in all the major tree species has advanced by 9 days (i.e., 0.30 d/yr; range= 0.17 - 0.47 d/yr across the species) in the study area, likely due to CC. Similarly, mean date of peak leaf drop across these species has advanced by 12 days (i.e., 0.40 d/yr; range= 0.33 - 0.47 d/yr across the species), hence did not increase the overall length of growing season, as has been reported in the temperate latitudes of the world.

Table 3. Location of the study sites and dominant tree species in the forests along an altitudinal gradient in Kumaun Himalaya.

Forest Sites	Elevation (m asl)	Latitude	Longitude	Canopy / Sub-canopy tree species
Ranibagh	612	N29□17'32.7″	E 79□32'31.5″	*Shorea robusta* *Mallotus philippinensis*
Patwadangar	1529	N 29□20'24.1"	E 79□26'27.7"	*Pinus roxburghii* *Myrica esculenta*
Kailakhan	1872	N 29□22'37.5"	E 79□28'47.6"	*Quercus leucotrichophora* *Rhododendron arboreum*
Ayarpatta	2200	N 29□23'08.9"	E 79□26'56.5"	*Quercus floribunda* *Machilus duthei*

3. Physicochemical and biological analysis of soil samples in pure Pine stand and the enriched stand after fourteen months of plantation (summer) revealed significant differences in soil moisture, microbial biomass carbon (MBC) and MBN due to plantation type, season and plantation type x season interaction (Table 4). MBC was correlated with soil microbial biomass N ($r^2 = 0.41$, $P < 0.01$). MBC and MBN ratio ranged from 9.7 to 10.2. The MBC was 1.78 to 1.97% of organic carbon. Percentage of soil N reflected in microbial N pool (MBN: total N (%) were 1.87 to 2.03%. Results indicated that enrichment plantation leads to carbon sequestration and over all soil fertility that improves the ecosystem services supplied by the soil, and thus may accelerate the return of a productive forest.

Table 4. F–ratios and their significance levels for two way ANOVA with repeated measures for soil pH, microbial C, N, organic C and soil moisture for the pure pine and enriched Pine, where sampling time was treated as a repeated measure. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, ns = not significant. n = 90.

Parameters	Source of variation		
	Between subject	Within subject	
	Plantation type	Time	Time x Plantation Type
pH	3.74 *	0.71 ns	1.49 ns
Microbial C	0.42 ns	18.63 ***	4.58 ***
Microbial N	8.67 ***	10.89 ***	2.03 *
Organic C	0.83 ns	3.47 **	1.37 ns
Soil moisture	12.31 ***	14.09 ***	15.26 ***

4. Perception based studies on climate change impacts showed that in Garur Ganga watershed (Kumaun Himalaya) the crop production during 2005 - 2015 showed negative trend for wheat, rice, vegetables and fruits, thereby increasing dependence on market for food grain etc. People perceive that due to CC, crop damage due to wild animals has increased and soil fertility has declined. People are increasingly facing shortage of drinking as well as irrigation water (both quantity and quality). During this period a decline of 21% in irrigated land and 14% in rainfed crop land has occurred that is affecting food security.

5. For assessment of economic relevance of recreational services which are mainly consumed as tourism the contribution of tourist seasons to the income of local business enterprises are analyzed, and the consolidated results suggesting income impacts are compared for Manali and Nainital towns. For Manali business community a clear cut impact of 3- months' summer season, on the income of all the business types was seen; the autumn season however doesn't show an impact on earnings of hospitality business ($p=0.12$), transport ($p>0.10$), café & restra ($p>0.20$), and adventure sports & equipments ($p>0.35$).

6. The income impact of tourist season on the earnings of the 14 business groups of the Nainital town were examined; an analyses of seasonal earnings suggest that nearly all the business classes earn more than 49% of their annual income during summer season and more than 19% during autumn season suggesting a clear cut impact of tourist seasons related to the recreational value of the Nainital environment. The projections of expenditure incurred based on survey of 198 tourists suggests that the tourism in Nainital pumps around Rs. 5856.04 million in local economy, and brings about Rs. 10841.44 million in circulation for tourisms spin-offs which also represent the lower end of the recreational value of the place as tourism.

Promoting pollinators using community based conservation approach at Kullu, Himachal Pradesh (2015-2016; Earthwatch Institute, India)

Pollinators are an important part of our environment and agricultural production. In our natural environment many plants would go extinct without pollinators contributing to their reproduction process. In agriculture, 35% of our food crops are dependent upon pollinators. While there are many other insect pollinators visiting our crops, honeybees are the most recognizable pollinators and the ones most commonly used by farmers Honeybees happen to be the most effective pollinator insects for most crops. Bees have relinquished their habit of hunting insects and other arthropods to secure food for their offspring and instead have become vegetarian, using pollen, nectar and other floral resources for food. As such, bees are entirely dependent on flowering plants and the abundant presence of these insects within any habitat is largely dependent on the availability of floral resources. This dependence on flowers makes bees the most important pollinators. A very common and most important fruit crop is apple, which also requires pollination by bees to produce fruit like other fruit and agricultural crops. The project activities will strengthen the conservation of important pollinator species and bee flora, investment in the next generation by engaging young people and women groups, and develop their knowledge in identification of important pollinators and bee flora.

Objectives

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

Achievements

1. Total 9 sites i.e., 1 site each in Karadsu and Raugi villages and 7 sites in Nashala village of Upper Beas valley, Kullu district were surveyed to study density and diversity of the pollinators. Mustard and Coriander were cultivated in nine sites during November and December 2016 to maintain the flora for bees and insects in winter season. The survival rate of the crops was up to 80-90%. After complete cultivation of bee flora the record of the density and diversity of the pollinators was observed which increased to a larger extent.

2. A total of 70 species of insect visitors/ pollinators were reported from different fruit, herb, tree and ornamental plant species belonging to different group of insects i.e., Honey Bees, Bumble bees, Carpanter bees, Solitary bees, Hover/ Drone files, and Syrphid flies from Kullu Valley, Himachal Pradesh.

3. Scan / visual observation (16 observations of 15 minutes each) on the blooms of Plum, Strawberry,

Apricot, and Lemon were carried out to know the preferential insect visitors of a particular species. Among the all observed species, *Apis cerana* is most frequent visiting species of Apricot, Lemon and Plum followed by Butterflies (Lemon), Drone fly (Strawberry) and Solitary bees (Lemon & Strawberry).

4. Among the observed insect visitors on the blooms of selected herbs, Honey bee (*Apis cerana*) is reported as most frequent visitors (24 observation of 15 minutes each) followed by Drone fly (Coriander), Butterflies (Milk thistle), Syrphid fly (Coriander), Solitary bees (Milk thistle) (Fig. 8). Among the observed tree species (16 observations of 15 minutes each), Honey bee (*Apis cerana*) and solitary bee were reported as the most frequent visitor on the blooms of Soapnut and Bottle Brush. Other frequent insect visitors are Drone and Syrphid fly both on the blooms of Bottlebrush.

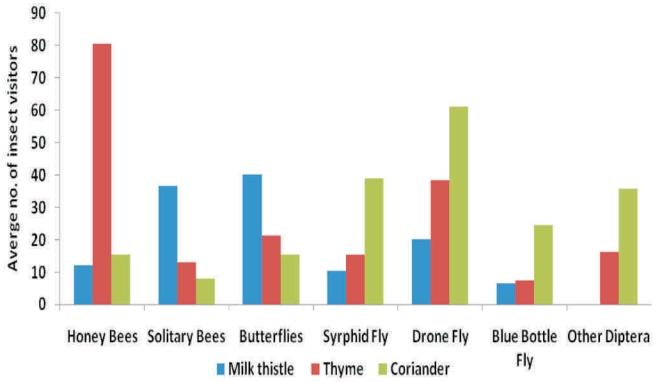


Fig. 8: Insect flower visitors of selected herb species

5. Among the ornamental species, the highest visiting rate of Honey bee *(Apis cerana*) was reported on the blooms of Cactus, followed by Cosmos and Marry Gold flowers. The highest visiting rate of Solitary bees is reported from the blooms of Cosmos. Higher visit of Butterfly and Syrphid flies were reported from the blooms of Marigold and Cosmos. Carpenter Bee (*Xylocopa* sp.), Bumble bee and *Apis mellifera* were specialist species and only reported from the blooms of Cactus, Marigold and blooms.

6. Among the potential pollinators species for wild and domesticated flowering species are *Apis cerana, Apis mellifera, Bombus haemorrhoidalis, Xylocopa fenestrata, Andrena leaena, Ceratina hieroglyphica, Eristalis tenax, Eristalis arvorum and Calliphora vicina* etc. Soap Nut (*Sapindus mukorosii)* tree is exclusively used by solitary bees for making their nesting inside the hollow branches. Many nestings of solitary bees (*Andrean* sp. & *Lassiglossum* sp.) are reported during the sampling. Based on the sampling Soap Nut and Wall Nut, tree are most potential for the conservation of solitary bees diversity and their nesting habitat.

7. The seeds and cuttings of wild bee flora, i.e., *Aesculus indica*, *Rubus biflorus*, *Rosa brunonii*, *Callistemon citrinus*, *Cornus macrophylla* and *Pyrus pashia* were collected from the natural habitats and developed in the nursery for plantation. The developed 1350 seedlings of *Buxus wallichiana*, *Pyrus pashia*, *Rosa brunonii, Rubus biflorus, Cornus macrophylla, Aesculus indica, Bauhinia variegata* and *Callistemon citrinus* were transplanted in two villages i.e., Nashala and Archhandi for the restoration of bees floral habitats.

8. Total 72 Bee boxes of *Apis cerana* with bees purchased and distributed to the 48 apple orchardists from 7 villages, i.e. Kradsu, Nashalla, Ghurdaur, Archhandi, Dobi, Bashkola, and Kathayal Gran of Kullu District. Also, 25 sets of apiculture equipments (queen cage, smoker, bee veil, gloves, uncapping knife, queen gate, pollen trap, hive tool and hive gate) and two extraction machines of four framed, were distributed to the farmers.

Scientific research on changing climate and its impact on floral diversity and ecosystem services (pollination) at Kullu region of IHR – a Citizens' Science initiative (2015-2018; Earthwatch Institute India)

Humankind benefits from a multitude of resources and processes that are supplied by natural ecosystems is known as ecosystem services. Among these, pollination, one of the significant provisioning services in the maintenance and promotion of biodiversity, in general, sustain life on Earth. Pollinators provide valuable ecosystem service in the form of pollination essential for sexual reproduction of wild and domesticated plants and maintenance of biodiversity. 87 species of the worlds leading food crops i.e., fruits, vegetables or seeds depend upon animal pollination, representing 35% of global food production. The production value of one ton of pollinator-dependent crop is approximately five times higher than one of those crop categories that do not depend on insects. Globally, bees and other associated pollinators diversity is gradually declining due to climate change, habitat loss and fragmentation, land management practices, agricultural chemicals, pesticides and diseases. Decline of Pollinators has adversely affected the productivity of pollinator dependent fruit and agro-horticultural crops. For instance, decline in pollination

services has been now identified as an important issue worldwide. It applies equally for the agro-ecosystems of the IHR, which calls for a systematic study on pollinators and other forest ecosystem services in the region.

Objectives

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

Achievements

1 The present study has been carried in the Upper Beas Valley in Kullu district of Himachal Pradesh Qualitative assessment of the vegetation in and around the orchard sites, 79 species of plants representing trees, shrubs and herbs including ferns were recorded by the participants, out of these 34 species were found to be bee/pollinators foraging resources based on the visitation of bees/pollinators on the flowers of these plant (Fig. 9).

Fig. 9. Citizen scientists working in the field

2. Six sites/plots were selected and sampled for the quantitative assessment of vegetation. Across these study sites *Cedrus deodara* (5 sites) and *Pinus wallichiana* (1 site) tree communities were delineated based on the Importance Value Index (IVI). Among shrubs, *Sarcococca saligna, Eleaegnus conferta* and *Berberis lycium* and among herbs, *Fragaria nubicola, Oplismenus compositus, Trifolium repens, Poa annua,* etc. were dominant.

3. The insect pollinators' diversity and density were assessed in and around selected orchards of apple by scan and visual sampling method. The results showed highest visitation rate of *Apis ceranna* followed by *Apis mellifera*, Drone, butterflies, syrphids, etc. in all orchards except in Hirni and Kradsu where highest visitation rate of *Apis mellifera* was observed (Fig. 10).

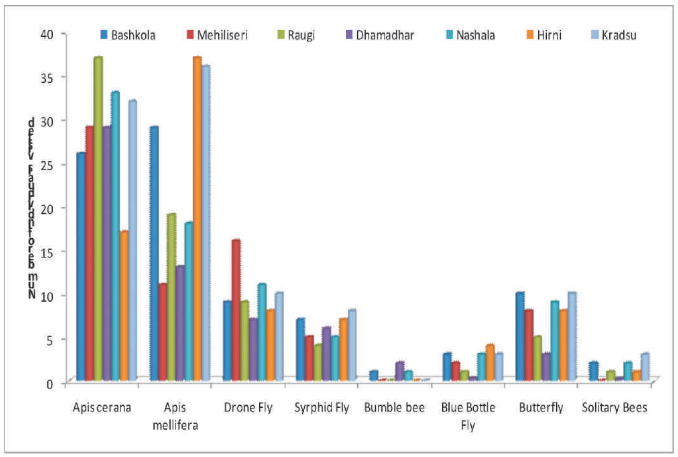


Fig. 10. Diversity and density (visitation/15 minutes) of Insect/pollinators on apple crop in the different orchard sites

4. For the assessment of preferential floral species of the insect pollinators, plant species in the flowering stage were selected at different orchards and then were observed for 15 minutes for the insect visitations. This exercise was replicated on the same species but on the different individuals at one orchard. The pollinators have different bee flora species preferences for foraging in different seasons at different orchards which depends on the availability of the flowering plants at the sites. The preferred foraging plants during April were *Brassica campestris* and *Zaphyranthes candida;* in May *Trifolium repens, Berberis lyceum and* the preferred foraging plants during March were *Brassica campestris*, followed by *Trifolium repens* and *Zaphyranthes candida* by *Apis cerana,* followed by drones, syrphids and *Apis mellifera*.

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 & Climate Change)

The Himalayan region is amongst the identified Global Biodiversity Hotspots. The IHR forms the major part of Himalaya and comprises of three bio-geographic zones and 8 bio-geographic provinces due to its typical physical features and environmental conditions. The unique topography, diverse habitats and large altitudinal range (200-8,000 m) support the representative, natural, unique and socio-economically important biodiversity. The region represents tropical, sub-tropical, temperate, sub-alpine, alpine and tundra ecosystems/biomes. The major population of IHR lives in the rural areas and the inhabitants are largely dependent on various services provided by these ecosystems. In view of the rapid depletion of biodiversity, a Protected Area Network has been established across the IHR and representative biodiversity rich areas have been notified as Biosphere Reserves, National Parks and Wildlife Sanctuaries for the *in situ* conservation of ecosystems, habitat and species, respectively. In addition, the native communities of the region practice an age old tradition of conserving trees and forests near their settlements and alpine meadows as part of their culture and religious belief. These are known as sacred groves. They believe that their deities live inside these sacred groves and these deities would be offended if any damage is caused to the plants and animals. Usually traditional sacred groves (forests) and Temple groves are found in the region. Of the 13,270 sacred groves documented from India, 5,627 sacred groves are known from the IHR.

Objectives

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

Achievements

- The study sites were sampled between 1490 – 3350 m and 3140'46" N to 3245'56" N Lat. and 7705'40"E to 7720'49"E Long. A total of 52 plots were sampled for floristic diversity of the Jamdagni Rishi and Kamru Nag. Out of these, 32 sites were undisturbed and 20 disturbed. A total of 285 species of vascular plants belonging to 135 families and 190 genera were recorded. Among the identified species, 31 species were trees, 33 shrubs and 209 herbs. Community wise comparison of Species Diversity (H') between undisturbed and disturbed sites of the Sacred Groves is given in Table 5.

- Carbon sequestration was estimated in Kamru Nag (undisturbed & disturbed sites) Sacred Groves. In undisturbed site above ground biomass, 53351 kg/400m^2 carbon content 26675 kg/400m^2, below ground biomass, 15472 kg/400m^2 and carbon content 7736 kg/400m^2 was estimated. In disturbed site above ground biomass, 56765 kg/400m^2, carbon content 28383 kg/400m^2, below ground biomass 1647 kg/400m^2 and carbon content 8231 kg/400m^2 were recorded.

Table 5. Community wise comparison of species diversity (H') between undisturbed and disturbed sites of the Sacred Groves

Sacred Groves	Community type	Sites					
		Undisturbed Total Density (Ind ha^{-1})			Disturbed Total Density (Ind ha^{-1})		
		Tree	Shrubs	Herb	Tree	Shrubs	Herb
Kamrunag	1.*Quercus semecarpifolia*	430 – 790	580 – 2150	34.95– 80.50	–	–	–
	2. *Abies pindrow*	380 – 620	1060- 1810	96.50– 179.95	340 – 380	750 – 1010	90.25– 102.65
	3. *Abies pindrow* - *Quercus semecarpifolia* mixed	450	1090	117.85	-	-	-
	4. *Quercus semecarpifolia* - *Abies pindrow* mixed	-	-	-	360	1810	93.05
Rupasana Devi	*Cedrus deodara*	250 – 400	280 – 670	20.70 – 34.00	220 - 350	220 – 370	15.10 – 25.05
Kalinag	*Cedrus deodara*	220 – 400	370 – 1320	23.55 – 36.75	200 - 380	280 - 710	14.65 – 18.76
Jamdagni Rishi	*Quercus leucotrichophora*	340 – 890	410 – 1150	13.40 – 32.78	110 - 260	120 – 340	9.95 – 18.75

Timberline and altitudinal gradient ecology of Himalayas, and human use sustenance in a warming climate (2016-2019; National Mission on Himalayan Studies, MoEF&CC, New Delhi)

Altitudinal gradients provide very effective natural experimental conditions for finding out ecological and evolutionary responses of species to environmental changes. In this regard, the understanding of environmental changes associated with the high-altitude limit of forests, generally called timberline or tree line or forest line is of critical importance because of its high sensitivity to temperature changes and human uses. That is why timberline is often used as an indicator of climate change. As observed by 4th Assessment Report of IPCC (2007), Himalayas are warming 2-5 times more than global average rate and the degree of temperature rise increases with altitude leading to shrinking of glaciers and beginning of upward shift of altitudinal ranges of many species, particularly of timberlines. The Himalayan timberline is unique. It is the highest in the world and somehow, it is among the least studied systems. This project is a multi-partner and multi-site coordinated project of 6 organizations having adequate experience of working in the Himalaya and possess expertise and infrastructure to work on diverse aspects of Himalayan ecology, vegetation science, biodiversity conservation, climate change, etc. GBPIHED has taken up following objectives in this project.

Objectives

- To characterize and map timberline zone in the IHR using satellite and ground based observations including smart phone applications
- To determine the temperature lapse rate (TLR) and pattern of precipitation along altitudinal gradients in different precipitation regimes across the IHR
- To study plant diversity, community structure, tree diameter changes and natural recruitment pattern along the three principal sites in the IHR
- To understand tree phenological responses, nutrient conservation strategies and tree-water relations in response to warming climate

Achievements

- In Chopta-Tungnath area phenological observations (viz., leafing, flowering, fruiting and leaf drop), and changes in leaf area, leaf mass and leaf nitrogen concentration were taken at monthly interval starting from May 2016 until December 2016 (just prior to snow fall) on five timberline tree species (viz., *Abies spectabilis, Betula utilis, Quercus semecarpifolia, Rhododendron barbatum and R. campanulatum*). In addition, microclimatic data within the selected tree stands were taken during each sampling periods which showed mean atmospheric temperature ranging from August (18.5 °C) to December 2016 (5.7 °C), RH from 79% in August to 61% in December and mean soil temperature from August (14.3 °C) and (5°C) November 2016 (Fig. 11).
- In a majority of individuals (50-75% of the 100 marked trees of each species) of *A. spectabilis, B. utilis* and *R. barbatum* leafing had been accomplished in last week of May-early June, whereas in *Q. semecarpifolia* and *R. campanulatum* it was < 20% by this period. Leaf drop in *B. utilis* was completed by December, whereas in *Q. semecarpifloia, R. barbatum and R. campanulatum* only 20-25% and in *A. spectabilis* ~ 50% marked individuals showed leafdrop activity by December. Leaf area (range= 0.28 cm^2/leaf in *A. spectabilis* - 52.6 cm^2/leaf in *R. campanulatum*) increased sharply till August in all the species, whereas leaf mass (range= 0.007-1.08 g/leaf in *A. spectabilis* and *R. campanulatum*, respectively) gain continued till October in all the species. Leaf mass loss at the time of leaf drop was computed ranging from 36.2% and 37.9% in *R. barbatum* and *R. campanulatum* to 56.0% in *B. utilis*.

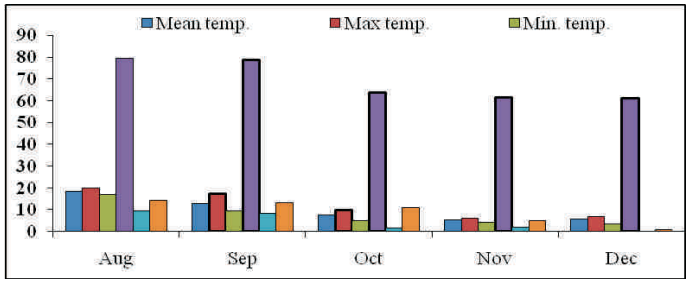


Fig. 11: Mean values of micro-climatic data observed at Tungnath forest sites.

Achievements

- Database and Catalogue of satellite images have been created to map high altitude vegetation of the Indian Himalayan region.
- Geodatabase for Sikkim state has been developed. Landscape characterization of Sikkim indicates that one fourth (27.6%) of the state has gentle slopes but mostly on higher altitudes of trans-Himalayan region. Middle part of the state has more steepness than other

parts. In nearly 30% areas slopes are steeper than 35°.

- A new approach was developed using satellite images based timberline mapping for more refinement and characterization, and timberline Maps (2 resolutions) of Sikkim state were prepared (Fig. 12). Worthwhile to note is that more than 39% of the total area of the state lies in tree devoid zone of high altitude region represented by Snow, Rocks and Moraines, and Alpine, while forest is dominating on the landscape covering an area of about 46.5% of the total area.

- Timberline in the year 2015 (derived from Landsat 8) indicates that it runs approx. 828 km in the state. In rare locations of the state, high altitude timberline may occur between 2600m and 3200 m altitude (negligible but present). Presence of timberline is more visual from 3200m onwards and scarcely reaches upto 4800 m.

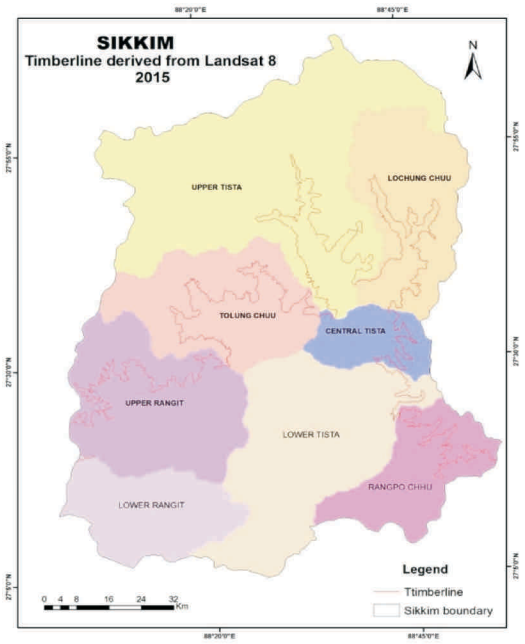


Fig 12. Timberline (2015) in the state of Sikkim

Assessment of Biomass, Carbon stock and Species diversity of Epiphytic Bryophytes along an Altitudinal Gradient in Kedarnath Wildlife Sanctuary (KWLS), Uttarakhand (DST-SERB, 2016-2019)

Bryophytes are recognized an important constituent of plant diversity. They are represented by nearly 26,000 species and form the most diverse group of terrestrial plants after angiosperms. They have evolved as an unparallel diversity in size and structure. The massive mats and turfs of epiphytic bryophytes cover forest trees, providing valuable resources such as a growth substrate and nutrition pool to entire communities of vascular epiphytes such as ferns and orchids, and serve as breeding and nesting space for a wide range of birds, amphibians and insects. Considering the role of lower plants as important functional groups in the ecosystem, the interest in biodiversity and conservation biology related to bryophytes is now rapidly increasing. The Himalaya is listed as the third richest region of the world in terms of bryophyte diversity and mosses are one of the dominant plant communities at higher elevations and sometime contribute more than 50% of active biomass and considered major source of carbon sink in Himalayan temperate ecosystems. The Garhwal Himalaya is one of the hot spots of biodiversity in the north-western Himalaya**.** The unusually wide altitudinal range and gradient even at small distances, habitat diversity and high level of endemism make it interesting for studies. Though, during recent past the loss of biodiversity in Himalaya continues to increase with developmental activities and therefore, there is an urgent need to develop practicable plans and strategies for conservation at different spatial scale. The impacts of global warming, though yet not monitored scientifically, but are clearly visible in Himalaya. Future changes in climate are projected to cause changes in vegetation distribution, which will also impact forests and biodiversity of Himalaya.

Objectives

- To assess species diversity and distribution patterns of epiphytic bryophytes along an altitudinal gradient in Kedarnath Wildlife Sanctuary.
- To assess biomass and carbon stock of epiphytic bryophytes along an altitudinal gradients.
- To design, conservation and management strategies for conservation and management of bryophytes diversity in the wake climatic change.

Achievements

1. An extensive review of relevant literature pertaining to epiphytic bryophytes and a preliminary field survey was carried out for selection of different forest types ranging between 1400 m to 3400 m along an altitudinal gradient in Kedarnath Wildlife Sanctuary to conduct the present study.

2. An inventory was made to collect the primary information of prevalent epiphytic bryophytes with regards to habitat, slope, aspect, life strategies, growth forms, altitudinal range and supporting host tree species of woody plant in KWLS for establishing permanent plot to study distribution pattern and

phytosociological aspect of the tree vegetation along altitudinal gradient.

3. Two sub-sites (A) Kalimath (30^0 54' 12" N - 79^0 08' 20" E)-Tungnath (30^0 48' 93" N - 79^0 21' 62" E) and (B) Sonprayag (30^0 38' 05" N - 78^0 58' 12" E) - Triyuginarayan (30^0 38' 07" N - 78^0 58' 8"E) were selected for conducting detail study and these sub-sites were again divided in 5 altitudinal zones (1400-1800, 100-2200, 2200-2600, 2600-3000 and 3000-3400 m asl) at 400 m intervals along an altitude to identify the diversity and distribution pattern of epiphytic bryophytes with increasing altitude.

4. During the preliminary survey a total of 28 prominent woody plant species has been reported in the present study and emphasized that the recorded species belongs to 19 genera and 10 families. The Pinaceae and Betulaceae represent 4 genera and 5 species followed by Ericaceae having 2 genera and 4 species, Sapindaceae having 2 genera and 3 species, Fagaceae having 1 genera and 5 species, however, Buxaceae, Cupressaceae, Juglandaceae, Myricaceae, Symplocaceae, Taxaceae having single genera single species in the study sites.

5. In the initial phase of survey, a total of 37 species of epiphytic bryophytes belonging to 14 families and 30 genera were found along an altitudinal gradient of KWLS. The family Meteoriaceae recorded the largest family, represents maximum number of species (8) and genera (7) of epiphytic bryophytes followed by Bryaceae having 3 genera and 7 species of epiphytic bryophytes, Dicranaceae and Pottiaceae having 3 genera and 3 species, Hypnaceae represents 2 genera and 3 species while Sematophyllaceae, Brachytheciaceae, Neckeraceae represents 2 genera and 2 species. Orthotrichaceae represents 1 genera and 2 species, Leucodontaceae, Trachypodaceae, Leskeaceae, Thuidiaceae, Entodontaceae represents 1 genera and 1 species each.
6. The observation made in the present study revealed that the population and biomass of the epiphytic bryophytes are more at middle altitude (2000-2500 m) altitude as compared to higher altitude due to dense canopy and higher moisture content at middle altitude.

7. Strong linkages and coordination was developed among village communities and forest departments to strengthen community based initiatives in order to conserve and maintenance of forests and associated species in KWLS through creating awareness and motivational programmes.

THEME

CLIMATE CHANGE

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

Vulnerability Assessment of Mountain Ecosystems due to Climate Change: Ecosystem Structure and Functioning (Indian Institute of Remote Sensing (Department of Space), Dehradun, 2014-2019)

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

Objectives

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

Achievements

1. Establishment of permanent Sites for Long Term Monitoring of Tree line Vegetation in Pindar Valley of Uttarakhand State - 8 plots of 20x20 meter at three different locations ranging between 3180m and 3420m were established (location and geo-spatial attributes) for permanent monitoring.

2. Tree vegetation in each plot was marked and measurements were taken. Tree species (8 species of 6 genera) of 5 families (4 Angiosperm and 1 Gymnosperm) were recorded in these plots. *Ericaceae* was dominant family represented by two genera (*Rhododendron* & *Lyonia*) and 4 species (*R. arboreum*, *R. barbatum*, *R. campanulatum* & *Lyonia ovalifolia).*

3. Tree density in different plots varies between 23 and 50 individuals. Sampling density is very wide from 1 to 36. Seedling establishment in high altitudes varies considerably between not present to 9 individuals in a permanent plots of different locations (Fig. 12). This indicate location specific attributes influences establishment of trees in harsh environment and can be seen only in long term (as reflected by high number of saplings than the seedlings).

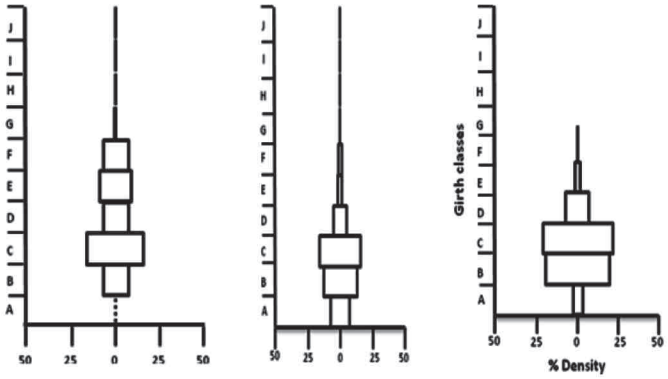


Fig.12. Population structure of treeline vegetation in different locations of Pindar valley of Uttarakhand

1. Pattern of vegetation in high altitudes (upto 4100m) of Great Himalayan National Park in Himachal Pradesh - Ten (10) Tree communities, (04) Shrub communities and One (1) herb community were identified. Maximum sites were represented by *Betula utilis* (7 sites) and *Betula utilis-Abies pindrow* mixed communities (6 sites), followed by *Taxus baccata ssp. wallichiana -Abies pindrow* mixed community (03 sites each) and *Abies pindrow-Acer acuminatum mixed, Abies pindrow-Betula utilis mixed, Betula utilis- Taxus baccata ssp. wallichiana mixed, and Taxus baccata ssp. wallichiana-Betula utilis mixed* (02 sites, each) communities. The remaining communities were represented by 01 site only.

2. The total tree density ranged from 90.00- 480.00 ind. ha^{-1}; total basal area 3.30-41.04 m^2 ha^{-1}; total shrub density 840.00-3190.00 ind. ha^{-1}; total herb density 18.15-379.00 ind. m^{-2}; total sapling density 150.00-662.00 ind. ha^{-1} and total seeding density 100.00-500.00 ind. ha^{-1}. Maximum total tree density was recorded in *Abies spectabilis - Betula utilis* mixed (480.0 ind. ha^{-1}) community, followed by *Betula utilis - Abies pindrow* mixed (441.66 ind. ha^{-1}) community.

Clean energy development to mitigate impacts of climate change in the Indian Himalayan Region (Fellowship under National Mission for Himalayan Studies (NMHS); 2016-2019)

Environmental and energy security are two major global concerns going parallel but often bridges by clean energy solutions. Developing countries like India where 17.31% of world's population reside, are still in dilemma or more often following the developmental markers set and tested in different socio-techno-economical spheres of developed countries, and Himalayan region is no exception. Modern fuels have been seen as a better environmentally suitable alternative over traditional energy obtained from biomass. In the Himalayan region still a large part of the population relies on biomass as primary source of cooking. This population growth coupled with rising paying capacity involves a chain of cascading effects of women drudgery, human and ecosystem health, depletion of bioresources, and emission of Green House Gases (GHG) mainly CO_2. There is need (i) to analyze gap between pace of growth development and policy interface for clean energy development, (ii) to document best practices/models for further promotion, and replication, (iii) to provide integrated solution on account of reducing women drudgery, improved human health of rural inhabitants and biological wealth of the Himalayan region linked with alternate livelihood options, and ultimately contributing to the India's Intended Nationally Determined Contribution (INDC).

Objectives

- To analyze existing policies and legal instruments for promotion of clean energy development in the Indian Himalayan Region
- To document and analyze best practices/models for further promotion, and replication of clean energy development
- To provide integrated solutions with reference to IHR region on account improving human and ecosystem health linked with alternate livelihood options and contribution to the India's Intended Nationally Determined Contribution (INDC)

Achievements

1. Database has been created on existing legal instruments (policies and acts) developed by various national and Indian Himalayan states agencies (Fig. 14).

2. At national level more emphasis is on policy formulation and power generation using solar energy and promotion of related technologies, however, Indian Himalayan states have not prioritized upon the solar photo-voltaic technology despite the solar potential of 230.25 GWp in the Indian Himalayan Region.

3. To tap potential of 8532 MW, and 1296.4 MW energy through hydro power in Indian Himalayan states has been installed.

4. Meghalaya, Manipur, Mizoram and Tripura do not have any specific policies with reference to renewable energy production through different technologies; however, each state facilitates it by one single policy which is common to all the different production technologies.

5. However, Manipur has only 96 MW potential for wind energy generation which is very less in comparison to total potential of the IHR states (6905MW), the state has specifically mentioned wind energy into the single policy document. Thus, there is need to further look forward by the other states for harnessing of wind energy potential.

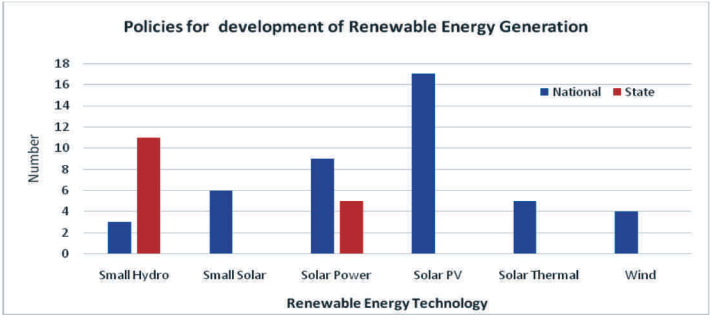


Fig 14. Status of legislative tools for the development of renewable energy in the Indian Himalayan region

Vulnerability assessment of mountain ecosystems due to climate change: Ecosystem structure and functioning (2015-2019; Indian Institute of Remote Sensing, Dehradun)

The Himalayan region is amongst the identified Global Biodiversity Hotspots. The Indian Himalayan Region (IHR) forms the major part of Himalaya and comprises of three bio-geographic zones and 8 bio-geographic provinces due to its typical physical features and environmental conditions. The unique topography, diverse habitats and large altitudinal range (200-8,000m) support the representative, natural, unique and socio-economically important biodiversity. The region represents tropical, sub-tropical, temperate, sub-alpine, alpine and Tundra ecosystems/biomes. The major population of IHR lives in the rural areas and the inhabitants are largely dependent on various services provided by these ecosystems. In view of the rapid depletion of biodiversity, a Protected Area Network has been established across the IHR and representative biodiversity rich areas have been notified as Biosphere Reserves, National Parks and Wildlife Sanctuaries for the in situ conservation of Ecosystems, habitat and species, respectively. In addition Ecological degradation and loss of biodiversity as a result of excessive anthropogenic pressures, particularly in the fragile Himalaya have caused much concern among the conservationists in the recent years. Therefore, it is pertinent to initiate a detailed study on biodiversity assessment, monitoring and give suitable management plans for conserving the Himalayan forests.

Objectives

- To assess the floristic diversity of sub- alpine and alpine ecosystems
- To assess the socio-economic and conservation values of the floristic diversity of sub- alpine and alpine ecosystems
- To assess the carbon sequestration of the sub-alpine ecosystem
- To assess the floristic diversity of sub- alpine and alpine ecosystems for vulnerability
- To map the habitats and communities for identification of ecologically sensitive areas using Remote Sensing and Geographical Information System
- To prioritize species, habitats and communities for conservation and suggest suitable management options for conservation

Achievements

1. Total 32 sites were surveyed between 2250-4095 m and 10 tree communities, 04 Shrub communities and 1 herb community were identified. The total tree density ranged from 10.00- 490.00 Ind ha1^{-1}; total basal area 0.10-75.00 m^{2} ha^{-1}; total shrubs density 230.00-3580.00 Ind ha^{-1}; total herbs density 2.92-116.05 Ind m^{-2}; total saplings density 30.00-325.00 Ind ha^{-1} and

total seedlings density 20.00-370.00 Ind ha^{-1}. Population structures of *Betula utilis community and Betula utilis-Abies pindrow* mixed community are presented (Fig.15).

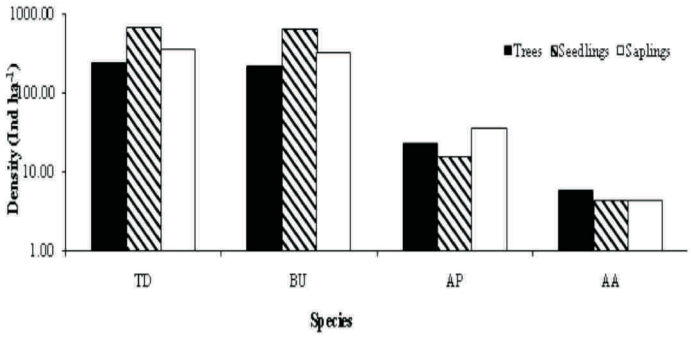


Fig.15. Population structure of *Betula utilis community*
Abbreviations used: TD=Total density; AP=*Abies pindrow,* BU=*Betula utilis* and AA=*Acer acuminatum*

2. Maximum sites were represented by *Betula utilis* community. A total of 112 species (trees: 3 shrubs: 19 and herbs: 90) were recorded. The total tree density and total basal area were 245.71 Ind ha^{-1} and 9.36 m^2 ha^{-1}, respectively. Total seedlings and saplings densities were 365.71.00 Ind ha^{-1} and 662.86 Ind ha^{-1}, respectively. Among the seedlings, highest density was shown by *Betula utilis* (352.71 Ind ha^{-1}). Highest saplings density was also shown by *Betula utilis* (642.85 Ind ha^{-1}).

3. In the communities, Species Diversity (H') of tree species ranged from 0.20 – 1.77; shrubs 0.66-2.17, and herbs 2.16-3.38. Concentration of Dominance (CD) of tree species ranged from 0.18-0.85 among the identified communities, of shrubs ranged from 0.13-0.53 and of herbs ranged from 0.05-0.91.

4. 308 species of vascular plants were recorded and out of these 262 species were economically important, 158 species were used as medicine, 21 as wild edible/food, 22 as fodder, 19 as fuel, 08 as religious, 08 as timber, 04 as dye, 06 as fibers, 10 for making agricultural tools, and 06 for various other purposes.

5. The pH was ranged from 5.71-6.94, moisture content ranged from 10.82-92.24%, Total Nitrogen from 0.07-0.51%, total Organic carbon from 2.63-6.71%, total organic matter from 4.54-11.56%, available phosphorus was from 0.20-0.58 mg kg^{-1} and potassium from 732.19-1163.5 Kg ha^{-1}.

Ecological Analysis of Indigenous Agroforestry Systems with Reference to Climate Change Adaptation, Mitigation and Coping Strategies in Indian Central Himalaya (DST-SERB, 2015-2018)

Agroforestry is one of the most conspicuous land use systems across landscapes and local environment. It provides assets and income from carbon, wood energy, improved soil fertility, enhancement of local climatic conditions, ecosystem services and reduces human impacts on natural forests. The agro-forestry systems in central Himalayan region of India are an integral part of the traditional farming communities. The system is managed indigenously, with best practices which have been evolved by the farmers through trial and error over the time. In Central Himalayan region of India local communities maintain naturally regenerating tree species, particularly on the edges or margin of rainfed terraced agriculture land without any significant external inputs or manpower. Such indigenous agro-forestry system plays an important role in carbon sequestration, provide option to adaptation to climate change and reducing pressure on natural forests for fodder, fuelwood, and timber extraction. The management of indigenous agro-forestry systems in the Himalaya region while maintaining and managing potential agro-forestry trees, intercropping understory crops, livestock rising and protection of adjacent forests for variety of ecosystem services is an adaptive indigenous practice of the mountain communities.

Objectives

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

Achievements

1. An extensive literature review and a preliminary field survey were carried out for selection of indigenous agro-forestry models in Indian Central Himalaya. Three village clusters e.g. Saknidhar, Jakhand and

Dagar in Tehri district along an altitudinal gradient ranged from 800 to 1800 masl were selected for conducting the present study.

2. Structured and semi-structured questionnaires were used to interview more than 40% households in each village clusters. Information was collected on population number, family size, land holding, altitudinal range, indigenous system, which included the pattern, production and uses of agro-forestry species.

3. A total of 30 woody agro-forestry species and 31 food crops have been listed and their traditional uses were documented in all three selected village clusters.

4. Land use pattern and distribution percentage of agroforestry species in different agroforestry systems was analyzed and categorized based on their occurrence e.g. agriculture land (44%), grass land (29%), barren land (20%), and kitchen garden (7%).

5. Dependency of local people on indigenous agroforestry systems in the study area was carried out and it revealed that the local people depend on different agroforetry produces such as fodder (33.7%), fuelwood (16.5%), food (27.6%), medicine (9.1%), timber (7.5%), fiber (3.3%), and other (2.3%).

6. Local people of three different village clusters e.g. Saknidhar, Jakhand and Dagar (5 villages and 50 farmers from each village cluster) were consulted to responses about the problems and document the factors those are responsible for strengthening and deterioration of indigenous agro-forestry system. Most of the respondents (81%) emphasized that application of lopping/pruning practices is crucial for sustainability of the system; this attribute scored first among the ten foremost requirements for strengthening the agro-forestry, while weeding techniques, stood last. Crop damage by wild animals was ranked first (92%) among the attributes/reasons responsible for deterioration of indigenous agro-forestry, while literacy rate scored was last.

7. The present study identified five broad categories of sustainability such as agriculture management, livestock management, forest sustainability, social benefits/needs, and policy inputs along with sixteen criteria and thirty four related indicators to strengthen and provides holistic approach for sustainable management of indigenous agro-forestry systems in Indian central Himalaya.

8. Fuelwood and fodder consumption pattern and energy budget was analyzed along an altitudinal gradient in selected village clusters. The results indicated that fuelwood consumption ranged between 242.95±22.22 to 373.16±23.96 kg capita^{-1} year^{-1}, whereas, fodder consumption ranged between 154.34±17.30 to 463.14±14.83 kg unit^{-1} year^{-1}. The energy budget of fuelwood and fodder consumption ranged from 2160.76±242.21 to 7317.66±234.36 MJ kg^{-1}.

9. Tree biomass, carbon stock and carbon sequestration rate was estimated from 3 prominent agroforestry tree species i.e., *Grewia optiva, Celtis australis, and Morus serrata* in the study area during the year 2016 and 2017.

10. The results indicated that the total tree biomass of *Celtis australis* was recorded *significantly higher (*5408.46±0.90 t ha^{-1} *to* 8210.19±0.90 *t ha^{-1}) compared to Grewia optiva (*343.02±2.70 t ha^{-1} *to* 1067.76±0.90 *t ha^{-1})* and *Morus serrata (*204.48±1.80 t ha^{-1} *to* 465.26±0.90 *t ha^{-1}).*

11. Similar pattern was observed in carbon stock and emphasized that the range of carbon stock was recorded significantly higher in *Celtis australis (*2704.48±0.90 t ha^{-1} *to* 4105.09±0.90 *t ha^{-1}) compared to Grewia optiva (*171.51±1.80 t ha^{-1} *to* 533.88±0.98 *t ha^{-1})* and *Morus serrata (*102.24±0.90 t ha^{-1} *to* 232.63±1.79 *t ha^{-1}). However, the carbon sequestration rate* was estimated highest in *Celtis australis* (481.27±0.0 t ha^{-1}yr^{-1}) followed by *Grewia optiva (*146.48±0.08 t ha^{-1}yr^{-1}*)* and *Morus serrata (*65.98±0.89 t ha^{-1}yr^{-1}*).*

Summary of the Completed Project

Alpine ecosystem dynamics and impact of climate change in Indian Himalaya (Space Application Centre (Department of Space), Ahmadabad, 2013-2017)

Three alpine summits in the Kumaun Himalayan region of Uttarakhand State were brought under internationally recognized GLORIA protocol for long-term monitoring of impacts of climate change on high altitude vegetation under HIMADRI programme of Department of Space, Govt. of India. Baseline (year 2015) data on different geographies of target region were collected on pattern of vegetation diversity in three established sites to understand present trends and for future pursue.

Herbarium records of alpine vegetation are being maintained to provide useful information regarding the vegetation of the target region along with treeline species. About 100 specimens have been collected from the study area, and were represented by 21 families, Asteraceae being dominant (5 genera), followed by Rosaceae (4 genera). With an increase in altitude total species number was decreasing -31 species were recorded from lower alpine summit, 28 species from upper alpine summit, and 13 plant species from sub-nival zone of the area. 15 plant species of alpine region were common between lower and upper summits whereas 3 species are common between lower alpine summit and sub-nival zone. Dominant species were different at different elevations, *Danthonia cashemyriana* (lower alpine), *Trachydium roylei* (upper alpine) and *Sibbaldia* sp. (sub-nival zone).

Treeline species data have been maintained and geo-tagged for long-term monitoring to record any shifting in treeline towards the higher altitude induced by climate change. Treeline species recorded from target region incliudes *Rhododendrdon arboreum,* R. *barbatum*, *R. campanulatum, Abies pindrow, Quercus leucotrichophora*.

Soil temperature data loggers have been installed in all the three summits to maintain a baseline data for soil temperature which will be used as referral in the future. Soil temperature indicates that eastern aspect was warmer than the other slopes in all the three summits, and during May temperature in the soil remained warmest while during January it was coldest. This has several implications on plant growth since most of the alpine plants propagate through underground parts.

THEME

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

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

Objectives

- Assessment and monitoring of physical, biological and socio-economic environmental attributes related to various developmental interventions/policies/plans in the Indian Himalayan Region (IHR).

- Development/formulation/suggestion of appropriate management plans ensuring ecological and economic sustainability.

Aerosols climatology over the northwestern Indian Himalayan region, Himachal Pradesh (ISRO, SPL, Thiruvanthapuram, 2005-06 - to date, long term science programme)

The Kullu valley in Himachal Pradesh is well known for its unique geographic entity from rest of the parts of the Indian Himalayan Region (IHR) as well as whole of the country. This valley has been world famous for tourist destination (Manali, Rohtang Pass, Solang nala, Marhi, Kothi, etc.), apple fruit and other horticultural crops and hydropower activities. However, in recent decades there have been lots of anthropogenic activities especially related to tourists' influx as well as ever increasing number of native populations. These anthropogenic activities result in emissions to a greater extent in its surrounding environment and have affected the local temperature. Upon interacting with atmospheric aerosol, there is extinction in solar radiation thereby unbalancing earth's radiation budget. Black carbon aerosols have tendency to absorb short wave solar radiation thereby warming the air and contributes to global warming. Also, black carbon aerosols if deposited on snow and ice, it darken their surface and reduce albedo and contribute to snowmelt, glacial retreat and decreased snowpack. This results in decrease in precipitation and increase in temperature. Aerosols not only affect the ecosystem and its climate but also the human health. High concentration of aerosols results in respiratory problems in human. WHO has also recently recognized black carbon as carcinogens. Aerosols, radiative forcing provides us information about the change in radiation budget of the atmosphere/surface. A positive forcing (more incoming energy) warms the system, while negative forcing (more outgoing energy) cools the surface.

Objectives

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

Achievements

- AOD in the Kullu valley is wavelength dependent. It is higher at shorter wavelengths and lower at larger wavelengths indicating dominance of anthropogenic interferences on the surrounding environment.
- Mean AOD_{500nm} at Kothi (2500 m) was observed to be 0.28± 0.09 in 2016 (Fig. 16a). It ranged from 0.07 to 0.52. The highest daily mean AOD_{500nm} was found to be 0.52 on 12 May 2016 while the same was observed minimum 0.07 on 10 January 2016.
- Mean AOD_{500nm} was observed to be 0.38± 0.08 at Gahidhar (1507 m) in 2016 (May 2016- June 2016). AOD at the same wavelength stood as lowest as 0.17 on 16 May 2016 and highest as 0.56 on 02 June 2016 (Fig. 16b).
- On the other hand, mean AOD_{500nm} at Mohal (1154 m) in 2016 stood to be 0.32± 0.12 (Fig. 16c). It was observed in the range of 0.12 to 0.69. Highest AOD_{500nm} was observed on 20 July 2016 and it was observed to be minimum on 21 February 2016.
- Diurnal variation of BC showed bimodal peak at all three sites; Kothi (January 2016 –November 2016), Gahidhar (May 2016- October 2016) and Mohal (February 2016 –May 2016) with its highest concentration in morning and evening hours of the day. At Kothi, it peaks around 7:00 hrs IST in morning with concentration of 2766.7 ng m^{-3} and around 17:00 hrs IST in evening with concentration of 3253.7 ng m^{-3} (Fig. 16d). Similar trend was observed at Gahidhar and Mohal. BC peaks around 7:00 hrs IST (3295.4 ng m^{-3}) and around 19:00 hrs IST (3825.9 ng m^{-3}) at Gahidhar (Fig. 16e) and at around 9:00 hrs IST (1875.2 ng m^{-3}) and around 20:00 hrs IST (1695.0 ng m^{-3}) at Mohal (Fig. 16f).
- The instantaneous mean aerosol radiative forcing was estimated to be –12.42 ± 7.99 Wm^{-2}, –29.26 ± 14.53 Wm^{-2} and +16.83 ± 7.76 Wm^{-2} on TOA, surface and atmosphere respectively at Kothi which translates into an average atmospheric heating rate of 0.47 K day^{-1} in 2016 (Fig. 16g).
- At Gahidhar (May 2016 - June 2016), the instantaneous mean aerosol radiative forcing was estimated to be –8.28 ± 3.38 Wm^{-2}, –32.13 ± 3.75 Wm^{-2} and +23.85 ± 2.59 Wm^{-2} on TOA, surface and atmosphere respectively (Fig. 16h) which translates into an average atmospheric heating rate of 0.67 K day^{-1} in 2016.

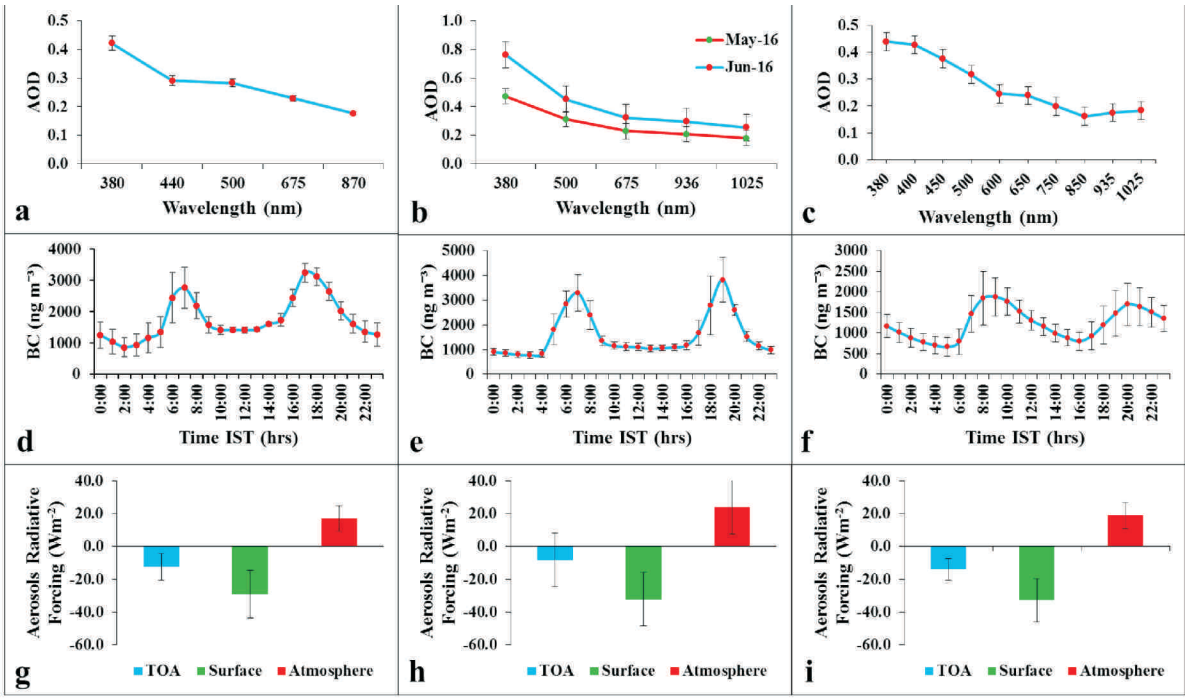


Fig.16. AOD at: (a) Kothi, (b) Gahidhar, (c) Mohal, BC at (d) Kothi, (e) Gahidhar, (f) Mohal, and Aerosol Radiative Forcing: (g) at Kothi, (h) Gahidhar, and (i) Mohal.

- At Mohal, the instantaneous mean aerosol radiative forcing was estimated to be -13.92 ± 4.7 Wm^{-2}, -32.79 ± 11.2 Wm^{-2} and $+18.87 \pm 8.02$ Wm^{-2} on TOA, surface and atmosphere respectively in 2016 (Fig. 16i) which translates into an average atmospheric heating rate of 0.53 K day^{-1} in 2016. Atmospheric forcing is found decreasing along with increasing altitudes. Hence, the temperature continues to rise.

Gaseous air pollution in the background sites of sprawling urban environment in Himachal Pradesh (ISRO, PRL, Ahmedabad; 2008-09 - to date)

Tropospheric or surface ozone (O_3) is an important air pollutant threatening human health, vegetation growth and increasing local temperature as one of the important 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 concentration 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 such as vehicle emissions and fossil fueled power plants. NO is a 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 analyze in the background of long range transport sources.

- To suggest some feasible mitigating measures implementing at policy level.

Achievements

- These precursors are mainly considered to be emitted in the present study sites due to anthropogenic emissions in the form as vehicular emission and biomass burning. Some are local while some are transported.
- In case of CO_2, it was observed highest in June, which was maximum as 260.5±7.7 ppm and minimum 160.58 ± 4.45 ppm in December respectively.
- Annual maximum concentration of NO was 4.07 ± 0.9 ppb in October, NO_2 6.99 ± 1.14 ppb in (January 2017) and NO_x 11.3 ± 3.8 ppb in June. On the other hand, minimum concentration of NO, NO_2 and NO_x were observed 0.29 ± 0.04 (March 2017), 1.42 ±0.5 (August) and 3.83 ±1.08 (February 2017) respectively.
- Observations of trace gases such as surface ozone and its precursors, nitrogen oxides (NO+ NO_2), and CO_2 were carried out at Kothi (2500m). In an Environmental Observatory, different related online analysers and equipments are functional. Among these worth mentioning are: UV Photometric Ozone Analyzer (Thermo Fisher Model, 49i), NO_x Analyzer (Thermo Fisher, Model 42i), and Carbon dioxide Analyzer (Thermo Fisher Model, 49i).
- The concentration of O_3 was found to be increasing gradually after sunrise (07:00-08:00 h IST), attaining maximum concentration during afternoon (14:00-16:00 h IST). However, thereafter it showed a gradual decreasing pattern. Analysis of meteorological data showed that the high O_3 concentration were associated with intense solar radiation, and minimum rainfall in every year.
- During a reporting period (2016–17), higher concentration of surface ozone was observed in June which was maximum as 29.50±5.33 ppb and minimum as 1.79 ± 1.08 ppb in October month.

Monitoring of different atmospheric gaseous pollutants, creation of long term data base on meteorological parameters to assess climate change scenario and its impact on apple orchards (NMHS-2016-2019)

The Kullu valley in Himachal Pradesh is a unique geographic in the Indian Himalayan Region (IHR). This valley is a world famous for tourist destinations, apple cultivation, other orchards and hydropower energy. The management of the fragile ecosystem like Kullu-Manali, varies with altitudes and climatic characteristics. The region therefore requires a detailed study regarding the adverse forms of pollution due to ever-growing human interferences. As a result, a greater awareness is required recently to assess pollution level, its probable sources and its adverse impact on the different ecosystems. The ambient air pollution studies particularly in sensitive locations where breathing air (oxygen) decreases with increasing altitude such as snow bound locations of the Kullu valley have much significance to unfold a current status of air quality. Air pollution parameters among gaseous pollutants included trace gases like sulphur dioxide (SO_2), nitrogen dioxides (NO_2), ammonia (NH_3) and acid rain which are critically dangerous to human beings, plants and crops. Particulate matter included total suspended particulates (TSP) matter, i.e. below 10 microns in size (PM_{10}) and below 2.5 microns in size ($PM_{2.5}$). Such studies will help in maintaining and regulating a level of clean air for the residents and tourists. Moreover, this study will also have positive impacts on agro-horticultural crops including apple by way of suggesting options to reduce impact of climate change in the valley.

Objectives

- To monitor atmospheric pollutants and generate a long term data base on meteorological parameters.
- To establish relationship between pollutants and their impact on climate change.
- To assess climate change impact on apple orchards.
- To suggest mitigation and adaption strategies.

Achievements

- NO_2, SO_2 and NH_3 as the primary pollutants under the present context were proposed to monitor at two different altitudinal gradients- Mohal (1154 m) and Kothi (2500 m) in the Kullu valley. Here, the results at Kothi have been shown and the results at Mohal are under process. Similar is the case of NO_2 and NH_3 which are either from local or from external sources. Daily NO_2 concentration at Kothi showed 9.98 µg m^{-3} as the highest on March 5, 2016. As against, its lowest value was monitored at Kothi as 0.32 µg m^{-3} in January 2016. The average NO_2 concentration at Kothi was observed 2.06 ± 0.15 µg m^{-3} during the observation days from January 2016 to December 2016 (Fig. 17a).
- On the other hand, SO_2 average concentration on monthly basis was observed as 1.27 ± 0.08 µg m^{-3}, where the highest value was 4.49 µg m^{-3} on 5th October 2016. However, the lowest value was obtained 0.31 µg

m^{-3} on 20th May 2016 at the experimental site- Kothi (Fig. 17b). SO_2 is often treated as a local pollutant, but it can also be transported through long-range transport sources such as air masses. The average concentration of NH_3 was observed 1.44 ± 0.10 µg m^{-3} from January to December, 2016. The highest and lowest concentrations were observed to be 5.98 µg m^{-3} on 5th October 2016 and 0.22 µg m^{-3} on 25th July 2016 (Fig. 17c). The results show that the concentrations of gaseous pollutants were below the permissible limit based on NAAQS.

- The particulate pollutants include the three important pollutants such as TSP (particles below 100 µ), PM_{10} (respirable particulate matter below 10 µ) and $PM_{2.5}$ (fine particulate matter below 2.5 µ). The daily maximum concentration of TSP at Kothi from January to December, 2016 was 340 µg m^{-3} on April 30, 2016, while the minimum concentration was 5.70 µg m^{-3} on October 11, 2016. The monthly mean concentration of TSP at Kothi was 52.16 ± 4.64 µg m^{-3} during observation days (Fig. 17d).
- The PM_{10} at Kothi was maximum in December, while minimum concentration was in August. The mean concentration from January to December, 2016 at Kothi was 26.20 ± 1.39 µg m^{-3}. PM_{10} at Kothi with maximum concentration 39.59 µg m^{-3} was observed in December 2016 while its lowest concentration was 9.99 µg m^{-3} in August 2016 (Fig. 17e). It is the summer season when the daily $PM_{2.5}$ at the study locations was found with maximum concentration. $PM_{2.5}$ at Kothi was the highest 47.22 µg m^{-3} during December while lowest was 4.72 µg m^{-3} in August 2016. The average concentration of $PM_{2.5}$ from January to December 2016 at Kothi was 19.38 ± 1.80 µg m^{-3} (Fig. 17f).
- The results of PM_{10} and $PM_{2.5}$ show that the highest concentrations were in December while their lowest concentrations were in August. Biomass burning during December and washout effect during August at Kothi were the primary reasons for the highest and lowest concentrations respectively.
- Local meteorology in terms of different parameters was assessed at Kothi in 2016. If daily maximum temperature was taken into account, it was 19.6 ^{0}C on June 29, 2016 and daily lowest temperature was 1.0 ^{0}C on February 11, 2016. The monthly mean temperature was 11.3 ^{0}C in 2016. The monthly maximum temperature was observed 17.4 ^{0}C in June 2016, while the monthly minimum temperature was observed 3.9 ^{0}C in January 2016. The figure illustrates that temperature changes remarkably according to the seasons.
- The mean humidity level was highest as 84% in July 2016 while the lowest ever relative humidity at Kothi was recorded as 34% during November 2016. The average relative humidity was observed 52.6% during the observation days in 2016. Rainfall plays a major

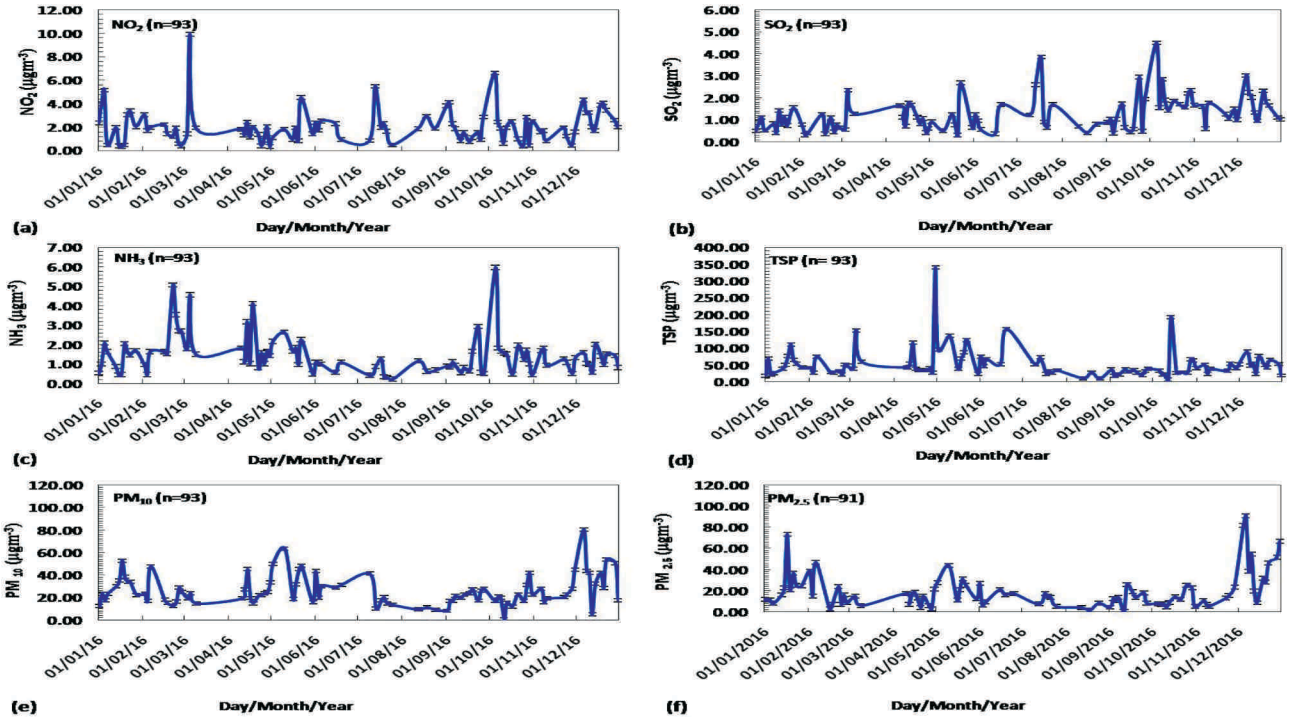


Fig. 17. Concentration of pollutants at Kothi: (a) NO_2, (b) SO_2, (c) NH_3, (d) TSP, (e) PM_{10} and (f) $PM_{2.5}$.

role and influences the humidity level in this region. Daily maximum total rainfall at Kothi was measured 42.9 mm on July 22, 2016. The monthly highest rainfall at Kothi was recorded 365 mm in July 2016. The total rainfall from January to December, 2016 at Kothi was observed 1050.4 mm.

- The windiest month at this location was April 2016 when its speed was noted to be 2.9 km hr^{-1}. The wind rose diagram makes it clear that winds at Kothi mostly come from the south-east (90^0-135^0) and south-west (225^0-270^0) directions. These meteorological conditions play their important role in affecting the TSP, PM_{10} and $PM_{2.5}$ concentrations at Kothi experimental site in the Kullu valley

Assessment of floral biodiversity and resource utilization pattern with special reference to climate change in the high altitude wetlands of Arunachal Pradesh of Eastern Himalaya (SERB, DST, 2016-2019)

The high altitude wetlands (HAWs) are an important category of natural wetlands found mainly in the higher elevations (above 3000 m) in the Himalayan region. They are extreme ecosystems, characterized by adverse climate and presence of a seasonal or diurnal permafrost layer. Arunachal Pradesh is ranked second in India after Jammu & Kashmir with 1672 HAWs covering a total area of 11,864 ha, accounting for about 7.6% of total wetland area of the state. HAWs provide a number of important ecosystem goods and services to sustain livelihoods of the upstream and downstream population of the region. They are the source of many major rivers, support rich and unique biodiversity, important for carbon sequestration and have religious significance among communities. At present, high-altitude wetlands are suffering from degradation, habitat fragmentation, desertification, soil erosion and anthropogenic disturbances, which are further aggravated by climate change impact. However, very little information is available for most of these wetlands due to their remoteness, harsh climatic condition and inaccessibility of the terrain. Therefore, comprehensive information is urgently required for developing and implementing plans for conservation and sustainable management of these unique ecosystems. The HAWs of the study area in the Himalayan region are among the most fragile ecosystems and are under severe threats from climate change. Impact of climate change on vegetation in the Himalayan region is yet to be carefully studied to establish a relationship. High altitude floral species, especially in the transition zone between sub-alpine and alpine are more vulnerable to climate change. In-depth scientific information on climate change impacts on floral diversity and dependent tribal community of high altitude wetland is so far unavailable for the Eastern Himalayan region. Therefore, there is an urgent need to study the floristic diversity and assess the climate change impacts on floral biodiversity, floral diversity utilization pattern of dependent communities and change in land use and land cover of high altitude wetland region of Eastern Himalaya. This study will help to frame a comprehensive climate change mitigation and adaptation strategy in particular for conservation of rich floral diversity of high altitude region in general of Arunachal Pradesh.

Objectives

- To assess the baseline status, both qualitative and quantitative, of floristic diversity in the selected HAWs area, and to study the status of rare, endangered, threatened and endemic species and identification of critical habitats for conservation and prioritization.
- To study the resource use pattern and dependency of local communities on floral biodiversity in and around the selected HAWs.
- To generate the Remote-Sensing (RS) and Geographical Information Systems (GIS) based database for the study area.
- Phenological study of selected indicator species to monitor the impact of climate change on vegetation, and to conduct physiochemical analysis of soil quality of HAWs.
- To assess climate change impact on floral diversity and resource use pattern of HAWs through community perception and to correlate them with the available climatological data.
- To recommend climate change mitigation and adaption strategies for floral biodiversity conservation and ecosystem management of HAWs.

Achievements

1. During the reporting period, status of high altitude wetlands of Tawang district of Arunachal Pradesh was documented through primary field survey as well as review of secondary information. There are around 253 HAWs in the district covering an area around 1139 ha. ISRO mapped 18 HAWs covering 36 ha area, 223 HAWs having 1076 ha area and 12 HAWs having 27 ha area in high altitude (3000-4000 m), higher altitude (4000-5000 m) and very high altitude > 5000 m altitudinal ranges, respectively for the district. Maximum number of wetlands are of small size (below

10 ha). Tawang district has mainly two wetland complexes, viz. Nagula and Bhagajang. Nagula wetland complex is situated to the northern part of the Tawang Township, bordering Tibet. It contains about 100 permanent alpine freshwater lakes located between the altitudes of 3500 m to 4420 m. The lakes are fed by snow melt water.

2. The complex is home of unique flora like *Primula, Gentiana, Frageria* and *Aconitum,* etc. and fauna such as Musk Deer (*Muschus chrysogaster*), Snow Leopard (*Uncia uncia*), Chinese Goral (*Nemorhaedus griseus*), Himalayan Goral (*N. goral*), Red Goral (*N. baileyi*), Bharal or Himalayan Blue Sheep (*Pseudois nayaur*), pika and Himalayan Marmot (*Marmota himalayana*). The Bhagajang Wetland Complex is located in the southwest part of the Tawang district, within the altitudinal range of 4000 - 4400 m amsl. Comprising nearly 20 lakes, this complex supports faunal species listed in the IUCN Red List of Threatened Species.

3. A total of 270 vascular plant species belonging to 56 genera and 74 families were recorded from the study area. These species were represented by herbs (200), shrubs (50), trees (15), and climbers (5). The largest number of species were noted from the family Asteraceae (36 spp.), followed by Ericaceae (23 spp.), Gentianaceae (21 spp.), Rosaceae (16 spp.), Primulaceae (13 spp.), Polygonaceae (11 spp.), Liliaceae, Scrophulariaceae and Apiaceae (8 spp. each), Saxifragaceae (7 spp.), Ranunculaceae and Campanulaceae (6 spp. each) and Berberidaceae (5 spp.), and *Rhododendron* (16 spp.), *Gentiana* (7 spp.), *Potentilla* (7 spp.), *Swertia, Saussurea, Allium* (6 spp. Each), *Berberis* (5 spp.) and *Berginia* (4 spp.), represented the species rich genera.
4. A total of 67 medicinal plant species were recorded during field survey in the study area. These species belong to 46 genera and 26 families, among these species 61 spp. were herbs and 6 shrub spp. For the preparation of herbal medicine, the rural and tribal communities of the region use different parts of the plants species. Mostly they use roots/rhizomes/tubers (49%), followed by flower (18%), whole plant (13%), leaf (10%), and fruit (8%). Medicinal plants were mainly used for curing various common diseases such as dysentery, chest pain, cough, cold, fever, rheumatism, gastritis, stomachic, dysentery, piles, skin diseases, urogenital disorders, cut and wounds, snake bite, anti-poison, eye and ear complaints. The most frequent type of preparation was decoction and paste of plant parts. Plant decoction is extracted by crushing the plant parts and sometimes plant parts are boiled with water and the liquid decanted.

5. Soil analysis revealed that soil moisture in wetlands ranged from 68.16 % to 140.57 %, pH 3.86 to 5.15, total nitrogen 1.30% to 3.83%, sodium 1.37% to 4.33%, potassium 2.33% to 4.87% and calcium 42.80% to 50.00%. The texture of the soil is very coarse with high gravel content.
6. Temperature loggers were installed to record the temperature, humidity and dew point of study area. During October, 2016 to February, 2017, maximum and minimum temperature was recorded 20.5^{0}C and -11^{0}C, respectively. Whereas, humidity was recorded between 10-102 % RH and dew point ranged from -18^{0}C to 14.1^{0}C (Fig. 18).
7. An education cum awareness program on 'Conservation of floral biodiversity of high altitude wetlands with special reference to climate change' was also organized for students, teachers, local communities at a very remote Govt. Residential School, Taktsang village of Zemithang Circle in Tawang district on October 09, 2016. Information on significance of high altitude wetlands, high altitude biodiversity conservation and impact of climate change in high altitude ecosystem were discussed with the participants.

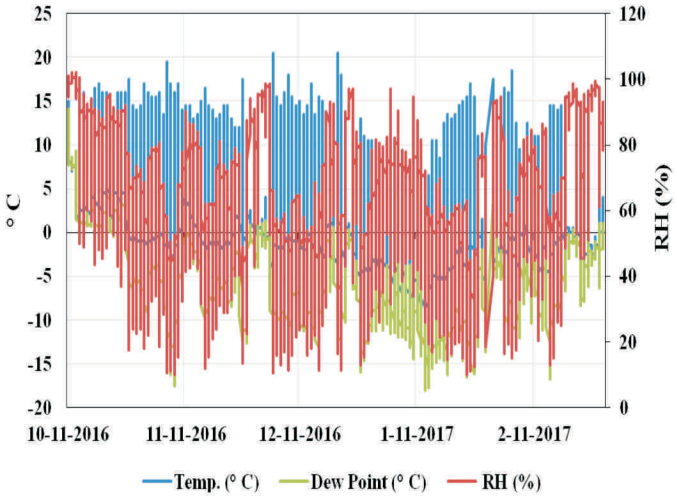


Fig. 18. Change in temperature and humidity at Tawang from October, 2016 to February, 2017

Summary of Completed Project/Activity

Strategic Environmental Assessment (SEA) of Hydropower Projects in the Indian Himalayan Region (2012-17, In-house)

The study was carried out in two selected sites, one is the Sutlej basin in Himachal Pradesh and other is River Ranganandi in Arunachal Pradesh. The objectives of the study were: (i) to know the status of selected hydroelectric projects (HEPs) in relation to SEA, (ii) to assess impacts in upslope and downslope regions of HEPs in addition to its immediate environment, (iii) to assess the future of HEPs in relation to climate change, (iv) to suggest measures to promote sustainable HEPs, and (v) to put forward adaptation strategies to combat climate change impacts.

The Indian Himalayan region has 1,17,139 MW (78.7%) potential for hydropower development. Among the Himalayan states, Arunachal Pradesh has a large (50,228 MW) capacity followed by Himachal Pradesh (20,415.62 MW). In India, Arunachal Pradesh (34%), Himachal Pradesh (13%), Uttarakhand (12%) and Jammu & Kashmir (10%) are the main contributor of the total identified hydropower generation.

Sutlej basin, Himachal Pradesh

- The impacts in the form of air, water and soil quality status and socio-economic conditions of natives were assessed. During post-monsoon 2016, PM_{10} (128.6 µg m^{-3}) was observed as highest at Shongtong-Karcham under construction stage. Water turbidity was not within desirable limit of 10 NTU (Indian Standard Specifications for drinking water IS:10500, 1983) and was not fit for human consumption. Soil nitrogen was low (112-224 kg ha^{-1}), phosphorus was medium (11-25 kg ha^{-1}) and potassium was high (281-467 kg ha^{-1}) in adjacent areas of HEPs in the Sutlej basin.
- Within a span of two and half decades in the small hydropower projects affected regions, snow/glaciers area (11.67%), and evergreen forest (0.18%) found a decrease. During twenty five years, barren/wasteland showed an increase 11.25%, agricultural land 0.28%, water bodies 0.25%, grass/grazing land 0.11%, built-up area 0.73% and erosion/landslides area 0.05%. Vulnerability assessment within a selected buffer (10 km) in the Satluj basin showed the three risk zones (high, moderate and low).
- Temperature is continuously increasing indicating maximum 14.37 ^{0}C and minimum 11.58 ^{0}C with a mean 12.69±12.69 ^{0}C. The basin temperature has been increasing at the rate of 0.1099^{0}C/year. The glacier area in 1980 was 1688 km^2, whereas, 913 km^2 area was left only in 2016.A total of 45.9% (775 km^2) snow surface area was reduced after 1980 time period.
- The maximum number (35) of hydroelectric projects lie in the middle and upper zones within buffer area (10 km) of 3934 km^2 of the total 7514 km^2 of the Sutlej basin. Determining rational number of hydroelectric projects in a basin based on carrying capacity, aerial inter-distance of 3 km radius for small, 5 km radius for medium, and 7 km radius for large projects would be sustainable; 18 projects out of total 38 did not follow this criterion in the Sutlej basin. Otherwise only 20 projects could be possible to construct in a sustainable way.
- During this reporting period, 4 training programmes and 1 brainstorming workshop were conducted. 100% respondents perceived at Reckong Peo that orchards are more affected by HEPs development. About 89% respondents perceived crops and agricultural land are affected by HEPs. Upon asking inter-distance of the projects from one project to other, about 71% respondents agreed to maitain 5 km inter-distance between two small HEPs and about 78% respondents for large HEPs agreed more than 7 to 8 km inter-distance.

- Brainstorming Workshop on SEA of HEPs held on 15 March 2017 suggested that policy guidelines need to be formulated regarding cumulative EIA or SEA based on carrying capacity of the basin. Extensive study needs to be done on glacier retreat using higher resolution data. Pre- and post- monitoring of pollution level of the proposed hydropower projects is required to be done.

Ranganadi Basin, Arunachal Pradesh

- The study is mainly focused on downstream impacts and the policy issues of the River basins of Ranganadi and Dikrong in the northeastern Indian Himalayan region. The land use change study reveals that moderate dense forest reduced by 13% in the Ranganadi basin, whereas the open forest increased by 17%. The land requirement per MW forest for Arunachal Pradesh was estimated to be 1.13 ha, whereas it is 14.69 ha for Manipur.
- Ambient air quality monitoring was carried out in 5 sites during winter season in the study area. The highest concentration of PM_{10} 66 µg m^{-3} was observed during winter season. Water quality, based on 7 upslope and downslope sites of the River Ranganadi, showed pH between 6 - 6.78 during pre-monsoon period and TDS from 0.12 mg l^{-1} to 1.12 mg l^{-1}. Other water quality assessment parameters such as alkalinity, total hardness, chloride, calcium and DO of the River Ranganadi were within the desirable limit. Soil samples were collected from upstream and downstream of dam site, powerhouse area and catchment, and showed total nitrogen from 0.14% to 0.31%, sodium from 0.04% to 0.13%, and potassium from 0.79% to 0.99%. Soil of the Ranganadi basin is slightly acidic mainly due to prevalent practice of shifting cultivation (*Jhum*).
- Arunachal Pradesh falls under Zone 'V' and is the most vulnerable part. A total of 137 major (>4.9) earthquake events occurred from 1927 to 2006. Among them 1927 (6.0 magnitude of Richter Scale), 1932 (7.0), 1939 (6.1), 1943 (7.4), 1988 (6.6) and 2000 (6.1) experienced the most devastating tremors. Based on 53 years (1897-1950) record, 4 major earthquakes exceeding 8 magnitudes occurred in the Himalayan Region. So there is a need for the well planned development of hydropower projects.
- Based on EIA reports, development of 23 HEPs will affect 32 rare, endangered, threatened (RET) and 10 endemic plant species of Arunachal Pradesh. It is also noticed that poor documentation of floral diversity was conducted in some HEPs, *viz.*, Tagurshit (recorded only 33 plant spp.) followed by Nafra (44 spp.) and Papu valley (55 spp.).
- In view of upcoming development of hydropower projects in the Himalayan region, the following suggestions and mitigation measures are proposed. These were: (i) basin wise strategic hydropower development planning, (ii) comprehensive biodiversity impact assessment study, (iii) biodiversity consideration during selection of hydropower project sites, (iv) compensation for biodiversity losses, (v) ensure uninterrupted environmental flow, (vi) integrated biodiversity conservation plan development and implementation, (vii) effective biodiversity monitoring, and (viii) strict enforcement of environmental and biodiversity conservation laws and measures.

Summary of Completed Project/Activity

Black Carbon and other Aerosols loading, and their impact on melting of the Parbati Glacier in the northwestern Himalaya, India (2013-16, DST, New Delhi)

The Parbati Glacier is located between 31^0 45'- 31^0 49' N latitude and 77^0 45'- 77^0 51' E longitude in the upper Beas Valley and falls under the Lesser Himalayan sub-humid belt of the western Himalaya. The Beas valley ranges from 1000-3978 m and is located between $31^0$38'N latitude and $77^0$60'E longitude. The Parbati Glacier is the source of the River Parbati along which two macro hydro projects in a run of the river scheme are under construction/commisioned. The Parbati HEP-II (800 MW) and Parbati HEP-III (250 MW) have their dam sites at Barsheni (2195 m) and Siund (1312 m) respectively. With the economic benefits of the present selected Parbati glacier, it also supports a rich biodiversity and represents unique micro-climatic characteristics. The primary focus of the field observations at Parbati Glacier were: (i) to observe the role of Black carbon (BC) and other aerosols on the Parbati Glacier environment, and (ii) to analyze snow and ice chemistry of the Parbati Glacier.

- Measurements of BC, aerosol optical depth (AOD) and ionic chemistry of the snow were carried out over the Parbati Glacier. The results showed BC and other aerosol loading over the Parbati Glacier is largely influenced by anthropogenic aerosols at local level and long-range transport through air masses at regional level. The concentration of aerosol loading exists due to fine particle laden air masses coming to this region far from the western desert regions. The highest and minimum mean value of daily BC was observed 0.69 µg m^{-3} on 9 September, 2015 and 0.17 µg m^{-3} on 31 August, 2015 respectively, while during 2016, the highest and minimum mean value of daily BC was observed 0.47 µg m^{-3} on 19 August and 0.07 µg m^{-3} on 5 September, 2016 respectively. The daily average concentration was 0.41 ±0.02 µg m^{-3} from August to September, 2015. Looking at the source contribution of the total BC at Parbati Glacier, biomass burning contributed about 13% and 19% during 2015 and 2016, respectively; other sources in the region include fossil fuel burning.
- The mean AOD value at 500 nm was observed to be 0.17±0.02. The mean AOD value at 500 nm in 2014 showed 0.1 increase in 2015 in the Parbati Glacier. However, minimum to maximum AOD value during 2015 ranged from 0.09 to 0.28, respectively. In the year 2014, mean AOD value remained 0.16 ± 0.01 ranging from 0.08 to 0.25 respectively.
- Among the ionic components, dominant anions were in an order of $Cl^- > F^- > SO_4^{2-} > NO_3^-$ which was similar to 2014. In case of cations, these were in 2015 in an order of $NH_4^+ > Na^+ > Mg^{2+} > K^+ > Li^+$ and in 2014 in an order of $Na^+ > NH_4^+ > Mg^{2+} > Li^+ > K^+$. The only transition metal Zn^{2+} was found in the Parbati Glacier.
- The analysis of satellite imageries shows that the snout of the Parbati Glacier is retreating 0.67 m yr^{-1} from 1962 to 2015. To find out the impact of these aerosols loading over the Parbati Glacier in future, it requires further continuous monitoring of aerosols. The results suggest that this study could be helpful in framing policies regarding reduction in aerosol emissions and getting control over the melting of the glaciers.

THEME

SOCIO-ECONOMIC DEVELOPMENT (SED)

Majority of the population in the Indian Himalayan region (IHR) sustains biomass-based economy. Such fundamental way of life has woven itself into numerous ecological and cultural tapestries, each in consonance with the ecological niche that it occupies. To address the issues of sustained livelihood and alleviation of poverty, it is vital to optimize the natural resource exploitation and farming systems productivity. The Socio-Economic Development (SED) theme addresses issues of sustainable development of the rural areas through identifying developmental bottlenecks, formulation of strategies for location-specific problem solving, demonstrating natural resource management and livelihood strategies and by providing inputs for policy formulation. The theme envisages to work on: i) develop resource planning and management strategies, ii) strengthen livelihood promotion strategies (on- and off-farm) through identification of innovative livelihood options, iii) minimize natural resource use by replicating best-management practices to see the efficacy of various developmental and R&D interventions for policy implications, and iv) develop 'Rural Enterprise Services' for socio-economic upliftment of Himalayan communities. The focus of the R&D projects being commenced under SED theme is to promote innovative livelihood options, sustainable tourism, entrepreneurship and self employment, document indigenous knowledge, and investigate socio-economic and socio-cultural implications of migration. The ultimate aim is to develop/suggest appropriate strategies for socio-economic development of smallholders and their farming systems, scaling up of innovative resources management practices by communities, strengthen ecotourism promotional activities, and scientific validation of traditions health care system. The projects undertaken in the reporting year and achievements are narrated in subsequent paragraphs.

Eco-tourism as a potential tool for biodiversity conservation and sustainable livelihood in Indian Himalayan Region (In house, 2012-2017)

IHR has long history of tourism, which evolved with pilgrimage to the shrines and religious places in the far-flung remote locations in pristine environments of Himalaya. In independent India, the hill towns established by the British during colonial times, developed into centers of climate based urban tourism and served towards spectacular growth of tourism. Later with the realizations of problems of conventional tourism and its trade-offs, and in wake of growing environmentalism and developmental paradigms, tourism got further diversified; the several low impact new variants such as - nature, adventure, rural, cultural, wildlife, and biodiversity, and fair/ festival/event based alternative tourism forms have gradually emerged. The rich cultural and biological diversity, the environmental ingredients, and the policy prerogatives of IHR states further helped in development growth of tourism. The eco-tourism, which is one of the most recent concepts in tourism, has built-in components of environmental conservation, community benefits, quality of touristic experience, and minimal negative impacts. Now-a-days, the concept is being promoted/ used as- an intervention to manage/ mitigate the negative impacts of mass-tourism, a model for transformation of low scale nature/ cultural tourism/ development of new tourism, and as an eco-friendly alternative to unsustainable/ exploitative resource use and management. The concept addresses a

host of concerns of ongoing tourism, and tends to promote a culture of eco-friendly responsible tourism. This project aims to study this potential of eco-tourism as an intervention tool for tourism management/ development, and as an alternative development substitution to destructive/ unsustainable natural resource management (NRM). Besides the seeking the conformance of such interventions/ modifications to eco-tourism's principles & goals, it also tends to address the concomitant issues of environmental/ biodiversity conservation, and the livelihood related benefits of local people/ communities. This is a multi-locational project being operated in four states of IHR, namely Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh.

Objectives

- To study the status of eco-tourism in terms of goals and impacts in select pockets across IHR.
- To document, assess and map potential eco-tourism sites 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 inventories 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

1. During the reporting year, the consolidation/ compilation of project work was initiated; synthesis of tourist inflow patterns to IHR and the region's tourism scenario was analysed for understanding of climate sensitivity and policy cues regarding eco-tourism interventions. The trends for IHR states and regions reveal that the states of Uttarakhand, Himachal Pradesh, and J&K account for nearly 94% of tourist inflow, and seven northeast states receive only 5-6% of IHR's inflow (Fig. 19a). Tourism in western Himalayan states suffers from the problem of inflow-overflow, and needs intervention for carrying capacity and impact management through product diversification by way of small scale eco-interventions, development of eco-tourism in suburban pockets, number restrictions, and suitable regulation measures. For Northeast states rich cultural and biological diversity, unspoiled environment, and indigenous knowledge of tribes, the eco-tourism can be ideal model for future tourism.

2. The climate induced disasters, as observed in 2013 in Uttarakhand and Himachal Pradesh, and in 2014 in J&K, resulted in a dip in tourist flow showing susceptibility of tourism to climate change. The clientele for different tourism forms in Uttarakhand suggested that the religious tourism cater to nearly 66% of total inflow, followed by urban commercial in Outer Himalaya (15.67%). The adventure of interior areas, which is more of eco-tourism in nature, exhibited very limited clientele (0.16% of total tourists' inflow) (Table 6). It clearly suggests that the tourism in outer fringes of IHR is less sensitive and most resilient to climatic events, and that of 'Mid Interior' is most sensitive and least resilient to such events. Therefore, under the climate change scenario the destinations in outer fringes would receive more inflow, resulting in enlargement of impacts, and hence would require more interventions for diffusion of inflow pressure from points/ resources of high tourist activity by way of eco-tourism in vicinity pockets/ local circuits. The tourism in interior IHR would require more efforts towards tourist safety, integration of disaster risk reduction in tourism planning, and regulated tourism.

Table 6. Participation, Climate Sensitivity & Resilience of Various Tourism Forms in Uttarakhand

Tourism Type	Clientele	Growth (2008-12)	Growth (2012-13)	Growth (2012-14)
Commercial Urban	15.10%	21.06%	-21.06%	3.14%
Nature-Mid Interior	2.14%	13.19%	- 18.45%	-6.35%
Relg-D-Interior	8.56%	4.74%	- 57.03%	-86.00%
Relg-Mid-Interior	7.81%	1.59%	- 83.79%	-82.40%
Adv-D-Interior	0.16%	1.36%	- 19.73%	-30.10%
Adv-Outer	3.78%	36.81%	- 46.09%	- 42.75%
Sacred Ganges				

3. The inflow patterns of selected eco-tourism sites, e.g. Fambonglho Bird Sanctuary (Sikkim) (Fig. 19b) and GHNP (H.P.) (Fig. 19c) reveal that at present such sites have very limited clientele. To increase their potential, such areas should be an integral part of tour packages for which due incentives and subsidies must be provided to concerned stakeholders.

4. In Uttarakhand, the modalities of eco-modification of nature tourism in Kausani, and religious tourism at Jageshwar were assessed by potential scoping, and analyses of strengths & impacts. The range-bound inflow patterns at Kausani, the rich forests, wide ranging income impacts of tourism in the town and adjoining places, shrines and places of scenic view in vicinity & trek-able distances can help in transformation of cohesive enterprising farming/ agri-community, and abundance of small scale enterprises/ marketable can help linking of existing tourism with agri/ rural tourism and its transformation to eco-tourism. In Garhwal area the possibilities of home stay activities in 10 villages in the periphery of Tehri dam was explored, and need for eco-tourism model villages was assessed.

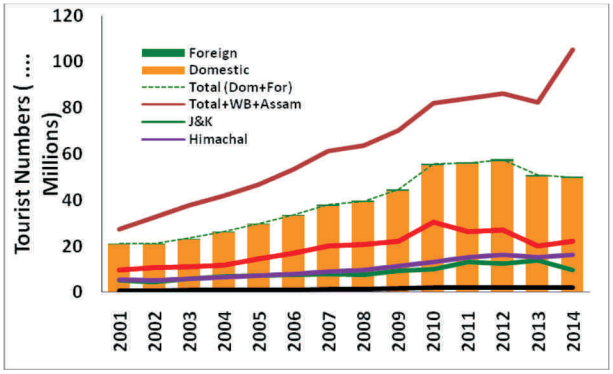


Fig 19a. Tourist inflow to IHR states & regions

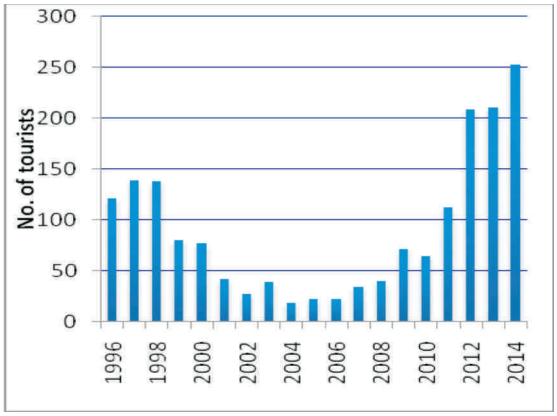


Fig 19b. Tourist inflow in Fambongloho, Sikkim

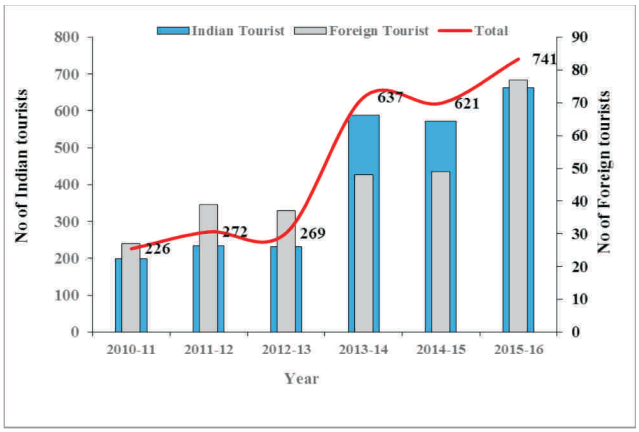
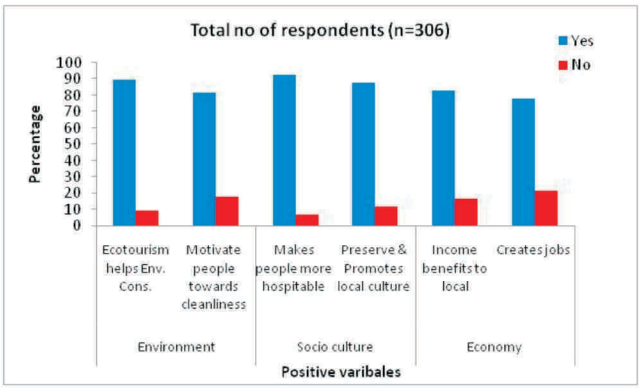
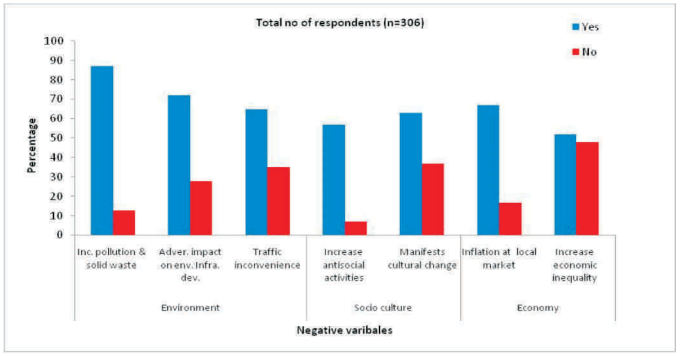


Fig. 19c. Tourist inflow in GHNP, Kullu, HP



(a) positive Impact



(b) Negative Impact

Fig. 20. Perceptions on (a) positive and (b) negative impacts of Tourism (Arunachal Pradesh)

5. In Himachal Pradesh net-working with State Forest Department, BTCA, Sunshine Adventures etc. was maintained and major stakeholders (BTCA, 185 nature guides & porters, 20 registered home stays, 12 trout fish farmers, 56 women groups, 437 beekeepers & 10 traditional potters were listed. Meeting and collaborative programmes on organic farming and skill development were conducted, and an area for organic farming in Tithan Valley was developed. Tourists and

stakeholders were interviewed for impacts, experience, etc.

Network Programme on Convergence of Traditional Knowledge System for Sustainable Development of Indian Himalaya (DST, 2015-2020)

The mountain population of IHR has been experiencing the multitude of undesired climate variability and extreme weather events, including change in the climatic conditions, viz., unpredictability in the timing and magnitude of rainfall, low or heavy precipitation, frequent occurrence of extreme heat during the summer season, glacial withdraw and melting snow that cut across both biophysical and social realms. These alteration have already been posing severe pressure on biodiversity, agriculture, water, human health and consequently on food security throughout the region. These factors will likely pose significant challenges on livelihoods of the indigenous community in near future owing to their dependence upon, and close relationship with the environment and its resources. Traditionally people in the region have lived in harmony with the nature and developed various traditional systems as part of their livelihood that sustained them for thousands of years. However, in recent times due to the factors such as increase in human population, low productivity of fragile mountain ecology and increased use of modern and/or unsustainable development practices, the Traditional Knowledge Systems (TKS) is eroding at a faster pace. It is now increasingly being felt that documentation of community knowledge regarding resource management can play key role in the conservation of resources and sustainable development of Himalayan communities. Unfortunately there is no single `Platform for Indigenous Knowledge Systems' in the Himalayan region' that integrates the rich ethics behind traditional knowledge to assist the formal decision support systems for sustainable development in the IHR. Therefore, the present Network Programme is being undertaken to attempt to converge TKS into decision support systems for sustainable development of the IHR.

Objectives

- Document, validate and analyze the IK (Indigenous Knowledge) in the IHR
- Create a digital library on TKS
- Understand linkages between TK and modern science (to identify promising TKS for improvement and adoption)
- Capacitate the institutions in the IHR to focus on TKS for sustainable development of local communities
- Formulate strategic framework for TK management in the face of Climate Change (CC)

Achievements

1. For documentation of traditional knowledge, three tribal communities of Arunachal Pradesh (*Aptani, Adi* and *Monpa*), one of Nagaland (*Ao*), three of Sikkim (Bhutia, Lepcha and Nepalese), non-tribal community in Uttarakhand, and nine tribal communities of Himachal Pradesh (*Gari, Todpa, Swangla*, *Tinnanba, Jecha* & *Malani, Laggal*, *Mandyal* and *Gaddi)* were selected for detailed investigation.

2. Documented indigenous land use, bioresource use and customary management for northeast communities. It was interesting to note for shifting cultivation Adi community use Patat system and community maintains 13-27 such plots in different villages. Each year one Patat is cleared for doing agricultural activities. *Monpa* tribe practice settled agriculture and they use large quantities of dry leaves of forest trees to apply in the agricultural fields to maintain soil fertility. For this Paisang *(Quercus sp.)* tree species was most preferred. At place farmers also use leaves of Roinangsing *(Pinus wallichiana)* and Lenthongsing *(Pinus roxburghii)* Both Adi and Monpa communities exhibited high dependence on wild plants and animal products, which are used as food, fodder, medicine, handicrafts, agricultural implements, house construction, religious rites & rituals, and a variety of other purposes. *Monpa* community use water mills *(Chuskor)* for grinding food grains.

3. In Sikkim a change in traditional land use pattern is being observed among Bhutia (5%), Nepali (10%) and Limboo (35%) and they are taking up animal husbandry, and cultivation of orange, large cardamom and kiwi fruits. TEK related to soil conservation and management practices is almost similar among all communities. Communities use 55 plant species for medicinal purpose, 22 as fodder, 19 in constructional purposes, and 12 in rituals. 60-90% households in different villages use various NTFPs.

4. In Uttarakhand the local community use a total of 70 plants belonging to 35 families and 63 genera for traditional healthcare. Of them 73% were herbs, 14% trees, 10% shrubs and 3% climbers. Root was the most commonly used plant part (28%) followed by leaf (21%), whole plant (16%), seed (14%), fruit (12%), Rhizome (4%), flower (3%), bulb and latex (1% each).

A total of 13 species used in the treatment of fever followed by stomach problem and cuts and wounds (12 species each), cough & cold (11species), diabetes and boils (4 species each). The community also uses a total of 104 landraces of cereals (47), millets (9), pseudo–cereals (5), pulses (10), vegetables (20), spices (7), oil yielding plants (5) and fibre crops (1) in Garur-Ganga and Saryu valley of district Bageshwar. Of them 47% landraces are still under cultivation under rainfed (29%), irrigated (8%), and under both (10%) conditions.

5. In cold desert of Himachal Pradesh (Spiti area), agriculture is the mainstay and communities use *kuhl* for irrigation and collect water from glacier/ rivers to villages. The *kuhl* often span long distances, running down precipitous mountain slopes and across crags and crevices; some *kuhls* are 10 km long, and have existed for centuries. *Dhara, Naula, Sheer,* as *jairu* or *bawdi* are traditional drinking water bodies; and at many places they are dying up due to the deforestation, mismanagement & climatic change.

6. Communities also use some local dishes, viz. in Sikkim they use *Gundruk, Sinki, Khalpi, Kinema*, *Jaanr and Raksi* at various occasions. In Uttarakhand *Bhatt ka fana, Bhatt ka Jaula* and *Rash-bhat* are some local dishes prepared from soybean (*Glycine max*). Similarly in Himachal Pradesh *some most preferred traditional dishes are Siddu, Seera, Sepubari, Churpy* (dry cheese), *tsasha (*preserve dry meat*), Marchu (*fried roties*)*. All communities use bamboo for various purposes (Fig. 21A-C), the houses exhibits local carving (Fig. 21D).

Fig. 21. A-B: Use of bamboo for house needs, making bridges (in NE region) and C: daily use items (H.P.), and D: house with local carving.

A sustainable approach for livelihood improvement by Integrated Natural Resource Management in the central Himalaya (NMHS, 2016-2019)

In IHR the foremost livelihood of rural people is mainly dependant on farming systems. Despite of rich indigenous wisdom to manage resources, the productivity of agricultural lands is low. Agriculture is largely characterized by traditional methods with high dependence on rainfall and forests that exhibits low productivity. The land holding size is too small, and per unit input cost is much higher than the output. Adverse climatic conditions (e.g. delayed monsoon, uneven rainfall) often reduce agriculture production ultimately affecting the livelihood of people. Such situation often compels people to migrate to towns and cities to find alternative livelihood options. There are, however, ample opportunities of increasing productivity of farming system by opting for crop diversification, switching over to cash crops, managing barren and wastelands, promoting organic production, strengthen post-harvest management, bring in market interventions, adoption of technologies, use of appropriate farm machinery, and promoting fodder and fruit cultivation and water harvesting, which can make farming system a profitable preposition. At the same time managing forest resources, which are integral part of local livelihood, could bring more remuneration. For example, Chir-pine is a dominant tree of mid-hills, which sheds heavy leaf-litter during summer months that is highly susceptible to forest fires. Use of dried chir-pine leaves for other productive use may bring new economic incentives to mountain communities, at the same time it can reduce risk of forest fire. Therefore, the present study aims to promote use of pine needles into useful product so as to provide communities additional income opportunity, strengthen natural resource management, and increase agricultural productivity of selected village clusters in Uttarakhand.

Objectives

- Manage natural resource sustainability in targeted villages by introducing innovative approaches and practical models by participatory management
- To extend technical help and packages for demonstrating of on-farm and off-farm activities for improving livelihood and environmental health
- Increase capacity of community for integrated and adaptive natural resource management at village level by developing knowledge and skills and strengthening local institutions
- Empower local community at, particularly women and weaker section, by promoting local governance

mechanisms that enable rural people to advocate for change that better their lives

- Create public awareness for implementation of integrated natural resource management strategies through enabling policy and institutional framework

Achievements

1. The study site falls in Hawalbagh Block of Almora District in Uttarakhand comprising a total of eight villages (viz. Gwala kot, Jyula, Tilour, Saknia Kot, Pitharar, Bhelgar, Darim Khola and Sakar) having 470 households with 1977 population. These villages have a total land area of 759.68 hectare, of which 26.27% land is under agriculture, 51% cultivated-waste and while 5.27% not suitable for cultivation. Over 60% of population of the area still depends on agriculture sector for livelihood and employment purposes. Majority of the cultivated land (79.2%) in the selected villages is under rainfed. A detailed assessment of socioeconomic status of the farmers of the study area has been undertaken before the project interventions.

2. Successfully demonstrated 9 technology packages at the project site. Participatory methods have been successful so far as many families (n=178) have adopted various on-farm technology.

3. Established 35 on-farm technology models include protected cultivation, integrated fish farming, cash crop cultivation, horticulture, vermi-composting, integrated poultry farming etc. in four village clusters (Fig. 22).

4. Developed 2.5 hectare of waste/abandoned land through horticulture (citrus spp.) and multipurpose tree (Tejpatta and fodder spp.) plantation.

5. In order to protect the surrounding pine forests of the study area, 62 families were successfully linked with the bio-briquetting. During winter months (Dec.-Feb.), these families have earned about Rs. 25000 through sale of bio-briquettes to Almora town. Use of pine needle for making bio-briquettes is providing double benefit, on one hand the stakeholders are generating income while on the other the pine forests are being conserved.

6. Capacity building of 164 persons (more than 85% women) has been done on various on-farm and off-farm technologies.

7. Establishment of chir-pine needle processing unit is in progress, equipments have been procured and under installation.

8. Strong linkages with the line departments (Horticulture, Agriculture, Forest, Livestock, Rural Development and District Administration) have been established to improve the livelihood through various government schemes in the farming & non farming sectors. Now stakeholders are quite aware about the developmental programmes of each line department. Various line departments are interested to extend support for livelihood enhancement; as a result many farmers are getting benefit of various government schemes.

Fig. 22. Various technologies transferred to the stakeholders

Standardization of Post Harvest Technology for Wild Rose Hips and promotion as sustainable livelihood option among poor self help women groups in Kullu Valley, Himachal Pradesh (DST, 2015-2018)

Wild Rose (*Rosa brunonii syn R. moschata;* family Rosaceae) grows wild in the degraded lands, near water resources, forest area and reverine habitat in and around the villages in Kullu Valley. It is a good fodder for goats and sheep, and most preferred forage for pollinators. It is currently considered of no economic value for communities and therefore, no collection or any processing has been undertaken by the people of the region. Kullu

district has a rural population of 92.08% with a sex ratio of 950 women per 1000 men (Census, 2011), as against the state average of 974. The 2011 Census puts the literacy rate for Kullu district at 79.40% with 87.39 % male literacy and 70.91% female literacy. According to 1994 statistics issued by Department of Rural Development, in Himachal Pradesh about 23% of total population of Kullu district lives below poverty line. Harsh climatic conditions and inaccessibility to basic services impose greater drudgery on poor households in meeting their livelihood needs. Even within the poor households the burden is much more on women because of the nature of their activity profile like, collecting fuelwood, fodder, grass cutting, grazing cattle, fetching water etc. Besides, using resources for own consumption, selling fuelwood, fodder, medicinal plants and sheep and goat rearing are main sources of income in the Valley. In spite of high value of the Wild Rose, its potential for economic development of local people has not been explored till date. The present project is focused on that approach so as to benefit local farmers, particularly poor village women.

Objectives

- To estimate composition and oil contents of rosehip and study altitudinal variation in content;
- To develop post harvest technology for collection and semi processing of rose hip;
- To form women Self Help Groups (SH Gs) and develop and test value added products like tea, oils and oil based personal care products;
- To promote sustainable harvesting practices and regeneration of rose plants in the collection area

Achievements

1. Eight Women Saving and Credit Groups (WSCGs) having a total of 103 women members were targeted in the study area and they were involved in the procurement of rosehip pods in different regions of the valley.

2. 3 trainings at village level for general awareness about the rosehips collection, regeneration practices and grading of rosehips seeds with different group members was done.

3. Rosehip seed shredder cum separator was developed for the decoding and separation of the pods with seeds. With the introduction of shredder, the rate of deseeding and the quality of kernels has improved considerably. As against the manual deshelling of roughly 3.5 kg per person per day (8 hrs) on ordinary pestle and mortar, the machine deseeds 200 kg per day. Procurement of the other minor equipments such as sealing machine, hot air gun, other storage containers, packaging materials (tea bags, dropper bottles, bottles packing boxes) has been done (Fig. 23).

Fig 23: a) Rosehip mint tea

b) Rosehip tea bag

c) Rosehip seed oil

4. Rosehip is a wild resource which is locally considered as a weed. The development of the niche value added product from the resource will add to the livelihood of local women. For the sustainable harvesting, collection, drying and development of the products from these rosehip species a protocol was developed. The protocol developed ensures the sustainability of the resources in long run.

5. Two types of tea were made i.e., plain Rosehip tea and an amalgamation of Rosehip and mint. The packaging of tea for further value addition and marketing is also done. Rose hip seeds were processed through supercritical CO_2 method for the oil yield from Proderna Biotech Pvt. Ltd, New Delhi. The current oil yield was 4.2%. The packing of rosehip seed oil is also done and ready for marketing through Mountain Bounties for its wider reach in the market.

6. Rosehip pods were analyzed for the antioxidant activities which shows percent scavenging activity as 84.01% 2,2-Diphenyl-1-Picrylhydrazyl (DPPH) at 517 nm, 0.32mmol Fe/ml Ferric Reducing Antioxidant Power (FRAP) at 593 nm and 79.93 % 2,2-Azinobis (3-ethylbenzthiazoline)- 6-Sulfonic acid (ABTS) at

734 nm. Similarly, Phenolic content at 650 nm was 26.98 mg/g fresh weight (FW), Flavanoid content at 420 nm was found 9.07 m/g FW and Ascorbic acid at 520nm was 0.025 mg/g dry weight (DW). Presence of fatty acids in the oil is considered to be have a high nutritional value. In the current rosehip species unsaturated fatty acids such as C16:0 Palmitic acid 5.56% and C18:0 Steric acid 3.18%, C18:1 Oleic acid 10.71%, C18:2 Linolenic acid 56.77% and C18:3n6, γ Linolenic acid 11.33% were observed which is much higher as compared to the many other species of rosehip reported.

7. Rosehip pods were purchased from the WSCGs @ 55/- per Kg for the product development process. A total of 2273 kg of rosehip pods worth 1,25,000/- were procured in the first year of the project. Till December 2016 approximately 1,80,000 were generated from the sale of the product developed.

Restoration of ecological balance in the degraded and fragile ecosystem through Development of Nanda Van at Almora (Inhouse, 2014-2018)

Throughout the Himalaya, growing wastelands and land degradation are among the serious problems. Land degradation means reduced productivity of land and the immediate result is the non-availability of food, fuel and fodder for the people living therein. Wastelands are formed due to indiscriminate and over utilization of forest produce standing over the area, unscientific land management by putting the area to improper land use and sometimes even as an unintended side effects of the very process of development. About 90 percent rural poor use common lands for fuel wood extraction and grazing their animals. A large portion of it is degraded due to overexploitation, which is greatly affecting ecosystem services. In view of high biotic pressure and erosion, the soil depth in such areas is very less with poor quality and low water holding capacity. The G.B. Pant National Institute of Himalayan Environment and Sustainable Development have been motivating the community for conservation and sustainable management of the degraded wastelands. Nanda van, located at Baldhoti in Almora, covering an area of 1.80 ha has been selected and given to the Institute for the above purposes by the Nagar Palika Almora in the Kumaun Himalaya (Uttarakhand). The altitude varies from 1600 to 1700 m and is being developed for eco-restoration of degraded and fragile ecosystem through MPTs. The species choice has been multipurpose including wild edibles for meeting the need of wild animals. This is a unique model under chir-pine trees.

Objectives

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

Achievements

1. A total of 1150 plants varying from 21 tree species (Banj, Utis, Tajpatta, Ritha, Mulberry, Phalyant, Bottle Brush, Sada Bahar, Bamboo, Padam, Deodar, Chinnar, Bedu, etc.) have been planted during July- August 2014 to improvise the degraded land condition. The area has been fenced to avoid biotic interferences. Nearly 20% of total species planted were wild edibles.

2. After two years the average survival of plants was recorded 80% at the highly degraded site whereas at the less degraded site it was 87%. Now the women from surrounding areas are collecting fodder grasses from the site.

3. Three water harvesting polyponds have been constructed at the site to fulfill the water demand of the plantation (Fig. 24).

4. Awareness meetings and regular maintenance of site and species planted is being done and soil nutrient status was also estimated (Table 7).

Table 7. Soil condition of Nanda Van

	Parameter	Soil Depth	
		0-30 cm	31-60 cm
1	Soil pH	5.23	5.36
2	Soil moisture (%)	13.97	15.53
3	Water holding capacity (%)	33.56	31.12
4	Organic carbon (%)	2.50	2.29
5	Total Nitrogen (%)	0.83	0.72
6-	Total Phosphorus (%)	0.93	1.04
7-	Total Potassium (%)	17.52	19.03

Establishment of Rural Bio-Resource Complex for Ecologically sustainable utilization for the Economic Empowerment of Himalayan region community (DBT, 2016-2019)

The Indian Himalayan mountains are amongst the most fragile and complex ecosystems in the world. In these

Fig. 24. Development of Nanda Van at Baldhoti, Almora

mountain ranges majority of population is engaged in agricultural and allied activities, from which they are neither able to generate economic surplus nor to find off-farm employment opportunities. Over 70% workers, and 85% of the women workers are involved in land based or agriculture activities. The mountain people face a range of socio-economic and environmental problems for enhancing livelihood. They live in geographical isolation under ecologically sensitive and economically constrained conditions. 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 mountain context. All these conditions force the mountain people, particularly rural youth, to migrate and explore other options for livelihood in other parts of the country. The present project aims to develop a resource conservation and sustainable utilization model of natural resource management. In addition, capacity building of stakeholders and generation of year round employment opportunities are being promoted. Attainment of livelihood security coupled with food, nutrition, energy and environmental security will ensure better quality of life on a sustained basis. This will be achieved by scientific interventions, skill development of the human resource and strengthening of local institutions, etc.

Objectives

- To promote use of biotechnological processes and tools for socio-economic upliftment of vulnerable community in mountain areas.
- To source and standardized technology related to mountain from different institutions with establishment of viable models of rural bio-resource complexes/hubs and rural technological innovation and application centre.
- To create entrepreneurship development among the community and youth and dissemination centre to be linked with the Science communicators for propagating awareness on technological know-how on biotechnological interventions.

Achievements

1. Two technologies demonstration centres are being established, viz. (i) Rural Bio Resource Centre Shuklapur, Dehradun, by HESCO, and (ii) Bio

Resource Centre, Chaukhutiya, district Almora, by AMAN. Each centre will target 4 Blocks and 40 villages for community empowerment and capacity building. Local resources are being used to initiate enterprise in agriculture, vegetable cultivation and horticulture, post harvesting technologies, bio farm, bio-craft, health & nutrition, energy and biodiversity conservation with the technical support from various institution.

2. The role of G.B. Pant Institute of Himalayan Environment and Development (GBPIHED) is to extend technical support to establish and develop these centers. Besides, it would also organize specialized capacity building and training programmes through Rural Technology Complex (RTC) of the Institute to benefit target groups.

3. So far a total of six training-cum-awareness programmes have been organized at the RTC of GBPIHED (Table 8). The beneficiaries were motivated and extended support for various interventions in agriculture and natural resource management sector, i.e. vegetable cultivation, organic farming, bio-briquetting, etc. To improve the productivity of the local horti-produces, low cost post harvesting and storage technology were demonstrated (Fig. 25).

Table 8. Training and awareness programmes organized

S.N.	Date	Place	Collaborating Organizations	No. of Trainees		
				Total	Male	Female
1.	02/09/2016	Basbheeda	AMAN, Almora	25	07	18
2.	03/09/2016	Dhanar	AMAN, Almora	68	03	65
3.	04/09/2016	Kheeda	AMAN, Almora	32	02	30
4.	22-23/09/2016	GBPIHED	HESCO & AMAN	16	09	07
5.	27/10/2016	GBPIHED	AMAN, Almora	28	10	18
6.	13/12/2016	GBPIHED	AMAN, Almora	33	10	23
Total				202	41	161

Enhancement of livelihood options based on locally available resources in disaster affected villages in Kedar valley of Uttarakhand (DST-SEED (TIME), New Delhi; 2016-2019)

Unprecedented rains (400 mm) for more than four days during mid-June 2013 resulted in flash floods followed by landslides at many places, killing more than 6000 pilgrims and tourists and destroyed many lodges/hotels, human settlements, thousands of hectares of agricultural and

Fig. 25. Various skill development programme at Rural Technology Center, Kosi, Almora

forest land. This natural disaster also has claimed the lives of many local living in the area (950). The peoples of upper Kedar valley are facing a range of socio-economic and environmental problems after flash flood (disaster) of June 2013 striving to cope up with food and livelihood security. Thus, in view of the above background, only location specific livelihood management plans can be useful instead of generalized and uniform action plan. Therefore, there is an urgent need to empower and develop the capacity and skills of these people in harnessing the potential of bio-resources available in the region through the application of simple, cost-effective technological interventions for diversification of land and bioresource based option for livelihood improvement for disaster affected areas. Participatory action research and on-site demonstration and dissemination to build the capabilities will facilitate to acquire knowledge of disaster affected local farmers which will provide them an opportunity to choose, test and start replicating/adopting some of these technologies according to availability of natural resources, their land capability and climate of the region.

Objectives

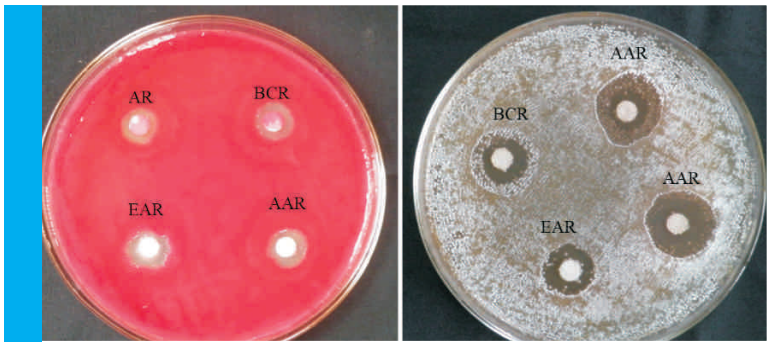
- Demonstration of cost-effective protected cultivation of promising high value off-seasonal and seasonal vegetables under protected condition (polyhouse/ shadenet house/polytunnels) through participatory approach.
- Demonstration through cultivation of selected high value low volume medicinal plant species and their integration with horticultural plants.
- Screening of potential multipurpose tree species based on ecological suitability and adaptability, economically valuable and socially acceptable for large scale restoration/ rehabilitation of flooded rural landscape of the region.
- Capacity building/skill development through training, live demonstrations/field exercise of disaster affected people on sustainable utilization and management of bio and land resources for livelihood improvement.

Achievements

1. Initiated work on nursery raising and yield production of high value-low volume economically important medicinal plants having conservation priorities e.g., *Valeriana wallichii*, *Inula racemosa*, *Picrorhiza kurooa* and *Saussurea costus* under different micro-climatic conditions (polyhouse, shade net and open condition) for large scale cultivation.
2. Developing demonstration model on integration of medicinal plants cultivation *(Picrorhiza kurooa, Saussurea costus, Valeriana wallichii* and *Inula racemosa*) together with horticultural system (apple, apricot, pears, walnut) as a potential option to increase per unit area production and income and may act as sustainable land use system particularly for high altitudinal region between 1600-2800 m where climatic conditions are favorable for such kind of intervention.
3. Initiated/screening and raising nursery of ten (10) multipurpose tree species (MPTs) (i.e. *Alnus neplenisis, Salix wallichiana, Betula alnoides, Morrus serrata, Litsea* spp., *Pyrus pashia*, *Quercus, Ficus auriculata, Grewia oppositifolia* etc.) for restoration/rehabilitation of flooded rural landscape in the valley.
4. Three training programmes have been organized between November 2016 to March 2017 through which 145 participants (60 women and 85 men) from 8 villages were provided training on different technologies, ie. Protected cultivation, followed by bio-prospecting of agro and wild bio-resources, including medicinal plant (MAP) cultivation as a source of income for user groups (farmers/villagers). Moreover, trainings on making a variety of value added edible products such as jam, squash, juice, sauce, pickle, etc. were also provided.

THEME

BIOTECHNOLOGICAL APPLICATIONS (BTA)



The 'Biotechnological applications theme' revolves around the identification, characterization and applications of the bioresources of Indian Himalayan Region (IHR), with particular reference to plants and microorganisms. Under plant sciences the propagation packages, mainly of medicinal and aromatic, plant species, have been developed through biotechnological interventions. Based on the active ingredient content of medicinal plants, elite clones are further being selected for bioprospecting and conservation aspects. Bioprospecting of IHR traditional knowledge for novel pharmaceuticals and nutraceuticals is currently one of the ongoing important activities of the theme.

For bioprospecting of microbial resources following lines of research are currently being pursued: Extremophiles (thermophiles and psychrophiles, in particualar), plant-microbe interactions, microbial enzymes of ecological and biotechnological relevance, biodegradation under low temperature environments, rhizosphere microbiology of ecologically and economically important species (such as *Rhododendron* spp., *Ginkgo biloba*, *Taxus baccata* and tea plantations), and plant based antimicrobials. A Microbial Culture Collection, representing the microorganisms of IHR, has been established. Accessioning of these microbial cultures as well as their sequences in IDAs and GenBank is one of the regular features in the ongoing activities with the objectives for (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 (in house, 2012-2017)

The microorganisms that thrive under extreme environments, from polar deserts to geothermal springs, are known as extremophiles. Such microbes contain enzymes (extremozymes) which function in extreme environments and have several biotechnological applications. The Himalayan region presents great variation, particularly in respect of topography as well as geographic and climatic conditions; this variation, in turn, supports a wide variety of habitats. Hot springs are manifestation of geothermal activity, provide niche habitat for a diversity of microorganisms, thermophiles in particular. The low temperature environments, such as the glaciers and cold deserts, provide excellent opportunity for studying the psychrophiles. The Microbiology Laboratory of the Institute has taken initiatives on various microbiological research aspects of IHR, covering a wide altitudinal range in last two decades. The focus of these studies has been on the isolation, characterization and the associated applications. A high altitude microbial culture collection, including extremophiles, has been developed in the laboratory over the years. One important issue, complementary to these studies, that requires attention is 'ecological resilience' possessed by these microorganisms. The present proposal was, thus, formulated to address these issues considering the characterization of extremophiles with particular reference to their biotechnological applications and ecological resilience. Plant biotechnology and plant-microbe interaction based studies with respect to use of cold tolerant microbial inoculants in plant growth and in bioremediation of heavy metals and estimation of chemical constituents including bioactive compounds of pharmaceutical as well as neutraceutical relevance were also planned in this project.

Objectives

- Phenotypic and genotypic characterization of extremophiles, inhabiting the extreme climatic regions in IHR (HQs), heavy metal contaminated sites (Kullu unit) and rhizosphere microorganisms (Sikkim).

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

Characterization of extremophiles

1. Fifty nine bacterial cultures, isolated from high altitudes in IHR, were characterized; the bacteria were represented by 10 bacterial genus with maximum species of *Bacillus* (15), followed by *Pseudomonas* (8), *Rhodococcus* and *Serratia* (3 each), *Lysinibacillus* (2), and *Alcaligenes*, *Arthrobacter*, *Carnobacterium*, *Microbacterium* and *Stenotrophomonas* (1 each). The bacterial species showed tolerance for wide range of temperature and pH with their optimum in mesophilic and neutral range, respectively.

2. A psychrotolerant, wide pH tolerant and halotolerant strain of *Pseudomonas chlororaphis* GBPI_507 (MCC2693) was investigated for its antimicrobial potential with particular reference to phenazine production and plant growth promoting traits. GBPI_507 showed phenazine production at the temperatures ranged from 14 to 25 ºC. The benzene extracted compound identified as phenazine-1-carboxylic acid through GC-MS exhibited antimicrobial properties against Gram positive bacteria and actinobacteria.

3. A psychrotolerant bacterial strain of *Serratia marcescens*, originally isolated from a glacial site in Indian Himalaya, was investigated for laccase production under different culture conditions. The bacterial strain was found to grow between 4 to 45 ºC (opt. 25 ºC) and 3 to 14 pH (opt. 5 pH) on prescribed growth medium, coinciding with production of laccase in laccase producing medium. However, the production of laccase was more consistent toward alkaline pH. Laccase enzyme was partially purified using gel filtration chromatography. The molecular mass of laccase was determined ~53 kDa on native PAGE. The Km and Vmax values were determined to be 0.10 mM and 50.00 µM min^{-1}, respectively with ABTS.

4. A newly isolated strain of *Pseudomonas proteolytica*, isolated from cold desert site in IHR, was investigated for the production of cold active lipase. The bacterium produced maximum lipase at 25 ºC followed by production at 15 ºC while utilizing olive, corn, as well as soybean oil as substrate in lipase production broth. Enzyme produced by bacteria was partially purified using ammonium sulphate fractionation. GBPI_Hb61 showed aggregation behaviour which was confirmed using several techniques including gel filtration chromatography, dynamic light scattering, and native PAGE (Fig. 26).

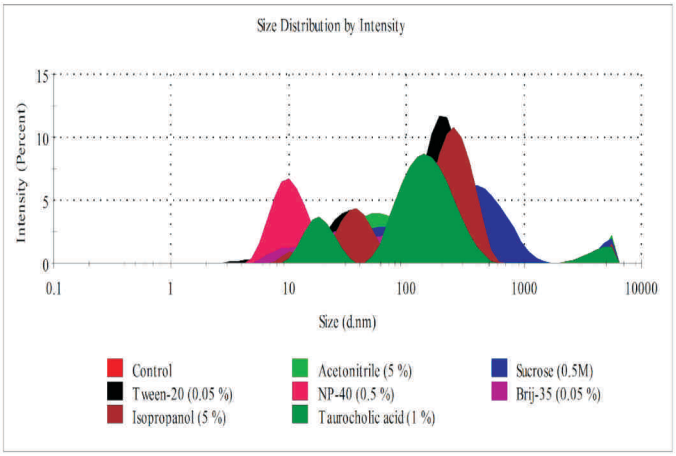


Fig. 26 Dynamic light scattering analysis of GBPI_Hb61 lipase for determining molecular size after several treatments

5. Four high value medicinal plants of the Sikkim Himalaya viz. *Astilbe rivularis*, *Artemesia vulgaris, Bergenia ciliata, Drymaria cordata* and *Eupatorium adenophorum* (invasive plant species) were investigated for the total phenolic and flavanoid content along with antimicrobial activity (Fig. 27). *Bergenia* extract exhibited effective antimicrobial activity, particularly against bacteria and actinomycetes. Identification and quantification of bergenin, catechin and gallic acid in *Bergenia* extract

has been done using High performance liquid chromatography. Considering high medicinal property of *B. ciliata*, *in-vitro* culture has been established using leaf disc explants.

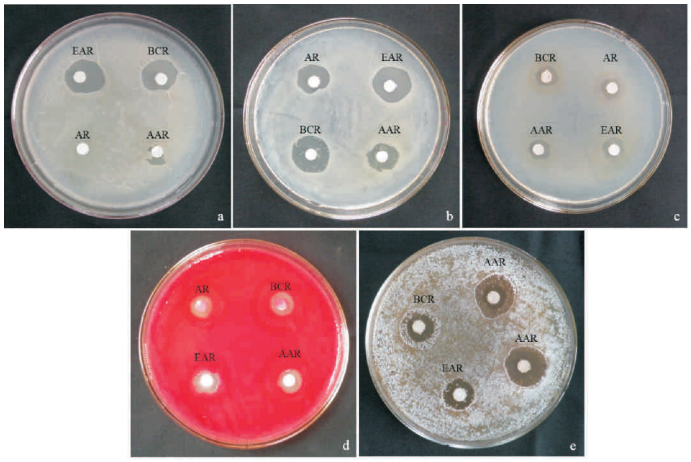


Fig. 27 Antimicrobial activity of different plant root methanolic extract in (a) *Bacillus megaterium*, (b) *B. subtilis*, (c) *Escherichia coli*, (d) *Serratia marcescens* and (e) *Streptomyces* sp. (BCR= *Bergenia ciliata* root; AR= *Artemesia* root; EAR= *Eupatorium adenophorum* root; *AAR= Astilbe rivularis* root)

Nutraceutical potential of wild edible plants of Sikkim Himalaya and their conservation through biotechnological interventions (DBT, 2014-2019)

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

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

Objectives

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

Achievements

1. To date, four wild edible fruits of Sikkim Himalaya viz. *Baccaurea sapida, Diploknema butyracea, Machilus edulis* and *Spondias axilaris* have been investigated for nutritional composition, antioxidant activity and bioactive compounds.

2. The moisture content of the fruits varied between 84.98% for *Baccaurea sapida* to 61.45% for *Diploknema butyracea.* The total sugar content of *Baccaurea sapida* was also found to be significantly higher than of other fruits.

3. The results obtained for the amount of lycopene, β carotene and ascorbic acid are depicted in Fig. 28. The results showed that the average ascorbic acid content and lycopene content varied from 287.65 to 447.17

mg/100 g edible portion and from 3.00 to 56.9 µg/100 g edible portion, respectively. The ascorbic acid and lycopene content of *Spondias axillaris* was higher than of other fruits evaluated. β carotene content was highest in *Machilus edulis* (468.39 µg/100 g edible portion) and lowest in *Baccaurea sapida* (27.6 µg/100 g edible portion).

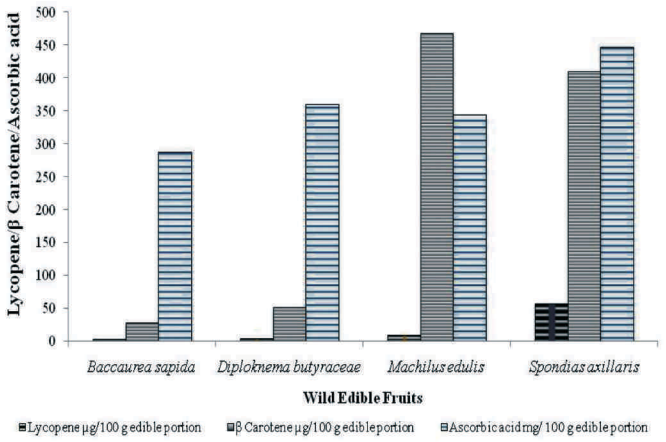


Fig. 28. Lycopene, β carotene and ascorbic acid content of wild edible fruits

6. Above mentioned fruits were also investigated for total phenolic content, total flavanoid content and antioxidant activity. Among different fruits, *Spondias axillaris* contained the highest amount of total phenolic compounds i.e. 341.99±4.00 mg GAE/g extract and showed maximum antioxidant activity in DPPH and ABTS assays (Fig. 29).

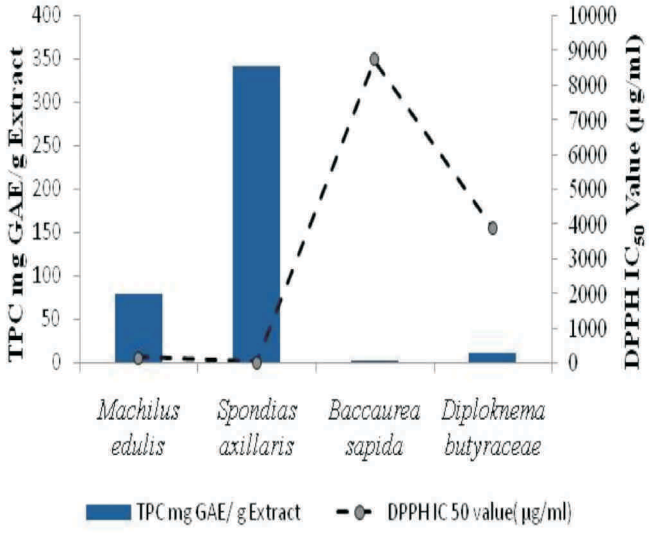


Fig. 29 Total phenolic content (TPC) and antioxidant activity of wild edible fruits

7. Mineral content in the fruit samples were analysed by atomic absorption spectrophotometric method. Results showed that *Spondias axillaris* contained the highest amount of Fe and Zn.

8. Attempts were also made for propagation and conservation of these wild edible species. Results suggest that the seeds of studied fruits could be germinated without pre-treatment, however, to attain higher germination percentage the seeds should be pre-treated with plant growth regulators. Gibberellic acid treatments found to be most effective.

Assessment of Molecular and biochemical diversity for conservation and effective utilization of *Roscoea* spp. in west Himalaya (DST-SERB, 2014-2017)

In terms of setting priorities for conservation, especially with regard to successful reintroduction of the populations in the wild, studies on genetic diversity are being increasingly used. Supporting evidences from several theoretical and empirical studies has established a positive relationship between genetic variation and fitness of plant species. In plants, genetic diversity within a species is often correlated with its geographical and ecological ranges. Among various factors, population size and habitat distribution greatly affect the level and distribution of genetic variation. According to population genetic theory, the populations: (i) that remain small for several generations (genetic drift), (ii) initiated from a small number of colonists (founder effect), or (iii) that suffer rapid decline in size (population bottleneck), are vulnerable to loss of genetic diversity. Such anticipated effects not only reduce the chances of population persistence but also have serious implications for the probability of species extinction. Understanding the genetic consequences of such changes in population structure and their effects on the conservation value are major research challenges. Likewise, biochemical traits are often used for evaluation of the plant genetic diversity. The biochemical traits are limited in number, modified by the environment and may be controlled by epistatic and pleiotropic gene effects. In spite of several limitations, morphological and biochemical traits have been successfully used for predicting genetic diversity of species. Analysis of biochemical parameters are most often results in evaluation of genotype – phenotype relationship and in accumulation of useful information for selection of desired combinations in further breeding studies. However, such studies on Himalayan plant species is meager in spite of the fact that information on genetic and biochemical traits are important for planning strategies for

conservation and sustainable utilization of any plant species, assume greater importance in case of rare, endangered and threatened species.

Objectives

- Understand patterns of morphological, genetic and biochemical variability within and among populations of selected species
- Determine the level of polymorphism within and among populations and between species using different molecular markers.
- Establish association of different molecular markers with morphological and biochemical traits.
- Develop detailed conservation and sustainable utilization plan of the species based on the results of objectives (i-iii).

Achievements

1. Significant variations were recorded among all studied morphological parameters among studied populations of *R. procera* using Analysis of variance by Duncan multiple range test. AGFW was significantly higher in Surkanda (13.26±0.38g) population while it was lower in Doonagiri (8.02±1.21g) population. Significantly higher AGDW was recorded in Jaberkhet (2.88±0.22g) and lowest in Mussoorie (1.24±0.20g). Similarly, BGFW was significantly higher in Lamgarha (12.11±0.43g) and lower in Mussoorie (3.44±0.30g) population. BGDW was significantly higher in Pandukholi (1.08±0.18g) and lower in Ranikhet (3.31±0.41g) populations. In case of plant height, significantly higher value was recorded in Surkanda (33.85±0.76 Cm) while it was minimum (14.00±0.67Cm) in the population from Mussoorie.

2. Among populations the total phenolic content varied from 2.11 mg (Ranikhet) to 3.58 mg (Mussoorie) gallic acid equivalent dry weight [(GAE/g dry plant material (dw). These values varied significantly ($p<0.01$) among different populations.

3. Gallic acid (72.02 mg/100 g dw) and catechin (12.05 mg/100 g) were found to be the major phenolic compounds and their level varied significantly ($p<0.01$) within populations while *p*-coumaric acid was detected in only a few populations.

4. Antioxidant activity determined by six different *in vitro* assays, i.e., 2, 2'- azinobis benzyl ethyl thiazole, 6- sulphonic acid (ABTS), 2, 2- diphenyl-1-picryylhydrazyl (DPPH), Ferric reducing antioxidant power (FRAP), NO scavenging assay, total antioxidant capacity and metal ion chelating assay exhibited antioxidant potential of the species.

5. No significant variations were recorded in leaf number, above ground dry weight, below ground fresh weight and rhizome length in case of *R. alpina*. However, AGFW was significantly higher in Tungnath (1.39±0.15g) population while it was lower in Maher Devi (0.83±0.08 g) population. Similarly, BGDW was significantly higher in Tungnath (0.53±0.08 g) population while it was lower in Mahar Devi (0.08±0.02 g) population. In case of plant height, significantly higher (9.56±0.45 Cm) value was found in Mahar Devi while lower (6.78±0.48 cm) value was recorded in Mapang population.

6. Genetic diversity analysis of *R. procera* collected from 11 different populations using ISSR markers is performed. Of the total 130 ISSR primers screened, only ten ISSR primers generated 94 clear and reproducible banding patterns of which 89 bands (94.68 %) were polymorphic. Based on the percentage of polymorphic loci (94.68 %), Nei's gene diversity (0.198) and Shannon's information index (0.329), high genetic diversity was detected at the species level. Genetic differentiation (G_{ST} = 0.202) was also recorded as moderate level due to high gene flow (Nm = 1.976) among populations.

7. Analysis of molecular variance (AMOVA) indicated that most of the genetic variation (90 %) resided within the populations (Φ_{ST} = 0.10). STRUCTURE analysis revealed two ancestral groups of the species, which were further supported by neighbour-joining cluster analysis. Among the different ecological habitats, high genetic diversity in populations under open grassy land showed suitability and preferred habitat conditions. High genetic diversity within population suggests *in situ* and *ex situ* conservation of selected populations for conserving and maintaining wide genetic pool of the species.

8. Using MRA, a number of ISSR markers with a statistically significant correlation (Either negative or positive) to different biochemical traits was detected. Two markers (OPA6-8 and OPA8-2) were found to be associated with total phenoloic content and three markers (OPA01-11, OPA6-8, and OPA6-2) was found to be associated with gallic acid.

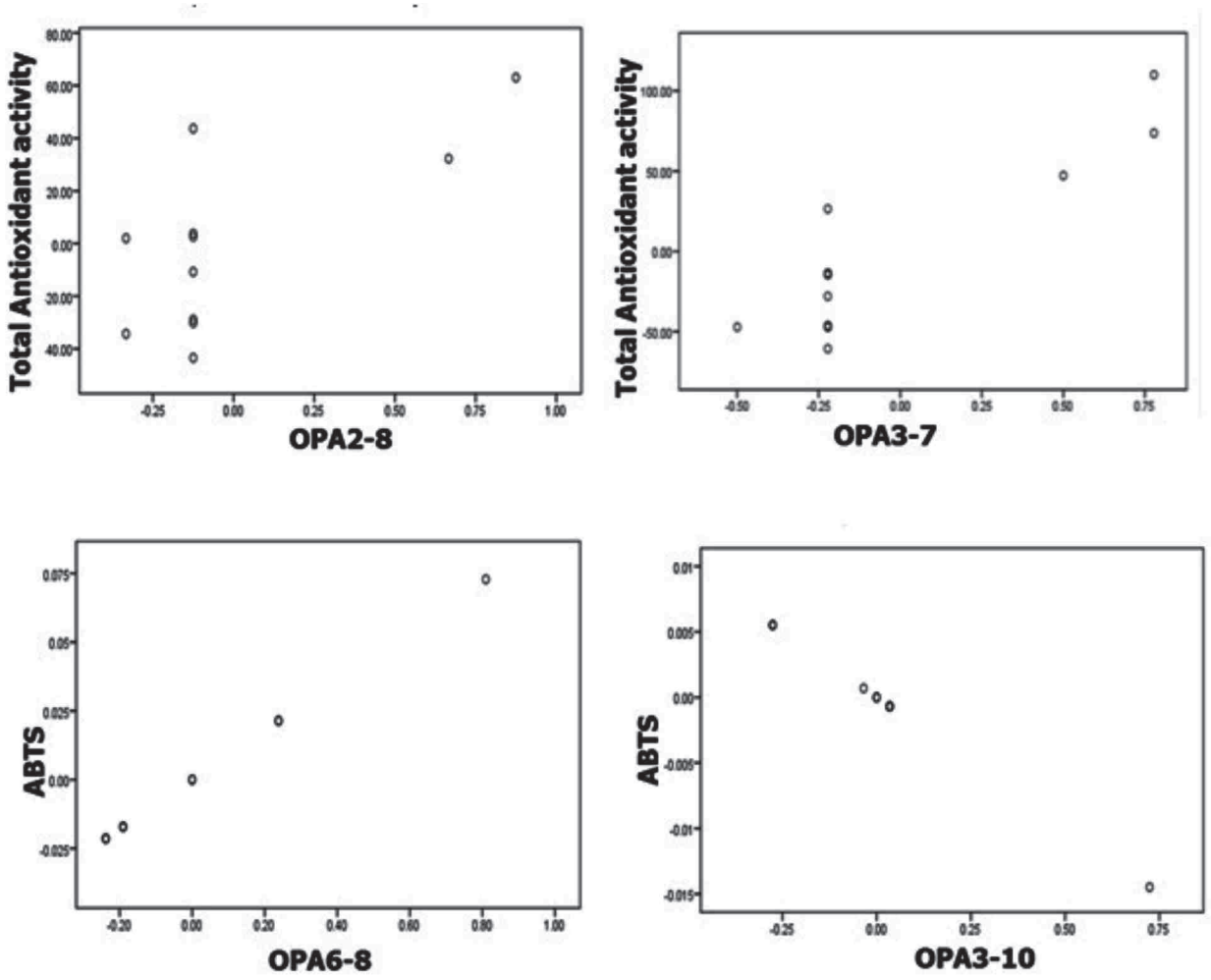


Fig. 30. Association of the molecular markers with the antioxidant activity measured by different assays

9. MRA revealed a total of 10 ISSR markers significantly associated with the antioxidant activity measured in all three assays. In the case of ABTS assay, 7 markers (OPA2-3, OPA3-10, OPA8-6, OPA9-4, OPA01-3, OPA6-8, OPA5-8), total antioxidant assay 2 markers (OPA4-7 and OPA2-8), NO inhibition assay single marker (OPA01-2) exhibited significant association with antioxidant activity (Fig. 30). Based on the above mentioned results conservation plan for both species is suggested.

Preventing extinction and improving conservation status of threatened plants through application of biotechnological tools (Sikkim Unit; DBT, 2012-2017)

Threat to the world biota is a modern-day problem ushered in by two major factors, namely, global industrialization and the expanding populations all over the world. Innumerable ramifications of these two factors represent the face of the resident evil which spells mortal threats to all life on Earth. Both of these factors are largely responsible for the gradual diminishing of biotic count through resource exploitation, habitat encroachment, chemicals and pollutants, and a variety of other reasons.

Sikkim Himalaya being a part of the designated Eastern Himalayan Hotspot region has its own share of threatened elements and most of it constitutes the plant species. A total of 54 plants have so far been classified as falling under various threatened categories (CR, E and V) of the IUCN conservation status. This figure has risen within the last decade when the threatened plants were 47 species. Recent survey on regional rhododendrons (total species =36) also reveals that 14 species fall under

threatened categories. This warrants a serious concern over the state of affairs in conservation aspect in the hills of Sikkim. Under the prevailing situation of increasing number of regional threatened plants, interventions have become outright mandatory to check species erosion and work for a meaningful conservation. It is under this state of affairs that the proposed project was envisioned, brain-stormed and proposed to save the plants through artificial regeneration, propagation and reintroduction in its natural habitat.

The proposed project is basically designed to work on the threatened status of 3 plants which are priority targets as of today and develop biotechnological approach models to save, multiply and reintroduce them in their respective atural habitats.

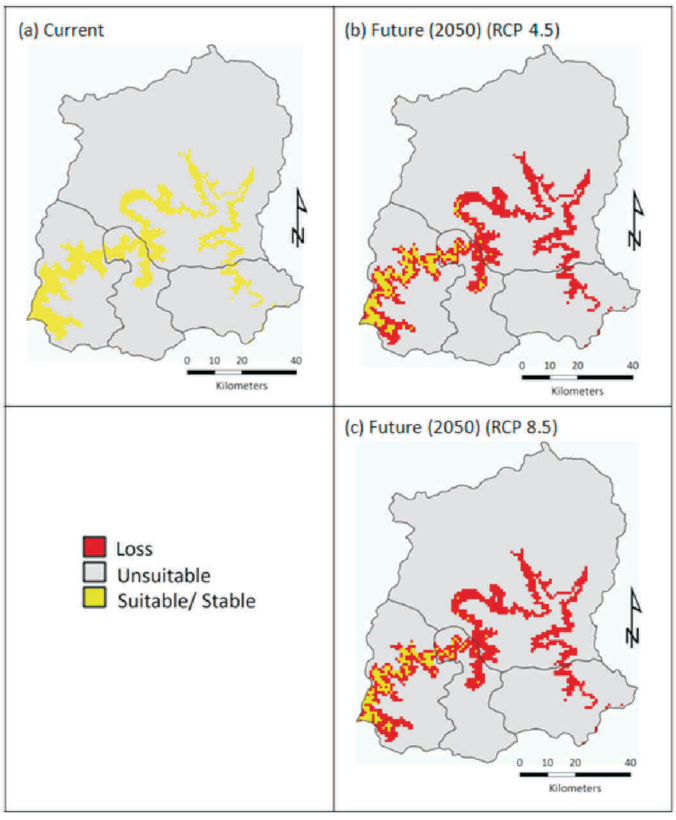


Fig. 31. (a), (b), (c) Predicted current (suitable and unsuitable) and future (suitable/stable, unsuitable, and loss) habitats for *Rhododendron micromeres*. Future predictions are based on two Representative Concentration Pathway (RCP) scenarios, RCPs 4.5 and 8.5 for the year 2050.

- The maximum entropy based (MaxEnt) Ecological Niche Modeling (ENM) technique was used to predict the potential suitable habitat for *Rhododendron micromeres*. The model performed better than random with an average test AUC value 0.931.
- The potential current distribution of *R. micromeres* was predicted by MaxEnt model (Fig. 31). Based on model predictions, about 890.30 km^2 (12.5%) of the studied area is currently suitable, and confined to mainly in central and southern parts of North Sikkim district, north-eastern parts of East Sikkim district, northern parts of South Sikkim district and central parts of West Sikkim district.
- Maxent model output collectively with field survey revealed that suitable habitats of the species concurred with the distribution of upper temperate mixed forest at altitudes ranges 2900 to 3100 m. These habitat areas would act as in-situ conservation area for the species and serve as highly suitable habitats for persistence and reintroduction of species in the wild.
- For sustaining the population of this climate sensitive species in Eastern Himalaya, large scale reintro-duction in suitable habitats is highly required. To achieve this, an efficient *in vitro* propagation technique was developed.
- Seeds of *R. micromeres* were collected from Tsokha, West Sikkim (27°43'06" N and 88°45'21" E) during October, 2014. Immediately after collection, capsules were dried at room temperature for 1 week, then stored in plastic bags at 4°C.
- Different culture media, viz. Murashige and Skoog media (MS), half concentration of Murashige and Skoog media (½ MS) and Anderson Media (AM) augmented with different combinations and concentrations of growth regulators were tested for developing propagation protocol for selected species of Rhododendron.
- The cotyledonary nodes that were obtained from six weeks old *in vitro* aseptic seedlings of *Rhododendron micromeres* were used as the explants for shoot multiplication. Among media tested, AM medium supplemented with 5 µM N^6-(2-isopentenyl) adenine (2-iP) induced maximum shoot multiplication (85%) after 6-7 weeks of culture. *Result showed that the* rate of shoot multiplication decreased simultaneously with increase in concentration of 2-iP and N^6-Benzylaminopurine (BAP).

THEME

ENVIRONMENTAL PHYSIOLOGY & BIOCHEMISTRY (EPB)

The thematic area 'Environmental Physiology & Biochemistry' is focusing on understanding the mechanism of plant adaptation to stress and monitoring physiological, biochemical or molecular aspects, which are extremely relevant for increasing productivity of plants. Developing propagation packages of different threatened and high value species for conservatin and sustainable utilization is another task of the teme. The theme focuses on to (i) identification and documentation of bioresources of applied value of IHR, (ii) generation of technological knowhow of the process development, and (iii) identification of mechanism of plant adaptation

Promoting conservation and sustainable utilization of Himalayan Biodiversity elements using biotechnological and physiological approaches (2012-17, In-house)

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

National Biodiversity Strategy and Action Plan (NBSAP) 2002 and Strategic Goals of the Aichi Biodiversity Targets also envisage improvement of status of biodiversity by safeguarding ecosystems, species and genetic diversity, enhancing the benefits to all from biodiversity and ecosystem services, and enhancing implementation through participatory planning, knowledge management and capacity building. Keeping in view the local, regional, national and global importance of ecologically and economically important biodiversity elements, the present study will be conducted on above lines in Himachal Pradesh, Uttarakhand and Sikkim in Indian Himalaya with a particular focus on the selected ecologically and economically important biodiversity elements. The project thus focuses on to (i) 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, (ii) evaluate the responses in different propagation systems of sensitive and high value biodiversity elements, use of biological material for hardening and genetic fidelity analysis of propagated plants in order to optimize the suitable methods for large scale production of quality plant material production, (iii) establishment of demonstration models, development of dissemination packages on cultivation and establish *ex situ* gene banks of elite planting materials, and (iv) inculcate

awareness among the diverse stakeholders about the potential benefits (including value added products) and benefit sharing mechanisms.

Objectives

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

Achievements

Results of physiological responses in *Valeriana jatamansi* revealed variation in photosynthesis activity among the different environmental conditions and photosynthetic active radiation (PAR). Maximum photosynthesis (5.98±0.97 µmol CO_2 $m^{-2}s^{-1}$) was observed at 1000 µmol $m^{-2}s^{-1}$ followed by at 2000, 1500 and 500 µmol $m^{-2}s^{-1}$. Among the various environmental conditions examined, maximum photosynthetic activity was observed under net house condition followed by polypit, glasshouse and mist chamber (Fig. 32). On the other hand minimum photosynthesis (3.28±0.23 µmol CO_2 $m^{-2}s^{-1}$) was observed at 1500 µmol $m^{-2}s^{-1}$ in a mist chamber.

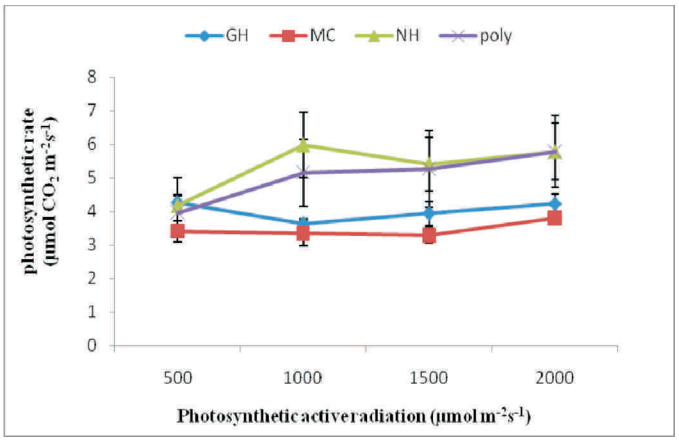


Fig. 32. Photosynthesis response of *Valeriana jatamansi* in different light and environmental conditions

1. Variation in total phenol, flavonoid, flavonol and tannin content among different species was observed (Table 8). Significantly ($p<0.05$) higher total phenolic content was recorded in *Polygonatum cirrhifolium* (8.74 mg GAE/g DW) followed by *P. verticillatum* (8.63 mg GAE/g DW) and minimum in *Roscoea procera* (1.16 mg GAE/g DW). Total tannin content was found significantly ($p<0.05$) higher in *R. procera* (4.88 mg TAE/g DW) followed by *Habenaria edgeworthii* (4.80 mg TAE/g DW) and minimum in *Malaxis acuminata* (1.69 mg TAE/g DW). Similarly, the highest flavonoid content was found in *R. procera* (5.31 mg QE/g DW) and minimum in *P. verticillatum* (1.26 mg QE/g DW); flavonol content ranged between 1.02 mg 1CE/g DW (*Lilium polyphyllum*) to 1.85 mg CE/g DW (*P. cirrhifolium*).

Table 8. Total phenol, tannin, flavonoid and flavonol content in different medicinal plants

Ashtvarga extracts	Phenol (mg/g)	Tannin (mg/g)	Flavonoid (mg/g)	Flavonol (mg/g)
Habenaria edgeworthii	6.42±0.01^{c}	4.80±0.02^{b}	2.29±0.01^{d}	1.68±0.01^{b}
H. intermedia	4.83±0.01^{d}	1.88±0.01^{g}	2.04±0.01^{e}	1.48±0.02^{d}
Malaxis acuminata	1.72±0.01^{g}	1.69±0.01^{h}	1.71±0.01^{f}	1.81±0.02a
M. muscifera	3.34±0.02^{f}	3.61±0.01^{d}	2.83±0.02^{b}	1.51±0.02^{d}
Polygonatum cirrhifolium	8.74±0.01^{a}	3.11±0.03^{e}	2.41±0.02^{c}	1.85±0.01^{a}
P. verticillatum	8.63±0.01^{b}	2.02±0.01^{f}	1.26±0.01^{h}	1.58±0.02^{c}
Lilium polyphyllum	4.26±0.03^{e}	3.68±0.021^{c}	2.79±0.02^{b}	1.02±0.02^{f}
Roscoea procera	1.16±0.02^{h}	4.88±0.02^{a}	5.31±0.01^{a}	1.40±0.01^{e}

Mean values followed by the same letter(s) in a column are not significantly different ($p < 0.05$) based on DMRT

3. A significant ($p<0.0005$) variation in germination percentage of *B. jaeschkeana* in different cold storage time period was observed. The highest germination percentage after one month of seed storage was 77% (3200 m) and 42% (3700 m). As the storage duration increases up to 4 months the germination percentage decreases up to 72% and 61%, respectively in the seeds collected from 3200 m and 3700 m populations. In case of *B. aristata,* a significant [2200 m ($p<0.005$); 2600 m ($p<0.05$)] variation in germination percentage among all durations of cold storage was observed. The highest germination percentage (53.35%) in the seeds collected from 2600 m population after two months of cold storage and 28% for 2200 m population without any storage was observed. As the cold storage duration increases from 0 to 4 months the germination percentage decreases more than 75% in the seeds collected from both the altitudes.

4. Storage time significantly affect the germination rate of *B. jaeschkeana* seeds, but in case of *B. aristata* only seed collected from 2600 m population showed significant ($p<0.05$) variation in germination rate. The germination rate of *B. jaeschkeana* seeds collected from 3200 m population recorded highest as 3.2 seeds/day after 2 months of cold storage, but rate was slow down up to 68% after 4 months of cold storage. *B. jaeschkeana* seeds collected from an altitude of 3700 m germinated at a rate of 1.4 seeds/day after 1 month of cold storage and reduced up to 71% after 4 months of storage. In case of *B. aristata*, seed collected from 2600 m population showed highest germination rate of 1.8 seeds/day after 1 month of cold storage, which slow down up to 50% after 4 months of cold storage for both the populations.

5. Plant growth regulators (PGRs) influenced the seeds germination and radicle length to different extent in the *Oroxylum indicum*. Among the tested PGRs, BAP was found to be highly effective to induce seed germination. At 50 µM BAP, only 50% seeds germinated, whereas at 100-200 µM concentrations it reached >70%. There was no significant ($p< 0.05$) difference in the percent germination from 100-200 µM BAP treatments, but BAP significantly influenced the development of radicle length with increasing concentration (Fig. 33). At 200 µM BAP, 76.4% seeds germinated with rudimentary roots.

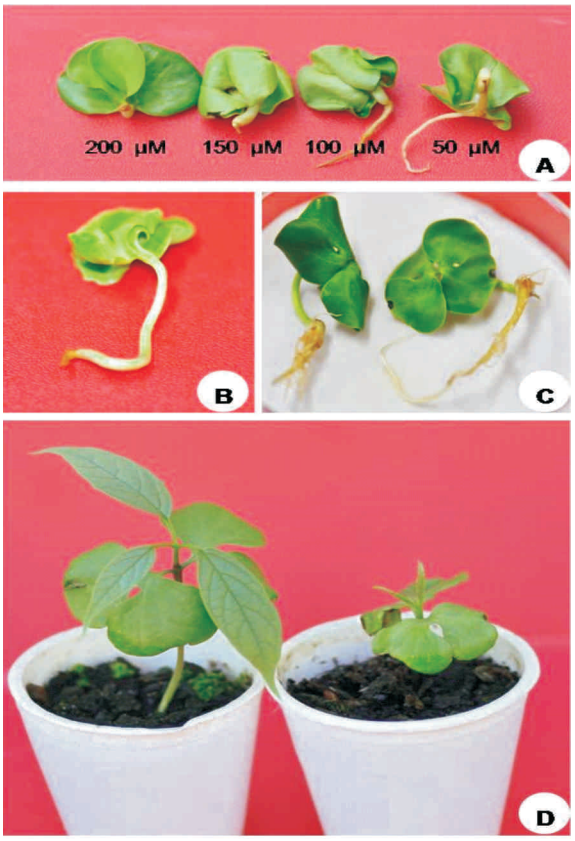


Fig. 33. (A) Three-week old BAP treated *Oroxylum indicum* seedlings showing decrease in radicle length with increase in BAP concentration. (B) *Oroxylum indicum* seedling (same seedlings as in A, depicting long hypocotyl and rudimentary root. (C) Three-week old cold water treated *Oroxylum indicum* seedlings having green leaves and well developed roots and root hair. (D) Cold pre-treated (left) and control (right) *Oroxylum indicum* plants after 9 weeks.

Nutritional status of traditional food of Uttarakhand utilized by scheduled community (2016-2019, DST-NRDMS)

Uttarakhand is a hill state, situated in central Himalaya and can be differentiated from other areas on the basis of topography, geographic features, flora and fauna, land use system and socioeconomic conditions. Due to this, lifestyle of the people residing here also differs from plain areas of the country. There are different types of traditional crops like cereals, millets, pulses, oilseeds; vegetables which have been grown in the region. But the people are taking less interest in their cultivation. That's why food insecurity exists in the region. Diversification of food recipes is a major specialty of the region. There are many

recipes used as substitute of items, which are meagerly produced in the region. The nutritional information of processing steps starting from raw materials to final recipes following different processing steps is not yet available. The present study will develop proper documentation of traditional food consumed by Scheduled communities residing in the selected areas of study along with their nutritional content, which will definitely give importance to the nutritious food consumed by the community. Carrying out the proposed scientific evaluation would help in objectively promoting the traditional recipes not only for better health but also for economic advancement of the large farming community in the state. These foods can also become a part of food consumed in other regions of the country. Requirement will increase the pressure on production of these crops which will directly increase the income of schedule communities along with other sections of the society over a large region.

Objectives

- Analyzing the traditional way of food processing of ethnic cuisines.
- Step by step nutritional analysis of traditional foods.
- Marketing of selected cuisines (having detailed nutritional status) in national forum.

Achievements

1. Checklist of parameters to be studied was finalized. Literature regarding nutritional quality assessment of the selected crops i.e *Echinochlora furmentacea* (Barnyard millet), *Vigna umbellate* (Ricebean), *Macrotyloma uniflorum* (Horse gram) and*Glycine max* (Black soyabean) has been collected.

2. To analyze the traditional way of food processing of ethnic cuisines six villages (Katarmal, Hawalbagh, Matela, Mahet Gaon, Dalim Khoal and Shiona) of Almora district were selected.

3. Preliminary meeting with the Gram Pradhan and Asha of the village was held to identify the total number of families who fall under the category of Schedule community. Out of the above-mentioned villages, Katarmal with around 35 families (i.e. n=35) has been surveyed till now.

4. The survey method was based on pre-developed questionnaire which was further broadly divided into two categories, i.e. one based on the personal information and the other based on the information related to their dietary aspects and the selected crops. Further, the main emphasis of the survey was to gather information related to collection of detailed procedure of the ethnic cuisines that are being prepared by the villagers.

Removal of pharmaceutical and personal care products (PPCPs) from contaminated water using pine needle based activated carbon/ biological activated carbon (2016-2019, DST-WTI)

Pharmaceuticals and personal care products (PPCPs) are widely detected in natural surface and ground water and have emerged as the environmental contamination with potentially widespread environmental effects. A wide range of PPCPs wide range has been detected in a variety of environmental samples at levels ranging from ng kg^{-1} up to g kg^{-1}. Over the past few years, there has been increasing awareness of the unintentional presence of PPCPs in various compartments of the aquatic environment (e.g. water, sediments and biota) at concentrations capable of causing detrimental effects to the aquatic organisms. This has become a major concern because PPCPs are extensively and increasingly used in human and veterinary medicine as well as in cosmetics resulting in their continuous release to the environment. There is an urgent need to develop technologies for removing these group of compounds from wastewater. The objective of the present project is to develop pine needle based activated and biological activated carbon having capacity to remove PPCPs from waste water. The four target compounds of our study are caffeine, bis- phenol-A, estriol and ibuprofen.

Objectives

- Preparation of activated carbon (AC) and biological activated carbon (BAC) using pine needles and microbes (in case of BAC)
- Estimation of AC/BAC efficiency for removal of detergent metabolites, plasticizers and pharmaceutical components from model feed system
- Regeneration studies of AC/BAC

Achievements

1. Activated carbon using pine needles are being developed using pine needles following different activation and carbonization methods. These prepared carbons have shown very high surface area equivalent to commercial activated carbon. Further characterization will tell more about these carbon samples.

2. Different Himalayan bacterial strains, provided by microbiology laboratory of GBPIHED Kosi-KatarmalAlmora, are being tested for estimating their capacity of degrading the selected PPCPs compounds along with their intermediate products. Initially growth conditions of microbes along with these PPCPs are being optimized at different pH, temperature, ppcp concentration etc.

3. Best bacterial strain/s which will tolerate all the conditions and still degrade PPCPs will be utilized for preparation of biological activated carbon.

Quality plants production and promotion of cultivation of selected Himalayan medicinal plants for livelihood enhancement (Uttarakhand council of Biotechnology 2016-2019)

The Indian Himalayan Region (IHR) is one of the major repositories of biodiversity and a home of large number of medicinally useful species. However, the increasing demand of medicinal plants coupled with harsh climatic conditions, slow growth rate and limited natural regeneration, a large number of species are declining. Moreover, increasing demand for medicinal plants in the pharmaceutical industries, there has been a large scale and uncontrolled collection from the wilds and in the absence of organized cultivation, pressure in their natural habitat is increasing. As a result, many of the plant species are found place in the list of different threatened category. In such circumstances, there is a need to develop approaches for conservation and sustainable utilization. In this context, mass propagation, field plantation, and demonstration for cultivation and conservation of medicinal plants will be a viable option. The proposed project is, therefore, planned to take up the following studies, a) germplasm collection from different ecozones, b) plant production using conventional and in vitro methods, c) quality assessment using phytochemical, pysiological and biochemical parameters d) establishment of demonstration sites at different locations, e) development of agrotechnology practices, f) initiate attempt to commercial cultivation, and g) training and distribution of planting material to farmers. The selected species are valued for their medicinal properties and used since the early times. At present these species have high commercial importance, as they are constituents of modern pharmaceutical formulations.

Objectives

- Mass multiplication and quality plant production of target species
- Quality assessment of the propagules using phytochemical, physiological and biochemical parameters
- Imparting training and distribution of planting material to farmers and interested persons
- Field plantation and establishment of demonstration plots at different Himalayan locations

Achievements

1. Standardized explant establishment, medium type and plant growth regulator concentration in *Valeriana jatamansi.* Optimized shoot multiplication and rooting and standardized acclimatization and hardening process.
2. Production of around 5000 tissue culture raised plants of *V. jatamansi* and data on morphological attributes, e.g., leaf shape, size, plant height, root length, rhizome diameter, etc. were recorded.

3. Physiological responses, i.e., photosynthetic rate, water use efficiency, stomatal conductance, transpiration rate, etc. were initiated in tissue culture raised plants at different environmental conditions (Glass house, shade house, mist chamber, and open nursery) using standard methods.

4. Phytochemical attributes like, total phenols, flavonoids, tannins and antioxidant activities were analysed using standard methodologies in tissue culture raised plants.

5. Survey in 9 villages of Chaudas valley was conducted and meetings with different households were organized.

6. People's perception on cultivation of medicinal plants was obtained and number of households interested in cultivation of target species was identified.

NMSHE Task Force (3): Forest Resources and Plant Biodiversity (2014-19 DST, Govt. of India)

The National Action Plan on Climate Change (NAPCC), which includes a comprehensive set of mitigation and adaptation measures, aims to promote India's development objectives while yielding co-benefits for addressing climate change effectively. The NAPCC, among others, recognizes the Himalayan ecosystem as vital for preserving the ecological security of the country. Also, it underlines intense vulnerability of this ecosystem towards both anthropogenic and environmental

perturbations. With this realization, NAPCC sets out 'Sustaining the Himalayan Ecosystem' (NMSHE) as one and the only area-specific missions among the eight National Missions. This mission envisages measures for sustaining and safeguarding the glaciers and mountain ecosystems. Considering the relevance of mandate, G. B. Pant Institute of Himalayan Environment & Development (GBPIHED) has been identified as coordinating institution for Task force 3: Forest Resources and Plant Biodiversity. The project covers three major aspects on Mission Approach – (a) enhanced monitoring through observational and monitoring network, (b) promoting community based management, and (c) strengthening regional cooperation

Objectives

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

Achievements

1. List of 616 tree species (604 angiosperms and 12 gymnosperms) of Trans, North Western and Western Himalaya was prepared. Of these, 538 tree species of angiosperms were listed from Uttarakhand, 323 tree species from Himachal Pradesh and 280 tree species from Jammu & Kashmir. Further, list of 4035 species of economically important plants of Jammu & Kashmir (2571), Himachal Pradesh (2349) and Uttarakhand (3390) has been prepared and database being developed.

2. Tree diversity of Western Himalaya has been published as a book that includes an inventory of 490 tree species, of these 372 species are represented in wild and 118 as cultivated.

3. In Western Himalaya, towards understanding the wild tree species diversity along the altitudinal range, distribution of trees in the six altitudinal belts (<1000, 1001-1500, 1501-2000, 2001-2500, 2501-3000, >3000) was analyzed. The altitudinal patterns of tree species, exhibits a continuous trend of decline in number from low altitude zone (< 1000 m asl) to highest altitude zone (> 3000 m asl). Of the total (i.e., 372 species), over 66.6% tree species are represented in <1000 m altitude zone, whereas only 4.30% (17 species) were present in zone >3000 m altitude.

4. Database of threatened plants of IHR from IUCN list was prepared. Of the total 456 threatened species listed, 13 (2.7%) species were Critically Endangered (CR), 27 (6%) species were Endangered (EN), 8 (1.9%) species were Near Threatened (NT), 23 (5%) species Vulnerable (VU), 356 (78%) species Least Concern (LC) and 28 (6.1%) species Data Deficient (DD). As per IUCN database, 01 specie (0.2%) *Sterculia khasiana* Deb. was extinct.

5. Representative Long Term Ecological Monitoring (LTEM) sites has been established (06) for intensive long term monitoring in Byans valley of Kali river catchment and Hat Kalika Watershed, East Ramganaga catchment of Pithoragarh district, Uttarakhand (Western Himalaya) representing sub-tropical, temperate and sub-alpine (timberline) zones.

6. Long-term monitoring criteria and indicators for forest ecosystem w.r.t. climate change have been identified.

7. In addition, anthropogenic factors such as tree lopping, number of head loads (firewood, leaf-fodder), livestock population, fire events, impact of ban on tree cutting, LPG gas consumption, free grazing, etc. also considered for decoupling the impact of climate change.

8. Rapid vegetation sampling in campaign mode was completed in Byans, Darma, Chaudas and Johar valley of Pithoragarh, Uttarakhand to see the forest structure, composition and regeneration status of different forest types.

9. Chronology of ring width in relation to precipitation and temperature was developed for indicator species *Cedrus deodara* and *Pinus roxburghii* in Gangolihat area of Western Himalaya. Studies w.r.t. other selected species (*Pinus wallichiana, Abies pindrow* and *Betula utilis*) have been initiated.

10. It has been found that tree ring width has positive relationship with precipitation of previous year of October to current year of May while other months June and July of current year have negative correlation with precipitation. The only significant positive relationship between tree ring width and precipitation

was found for current year of March (r=0.34, p=0.018) and April (r=0.33, p=0.02).

11. The SEIB-DGVM model was identified to simulate vegetation dynamics of certain forest type. The model climate input parameters on a daily scale are generated for the period of 2014 for a Pine dominated forest by combining meteorological observations at the site and using climate data of CRU TS3.22, Exeter University interpolated data. The number Plant Functional Type (PFTs) of the vegetation for a 30 m x 30 m grid was found to be 21 and classified amongst 7 model phenology types and life types. Amongst 21 PFTs, 11 number of PFTs were found to be under the category of temperate deciduous with 8 PFTs under evergreen category and 1 PFT each under C3 and C4 grass category. Model simulations and validations are under process.

12. For reconstruction of climate, linear regression model was developed for mean relative humidity of February to April months for which a significant positive relationship was observed. To verify transfer function model, the reduction of error (RE), product mean (t), coefficient of efficiency (CE) and sign test (S1,S2) was used. To test the agreement between observed and reconstructed data at high frequency and low frequency variations, S1 and S2 were used. Thus, based on tree growth and climate relationship (i.e. between tree ring width and mean February-April relative humidity), a transfer function model is developed which will be used for reconstruction of past climate.

13. People's perception on climate change and climate change impact has been analysed in the different parts of IHR i.e. Byans, Darma, Chaudas, Johar (UK), Sutlej valley (Himachal Pradesh), Zuluk, Rumtek, Sadam-Melli and Mamlay watershed (Sikkim), East Siang, West Siang and Upper Siang (Arunachal Pradesh). The majority of respondents agreed that during recent decades there have been many changes in the climate and they cited various examples and indicators i.e. increase in temperature, warmer summer, winters are getting warmer, erratic rainfall, low snowfall, water springs are drying up, declined crop yield, change in phenology, increase in invasion, higher incidents of cloudburst etc.

14. Documentation and validation of adaptations to cope up with climate change by different community of IHR have been carried out throughout the IHR.

15. National Workshop on 'Forest Resources and Plant Biodiversity' has been organized between November 16-18, 2016 with major objective to validate, refine and finalize the common methodology, and to identify and discuss various thematic gap areas this task force. In total the workshop was attended by over 120 participants representing 18 Institutes and universities all across the country.

16. Prioritization matrix was attempted on the basis of the selected indictors/parameters such as climate indicators, hazards, anthropogenic and biological indicators to know climate change impacts and to identify vulnerable indicators on the basis of ranking.

17. Climate as vulnerability indicator included the two parameters: temperature and precipitation. During survey, respondents told that snowfall has reduced within a gap of few years and precipitation has increased in the areas once experiencing snowfall. These have become the major cause of forest degradation in terms of landslides, sheet erosion and floods. The highest rank by respondents was given to precipitation (2.84), followed by temperature (1.76) It was made clear that overall average maximum temperature (4.07°C) and average minimum temperature (-7.87° C) were recorded during a period of 34 years. The average precipitation increase (2.04 mm) was recorded from 1979 to 2013.

18. The study area is topographically fragile and is prone to numerous hazards, namely, landslides, flash floods, cloudbursts, snow avalanches, drought, soil erosion and earthquakes. Based on respondents as well as our field observation, 'landslide' is a major hazard and cause maximum disasters to the forest and the human resources. Mass-movement ranked as the highest 1st (6.69) by people. It was made clear from the visual interpretation of satellite data that the Kinnaur division witnessed about 2.09 km^2 forest area severely affected by landslides along the Sutlej valley particularly from Khab to Rampur. Flash flood was ranked 2nd (5.49) by people. GIS analysis showed that in Kinnaur division, about 111.63 km^2 area of forest was found under the flood risk. While in Rampur division, 67.72 km^2 area was found under the high risk of vulnerability to forest land. Soil erosion was ranked as 3rd (4.92) by the respondents followed by cloudburst as 4th (4.00). Respondents believed that forest loss was also due to snow avalanches ranked by people as 5th (3.9). The losses due to earthquakes stood to be at 6th rank (1.94) and drought 7th (1.06).

19. Respondents highlighted anthropogenic pressure in the forest division of Kinnaur. Under the anthropogenic factors, eight parameters were taken, as was ranked by respondents. Land use change (6.45) was ranked as the highest. LULC since 1990 of the study area depicts that the area under forest accounts for only 8.8% (628.31 km^2) of the total 7127.71 km^2 whereas non-forest category occupied 91.18% (6499.40 km^2) of the total area. The Rampur division had 1082.72 km^2 total area, under which forest accounts for 39.62% (428.99 km^2) of its total share (Table 10). Forest fires ranked as 2nd (6.41). About 132 forest fire incidences have been recorded from 2000 to 2014. Maximum forest fires occurred in 2009. Total 17.9 km^2 areas were highly vulnerable to forest fire in Kinnaur and Rampur division. Deforestation was ranked as 3rd (4.88), timber cutting / stealing incidences ranked as 4th (4.63), loss in water resources ranked as 5th (4.43), encroachment in forest area ranked as 6th (3.35), illegal extraction of herbs/medical plants ranked as 7th (2.29) and over-grazing was ranked as 8th (1.12).

20. During the group discussion with the villagers, it was made clear that climate change is highly experienced in terms of increasing temperature and decreasing rainfall. On the basis of people's perception, the high climatic variability was found in the study area among biological parameters. Lack of chilling hours requirement stood to be 1st (6) and dry tree growth period was ranked as 2nd (4.96). However, pests attack on forest resources was ranked as 3rd (3.63), migration of tree species / loss of native tree species ranked as 4th (2.92). Even the forests of Bhojpatra (*Betula utilis*) are very rarely seen nowadays. Extinction of tree species ranked as 5th (1.9) and wildlife ranked as the lowest as 6th (1.1). During field survey, respondents also perceive that climate change has its impact on forest products.

21. It is made clear from the overlay analysis that high vulnerability exists in terms of landslides, forest fires, soil erosion, flood incidences, and HEPs construction. It is obvious that the forest fires and human settlements have positive correlation. The GIS and RS study indicate that manmade activities are highly responsible for the forest loss in the study area.

Table: 9. Area (km^2) under different components of the land use land cover (LULC); Values in parentheses are in per cent

S. No.	LULC	Kinnaur division	Rampur division
a.	Forest	628.31 (8.8)	428.99 (39.62)
b.	Non-Forest	6499.40 (91.18)	822.67 (75.98)
i	Built-up area	0.97 (0.01)	0.44 (0.04)
ii	Agricultural crops and orchards	43.39 (0.61)	76.2 (7.04)
iii	Grassland	1467.32 (20.59)	298.37 (27.56)
iv	Scrubland	51.69 (0.73)	102.26 (9.44)
v	Water bodies	7.75 (0.11)	7.50 (0.69)
iv	Snow covered	1.67 (0.02)	0.11(0.01)
vii	Other wasteland	4926.6 (69.12)	168.95 (15.60)
	Total area	7127.71 (100)	1082.72 (100)

THEME

KNOWLEDGE PRODUCTS AND CAPACITY BUILDING (KCB)

The focus of knowledge products and capacity building programme is an enhancement of institutional outreach based on its research outcome Model demonstration, dissemination, capacity building through specifically designed models and on-site trainings; develop linkages with knowledge providers, knowledge seekers and users to effectively utilize available knowledge resource/products to deal with prominent environmental issues; blending of traditional ecological knowledge with scientific knowledge for their livelihood improvement, natural resource management and sustainable development; and implement state-of-art methodological approaches for knowledge based products 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 and modern knowledge base; (b) to utilize natural resources for income generation using local knowledge and capacities through science and technology interventions; (c) to translate existing knowledge related to Bio and natural resources, etc. into products; (d) to enhance capacities and skill of human being 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 (2012-2017, In-house)

The traditional societies in Central Himalaya face a range of socio-economic and environmental problems. They live in geographical isolation under ecologically sensitive and economically constrained conditions. Remoteness, marginality, harsh climatic conditions, tough terrain, poor infrastructure, lack of employment opportunities, drudgery and meager livelihood opportunity are often responsible for poor economic conditions of the people inhabited in the rural set up. In addition, dominance of rainfed agriculture on the steep slopes (which constitutes 85% of the total agricultural land) that is too marginal, fragmented and scattered in nature, small land holdings result low crop yield and therefore, does not provide income generating opportunities for ever-increasing population of the region. As a result large numbers of the population migrated to the other part of the country in search of employment. Thus to minimize the existing rate of migration on one hand and to utilize diverse bioresources sustainably on the other, cost-effective, simple practices and technological interventions in most of the sectors of rural economy are required so as to provide viable alternatives for improving livelihood and food security of growing population on sustained manner. Therefore, under this project a number of cost effective

technologies for sustainable utilization of the various resources were identified and demonstrated across the Himalayan region by HQs, Garhwal and Sikkim Units of the Institute. The major highlights of the project are as below:

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 on specialized skills on relatively long term basis, and achive livelihood security for overall improvement in the quality of life of rural folk.

Achievements

1. A total of 41 simple, eco-friendly and cost-effective 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 for their livelihood enhancement. For implementation of technology packages a total of 170 training, capacity building and awareness programmes were organized for different user groups, and 7109 persons (Female, 3480 and Male, 3629) covering 14 districts and 736 villages were trained in target states (Uttarakhand and Sikkim). In addition, various technologies were also demonstrated that comprised 59 models of integrated protected cultivation (Polyhouses, poly tunnels, Net houses, various composting methods, vegetable, etc.), 94 polyhouses, 93 vegetable cultivation in rainfed areas, 86 vermi composting, 90 bio-composting, 15 water harvesting poly ponds & fish farming, 9 poultry farming, 38 nurseries, 4 honeybee rearing, 30 bio-prospecting of wild edibles, and 8 models of zero energy cool chamber. In addition, 46 prototypes of bio-briquetting frames, 5000 fingerlings, 15760 fodder and multipurpose tree saplings, thousands of plants of various vegetable plants and seed, were distributed to the beneficiaries for field implementation at selected sites.

2. A total of 15760 plants of multipurpose tree were raised at the RTC of HQs and distributed to the farmers. Similalry, 2.5 lakhs plants of *Valleriana wallichii* and *Inula racemosa* were raised in the nursery at Triyuginarayan, of which nearly 1.0 lakh seedlings of *Valleriana wallichii* were distributed to the farmers of Tarsali and Triyuginarayan (district Rudraprayag) and Pokhri (Pauri district) villages for domestication. The Institute is facilitating marketing of the final product through Emami Pvt. Ltd.

3. The yield of selected vegetables as influenced by different compost-types as well as grown under polyhouses and open conditions was evaluated. The yield was much higher when the crops was grown by adding vermi-compost.

4. An analysis of above- and below-ground biomass of *Valleriana wallichii* and *Inula racemosa* grown under different micro-climatic conditions (polyhouse, shade-net house and open) at 2200 m revealed that below-ground part was 3 to 6 times higher under polyhouse condition as compared to shade and open conditions.

5. The potential wild edible bioresources are being utilized as a source of income for user groups/unemployed youth of the region by making a variety of value added edible products such as jam, squash, juice, sauce, pickle etc. A small bioprospecting unit at the RTC Triyuginarayan helped 165 families in eight villages of upper Kedar valley to use locally available bioresources (wild edible) for value addition and income generation.

6. Developed detail methodological process and approach (involving farmers in all stages of technological development, implementation and sustainability evaluation) and strategic frame work for impact assessment of stakeholders trainings (adoption and follow-up).

7. The cost-benefit analysis of vegetables and a variety of medicinal and aromatic plants (*Allium strecheyi, A humile, Angelica glauca, Pleurosperm angelicoides,* etc.) used for spices and condiments after local value addition was worked out.

8. A model on integration of medicinal plants (*Picrorhiza kurrooa, Saussurea costus, Valeriana wallichii and Inula racemosa*) in horticultural farms (apple, *Juglans regia*) was tested and found a prospective option to increase per unit area production and income for high altitude areas.

9. An analysis of 1517 farmers, who adopted selected technologies in Uttarakhand state, revealed that most of the farmers adopted integrated protected cultivation, cultivation of off-season & seasonal vegetables, organic farming, nursery agro product; at low-hills farmers also preferred bio-briquetting, poultry farming, integrated fish farming, etc., whereas at mid-high hills bioresources processing and eco-tourism was favored. About 50% of total farmers have started generating income, some of them are earning up Rs. 50,000/- per annum.

To create awareness among the stakeholders and for wider dissemination of technologies, various activities were carried out as follows organized 10 workshops by involving stake holders and subject experts, participated in twelve fairs/festivals & exhibitions, organized 14 field training programmes, published & distributed 8 folders, 15 training manuals, 9 technical manuals, 49 posters, one calendar for each year, etc. The findings of the various activities were also published in the research journals, articles, popular articles, etc. from time to time.

R&D HIGHLIGHT OF THE REGIONAL UNITS

Garhwal Unit

- Environmental and other related policies (i.e. forest policy, wild life protection, environmental education, awareness and training, disaster management act) were analyzed in detail for understanding the gaps in knowledge and need for further improvement.

- Women's role and contribution in livelihood and environment management was analysed for *developing/coping strategies* and understating the gaps *between environmental policies and human actions in the Kedar valley*. Among the respondents, in all the village clusters, above 73.91% respondents expressed that women may contribute a lot in improvement of the socio-economic conditions of the affected families.

- Investigated the seasonal water scarcity and recorded the continuous water discharge data through integrated approach of isotope technique, remote sensing and GIS application, in small micro-watershed in Pauri district.

- Morphological, biochemical and genetic diversity of *R. procera* has been evaluated. For the first time a number of ISSR markers were identified statistically associated (Either negative or positive) with different biochemical traits. Two markers (OPA6-8 and OPA8-2) were found to be associated with total phenoloic content, three markers (OPA01-11, OPA6-8, and OPA6-2) with gallic acid. Similarly, for the first time a total of 10 ISSR markers found significantly associated with the antioxidant activity measured by ABTS assay, total antioxidant assay and NO inhibition assay. These markers can be utilized for breeding and conservation of the target species along with its sustainable utilization.

- The action and participatory research work carried out between 2016-17 in the Unit on various sectors (medicinal plant, agro-ecosystem, agro-forestry, wild bioresources. water and forest resources) is given due consideration by various line agencies at district and state levels and most of our findings has been incorporated in the action plan of MNREGA, ATMA, GRAMYA, horticulture mission, district planning etc.

- Assessment of farmer's perception, response, adaptation and coping strategies due to climate change impact/variability in rural landscape with major focus on agriculture and their overall impact on livelihood of the people inhabited in lower and upper Nayar valley and Alaknanda catchment were carried out.

- Developed huge nursery with total of 2.20 lakhs seedlings of economically potential medicinal plants i.e. *Valeriana wallichii, Inula racemosa*, *Picrorrhiza kurrooa* and *Saussurea costus* under different micro-climatic conditions (polyhouse, shadenet and open condition) and about 1 lakh plantlets were distributed to the interested farmers of different villages of the region for promoting large scale cultivation.

- A total of four training programmes each of two-days on "Capacity Building and Skill Development of the target population in the field of Management of Bioresources through Eco-friendly Technologies, Ecotourism, Livelihood Enhancement and Entrepreneurship Development" were organised between April 2016 to March 2017 and a total of 350 participants were imparted on- site training on the above mentioned areas.

- The density diameter curve of the key tree population of mixed and pure *Betula utilis* forests at north and south facing slopes in NDBR resembled a reverse J shape, and it indicates that both the forests are regenerating well, although *B. utilis* showed fair regeneration in both forests followed by *R. campanulatum, A. pindrow* and *C. deodara.*

- Identified the potential options of linking and supplementing pilgrimage tourism with other form of tourism (rural/agro tourism, heritage tourism, nature/eco-tourism and community based tourism) for socio-economic development of the disaster affected Kedar rural landscape.

- Developed package of practices of cultivation, value addition and value chain of seven wild herbal spices (*Allium strechyei, Allium humile, Allium rubellium, Angelica glauca and Pleurospermum angelicoides, Cinnamomum tamala*) and wild fruit resources (*Viburnum mullaha*) for large scale cultivation.

- In depth assessment of ecological, social-economic and policy dimensions and indicators of traditional agro-biodiversity loss has been carried out which formed the basis for developing priority interventions for conservation and management of the traditional mountain agro-biodiversity of the region.

- Adopted four (4) disaster affected village clusters (each cluster with 10 villages) in Kedar valley for empowering human resource particularly women and unemployed youth and farmers for capacity building / skill development in the field of livelihood enhancement, income generation and natural resource management through on-site training, exposure visit and live demonstration.

- The skill development, capacity building and outreach programme in the area of value addition of wild bioresources have made a significant impact and stimulated local youth and village institutions to harness the potential of wild bioresources. About 510 households of 30 villages in Alaknanda and Mandakini Valley have adopted the local value addition of variety of wild edible plants as household activity for income generation.

- Developed an innovative document (Monograph) on "Bioprospecting of wild herbal spices for sustainable entrepreneurship development particularly for hilly rural areas of the central Himalaya (Uttarakhand).

- Developed the policy document "Emerging Concern of Hill Agriculture of Uttarakhand: Policy Issues and Priorities for Sustainable Development" which provides the details about the hill agriculture, issues and concerns related to policy, governance, research, extension and suggest priority interventions for development.

- An appropriate options and strategies for sustainable development of disaster affected rural landscape/ areas of Kedar valley based on locally available bioresources (agro and wild origin) and their value addition through simple technological interventions were recommended.

- Assessment of socio-ecological vulnerability and coping strategy to natural hazards and climate change in the Kedar valley in the aftermath of 2013 disaster were carried out.

- The biomass estimation and carbon sequestration potential of timber line vegetation with particular emphasis to *Betula utilis* forest were carried out.

- Diverse stakeholders were consulted in ranking of plant species based on their multiple use value, and 10 species were prioritized for plantation and sustainable management of the indigenous system. The plant species having ecological and socio-cultural values to be promoted for plantation in agroforestry system through active participation of the farming communities.

HP unit

- Inventory of 1116 species (616 trees, 500 shrubs) for the Trans, North Western and Western Himalaya was prepared. Information on various aspects was gathered for developing the complete database of the total tree and shrub species in a standard format. Species were analyzed for nativity, endemism and threat categories.

- From Kanawar Wildlife Sanctuary, 209 species (Angiosperms: 198; Gymnosperms: 07; and Pteridophytes: 04) were economically important and used as medicine (88 spp.), wild edible/food (27) spp.), fodder (40 spp.), fuel (27 spp.), timber (5 spp.), religious (05 spp.), fiber (07 spp.), making agricultural tools (06 spp.) and some other purposes (9 spp.) were recorded from Kanawar Wildlife Sanctuary. The inhabitants of Gharan, Thunja, New Kasol and Old Kasol villages were dependent for fuel and fodder resources on six forest tree communities namely, *Quercus floribunda, Quercus floribunda-Pinus wallichiana* mixed*, Pinus wallichiana, Celtis australis-Toona serrata* mixed, and *Picea smithiana* communities. The lopping intensity in different communities was studied.

- Total 52 plots were sampled for floristic diversity of the Jamdagni Rishi and Kamru Nag Sacred Groves. Out of these, 32 sites were undisturbed and 20 disturbed. Total 285 species of vascular plants (31 trees, 33 shrubs & 209 herbs) belonging to 135 families and 190 genera were recorded. Community wise comparison of Species Diversity (H') between Undisturbed & Disturbed sites was done. Carbon Sequestration was estimated in Kamru Nag (Undisturbed & disturbed sites) Sacred Grove. In Undisturbed site above ground biomass was 53350.67 kg/400m^2 and carbon content 26675.34 kg/400m^2, where as below ground biomass was 15471.69 kg/400m^2 and carbon content 7735.85 kg/400m^2. In disturbed site above ground biomass was 56765.15 kg/400m^2 and carbon content 28382.58 kg/400m^2, where as below ground biomass was 1646.89 kg/400m^2 and carbon content 8230.95 kg/400m^2.

- In Sainj Valley, 30 sites were surveyed between 1,385– 2,070 m and 260 vascular plants, 17 Trees communities and (01) Shrub community were recorded. 225 species were used as medicinal; 35 as fodder; 19 as edible; 20 as fuel; 11 as religious; 09 as timber; 05 as dye; 03 as fiber; 05 as agricultural tools and 11 as miscellaneous uses.

- Total 55 populations of *Dactylorhiza hatagirea (05* populations*), Podophyllum hexandrum (14* populations*), Angelica glauca (12* populations*), Aconitum heterophyllum (11* populations*), Picrorhiza kurrooa (10* populations*)* and *Rheum australe (03* populations*)* were studied between 2387-4227m in the Chamba, Mandi, Kangra and Kullu districts of Himachal Pradesh. 62 distributional records, Bioclimatic and DEM variables were utilized for the prediction of potential areas of *Podophyllum hexandrum* with the help of ecological niche modelling packages (Fig.1). The model test yielded satisfactory results for *hexandrum* (AUC_{test}= 0.890 ± 0.060).

- 22 populations of *Polygonatum verticillatum, and Delphinium denudatum* were assessed between 1,565 – 2,230 m in Sainj valley. In *Delphinium denudatum* populations, Species richness of shrubs ranged from 1-09 and herbs, 09-29; total shrubs density 10-1680 Ind ha^{-1} and total herb density, 11.70-65.30 Ind m^{-2}; and relative density (%) of *Delphinium denudatum* 0.49-21.37%, and *Polygonatum verticillatum* populations, Species richness of shrubs ranged from 01-08 and herbs, 12-30 ; total shrubs density 40-830 Ind ha^{-1} and total herb density, 21.80-91.95 Ind m^{-2}; and relative density (%) of *Polygonatum verticillatum* 0.30-8.49 %. Seed germination trials for *Delphinium denudatum* resulted 80 percentage in BOD at controlled temperature, 23C in 6 days, reduced mean germination time (MGT). Seed germination trials for *Polygonatum verticillatum* resulted in 20% germination for seed kept in BOD. Plant tissue culture trials for *Polygonatum verticillatum* and *Delphinium denudatum* using leaves, root, tuber and young shoots as explants on Murashige and Skoog Medium (MS-Medium) were initiated.

- Four Citizen Science Programmes were organized jointly with Earthwatch Institute India, from 11th to 20th April, 2016; 25th July to 2nd August, 2016; 19th to 28th September, 2016 and 17th to 26th October, 2016. The volunteers were involved in qualitative and quantitative assessment of vegetation, assessment of insect pollinators' diversity and density, preferential bee flora based on the visitation by pollinators, etc. The results showed highest visitation rate of *Apis ceranna* followed by *Apis mellifera*, Drone, butterflies, syrphids, etc. in all orchards except in Hirni and Kradsu where highest visitation rate of *Apis mellifera* was observed. The pollinators have different bee flora species preferences for foraging in different seasons at different orchards which depends on the availability of the flowering plants in the sites. The preferred foraging plants during April *Brassica campestris* and *Zaphyranthes candida;* in May *Trifolium repens, Berberis lycium and* the preferred foraging plants were during March were *Brassica campestris*, followed by *Trifolium repens* and *Zaphyranthes candida* by *Apis cerana,* followed by drones, syrphids and *Apis mellifera*.

- Nine (9) sites, 1 site each in Karadsu and Raugi villages and 7 sites in Nashala village of Upper Beas valley, Kullu were surveyed to study density and diversity of the pollinators. Mustard and Coriander were cultivated in nine sites during November and December 2016 to maintain the flora for bees and insects in winter season. The survival rate of the crops was up to 80-90%. The density and diversity of the pollinators increased to a larger extent after the cultivation of these crops.

- Total 72 Bee boxes of Indian Honey Bee (*Apis cerana*) with bees purchased and distributed to the 48 apple orchardists from 7 villages i.e. Kradsu, Nashalla, Ghurdaur, Archhandi, Dobi, Bashkola, and Kathayal Gran of Kullu District. 25 set of apiculture equipments (queen cage, smoker, bee veil, gloves, uncapping knife, queen gate, pollen trap, hive tool and hive gate) and two (02) extraction machines of four framed were distributed to the farmers. 1350 seedlings of *Buxus wallichiana*, *Pyrus pashia*, *Rosa brunonii, Rubus biflorus, Cornus macrophylla, Aesculus indica, Bauhinia variegate and Callistemon citrinus* were transplanted in two villages i.e., Nashala and Archhandi for the restoration of floral habitats of bees.

- Various mycorrhizal structures, namely, intercellular, intracellular fungal mycelium, spores, very low presence of arbuscules and dark septate endophytes and unidentified nematode like structures were observed during quantification of root colonization of *Betula utilis*. The total per cent root colonization ranged between 66 – 91 out of them 46 – 66% colonization was contributed by fungal mycelium and 42 – 72% by dark septate endophytes. The minimum total colonization was observed from Solang Valley (66%); maximum from Hamta Pass (91%) whereas minimum fungus colonization was recorded from Rohtang Pass (46 %) and maximum from Hamta Pass (66%) and the minimum dark septate colonization was recorded from Solang Valley (42%) and maximum was recorded from Rohtang Pass (72%).

- A strategy for policy guidelines designed to determine the number of hydropower projects according to a carrying capacity of a basin under Strategic Environmental Assessment (SEA) of hydropower projects. There were unequal distributions of hydroelectric projects in a particular basin in the IHR. In case of the Sutlej basin, it is vivid from GIS analysis that the maximum numbers (38) of hydroelectric projects lie in the middle and upper zones of the buffer area of 3934 km^2 of the total 7514 km^2 in 10 km buffer of the Sutlej basin. For determining number of hydroelectric projects in a basin, there is a need to assess its carrying capacity. Keeping in mind local geomorphology, isostasy and other factors, the environmental, physical and social impacts could be minimized. Aerial inter-distance of 5 km radius for small (<25 MW), and 7 km radius for large projects (>25 MW) would be a sustainable way for introducing the hydro projects. The study reveals that 18 projects out of 38 could not follow this suggested criterion in the Sutlej basin. Based on this recommended inter-distance, only 20 projects could be appropriate in a sustainable manner. Similar approach is also required to follow throughout the Himalayan region.

- Long-term data base generated to understand the aerosols climatology, radiative forcing and

temperature rise in the Kullu valley of Himachal Pradesh. Mean AOD_{500nm} at Mohal (1154 m amsl) in 2016 stood to be 0.32± 0.12, while BC was found with biomodal peaks around 7:00 hrs IST (3295.4 ng m^{-3}) and 20:00 hrs IST (1695.0 ng m^{-3}). AOD in the Kullu valley is wavelength dependent. It is higher at shorter wavelengths and lower at larger wavelengths indicating dominance of anthropogenic aerosols due to high human interferences in the surrounding environment. The instantaneous mean aerosol radiative forcing in 2016 was estimated to be –13.92 ± 4.7 Wm^{-2}, –32.79 ± 11.2 Wm^{-2} and +18.87 ± 8.02 Wm^{-2} on TOA, surface and atmosphere respectively. This translates into an average atmospheric heating rate of 0.53 K day^{-1}. Atmospheric forcing is found decreasing along with increasing altitudes. However, temperature continues to rise slightly.

- A data base on surface ozone- a green house gas (GHGs)- and its precursors at high altitude station-Kothi (2500 m) was generated under Atmospheric Chemistry, Transport and Modelling (AT-CTM) under Environmental Observatory Scheme. Higher concentration of surface ozone was observed in June which was maximum as 29.50±5.33 ppb. O_3 was found to be increasing gradually after sunrise (07:00-08:00 h IST), attaining maximum concentration during afternoon (14:00-16:00 h IST). Thereafter, it showed a gradual decreasing pattern. Annual maximum concentration of O_3 precursors like NO was 4.07 ± 0.9 ppb in October in 2016, NO_2 6.99 ± 1.14 ppb in January 2017 and NO_x 11.3 ± 3.8 ppb in June. Analysis of meteorological data showed that high O_3 concentration was associated with intense solar radiation and low rainfall. The pollution sources are mainly due to anthropogenic emissions in the form of vehicular emissions and biomass burning in the region.

- Role of black carbon and other aerosols were assessed in snow melting over Parbati Glacier. The daily average concentration of black carbon was 0.41±0.02 µg m^{-3} from August to September, 2015 and 0.14 ± 0.01 µg m^{-3} during 2016. Looking at source contribution of the total BC, biomass burning contributed about 13% and 19% of the total contribution in the Parbati Glacier during 2015 and 2016 respectively, whereas other pollution source in the region was fossil fuel burning. The mean AOD value at 500 nm was observed to be 0.17±0.02. The mean AOD value at 500 nm in 2014 showed 0.1 increase over 2015 in the Parbati Glacier. Dominant anions were in an order of $Cl^- > F^- > SO_4^{2-} > NO_3^-$ which were similar to 2014. Cations were in an order of $NH_4^+ > Na^+ > Mg^{2+} > K^+ > Li^+$ in 2015 and $Na^+ > NH_4^+ > Mg^{2+} > Li^+ > K^+$ in 2014. Zn^{2+} was the only transition metal found in both the years of observation in the Parbati Glacier.

- Identification of 8 Women Saving and Credit Groups (WSCGs) with 103 women members was done, and these WSCGs were involved in the procurement of rosehip pods. Total 2273 kg seeds were procured and 1,25,000/- generated. Until December 2016, 1,80,000 was generated through sale. Rosehip seed shredder machine which deseed 200 kg per day as compared to 3.5 kg manually, was developed. Harvesting and post harvesting protocol developed. Two types of tea were developed and seed oil extracted for further value added product development.

- Documentation of water and irrigation systems; bioresource conservation practices, Traditional health care system, documentation of traditional cousins from the Lahoul and Spiti district, and Sacred grooves and their ethnicity in the villages of Kullu district was done. *Hadimba Devi, Manali; Jamdagni Rishi,* Katrain; *Krishna temple (Thauwa),* Naggar; *Gauri Shanka,* Jagatsukh *Sacred Grooves* have been studied in details. Documentation of the history of *Mamleshwar Mahadev* temple, Mandi Mahunaag temple and Komik village in Spiti valley was done.

- Geo-database of Drainage, DEM, Soil, Geology, Land use/land cover for year 2016 developed and Morphometric analysis for Mohal Khad watershed done. Water quantity, land use changes and watershed characteristics were studied. Watershed Evaluation and Planning (WEAP) model was customized and water allocation strategy was framed for effective water management. Geo-database for Sainj river basin developed. Inventory of springs and their details (e.g., location, elevation, discharge, water sample's pH, EC, TDS etc.) for Kanon Nallah watershed prepared.

NE Unit

- Successfully completed the R&D work assigned/ allocated to NE Unit under all in-house projects (4 Nos.) in the given time frame.
- The NE Unit research staff has published a total of 27 papers/articles in international and national papers and proceedings in the reporting year.
- Organized landscape journey under the 'Transboundary Landscape Development Initiative for Far-Eastern Himalayan (Hi-LIFE)' to identity the major priorities of the selected study region (ie. Namdapha NP & fringe areas in Changlang district, A.P.).
- Under the In-house project No-3 (SEA of hydropower projects in IHR), a workshop on "Hydropower Project and Environmental Impact Assessment (EIA)" was organized at Lakhimpur Girls' College, North Lakhimpur, Assam on March 12, 2017.
- Under the In-house Project No. 1 (Ecotourism as a potential tool for biodiversity conservation..", the NE Unit strengthen a local organization known as Achukru Welfare Society at Ziro (A.P.) by providing them antique items and in addition to that a short term training was also organized for the skill development of the people/groups working in the eco-tourism in Lower Subansiri Dist.
- Implementing NMSHE Taskforce-3 and Taskforce-5 projects, significant primary data has been collected from the study respective sites and analyzed.
- Under NMHS Project entitled "Rejuvenation of springs and spring fed rivers…", studied the river morphology of Senkhi River using Remote Sensing & GIS.
- Block Field Work Training (Sept. 2016): Provided 1 Month block filed work training to the students (Mr. Mobia Omo and Mr. Malom Sering) of Department of Social Work, RGU, Doimukh (A.P.) on "A case study of Socio-economic impact assessment of Ranganadi HEP, Arunachal Pradesh".
- Provided technical support and training to the students of Rajiv Gandhi Central University (A.P.) on water quality testing.
- Under In-house Project No. 9 (Extremophiles from Himalaya: Ecological resilience and Biotechnological applications), data has been collected on 23 species of ethno-medicinal plants with reference to their phytochemicals and pharmacological activities.

SIKKIM UNIT

- Strengthening of ex-situ conservation efforts through: (i) improvement of seed germination of *Phoenix rupicola* (ii) development of *in vitro* propagation protocols for *Aconitum ferox*, *Rhododendron leptocarpum* and *Bergenia ciliata* (iii) field plantation of tissue culture and conventionally propagated plants of important Rhododendron spp. and *Phoenix rupicola*.
- Medicinal plant species (1500) of Sikkim Himalaya are documented with their local name, family, conservation status, parts used and uses. Further, some high value traditional medicinal plants of Sikkim Himalaya were investigated for biological activities.
- Developed feasibility assessment and bioresource management plans for three pilot sites *viz*. Dzongu, North Sikkim, Barsey-Singalila, Darjeeling and West Sikkim and for Bandapani, West Bengal.
- PRA conducted in "Mamlay Watershed" resulted major issues like, i) change in cropping pattern, ii) scarcity of drinking water, iii) Human Wildlife Conflict (Monkey), and iv) high dependency on forest resources.
- Based on the preliminary surveys across timberline of Dzongri (4000m asl), *Abies densa* emerged as dominant tree species along with its common associates *Rhododendron lanatum* and *Sorbus thomsonii* in tree layer and *Rosa sericia* and *Ribes* sp. in shrub layer. The upper limit of trees (tree line) was observed 4011m in the region.
- Documentation of Traditional Knowledge System on Land and Soil (14 practices), Water conservation (6 practices), Bioresource utilization (160 nos.) and Bio processing practices (8 nos.) prevailing among ethnic communities (Lepcha, Bhutia, Nepalese, Limboos

etc.) of Sikkim Himalaya including Darjeeling district of West Bengal.

- Training on different low cost technologies were delivered to the targeted four (4) panchayat; Luing, Rakdong, Tintek, Lingdok farmers, SHGs, etc.

- Developed "Feasibility Study and Bioresource Management Plans" for three pilot sites of KL-India (i.e. Barsey-Singalila, Dzongu and Bandapani) and published a training manual based on the experiences from the Khangchendzonga Landscape, India title "Socio Economic and Bioresource Assessment: Participatory and household survey methods, tools and techniques" 2016,

- *Invitro* propagation protocol for threatened *Rhododendron leptocarpum* and *Aconitum ferox* of Sikkim Himalaya has been developed. For introduction, suitable habitats have been identified using ENM tool.

- Fambonghlo Wildlife Sanctuary has been studied in the context of employment opportunities and ecotourism impact policy analysis.

MOUNTAIN DIVISION

- Compilation of tree taxa databse of North East Himalaya were carried out. A total of 962 taxa are recorded from Arunachal Pradesh, 971 from Assam, 972 from Manipur, 1042 from Meghalaya, 927 from Mizoram, 831 from Sikkim, 855 from Tripura, and 916 from Nagaland. More than 61% of trees were recorded from Meghalaya.

- As per IUCN (International Union for Conservation of Nature and Natural Resourses), *25 tree taxa are categorized under various threat categories. The species namely, Dipterocarpus turbinatus* C.F.Gaertn., *Dipterocarpus gracilis* Blume, *Gymnocladus assamicus* Kanj. *ex* P.C. Kanj., *Ilex khasiana* Purakayastha, *Magnolia gustavii* King, *Magnolia pleiocarpa* (Dandy) Figlar & Noot. are critically endangered, *Adinandra griffithii* Dyer, *Dipterocarpus alatus* Roxb., *Goniothalamus simonsii* Hook.f. & Thomson, *Ilex venulosa* Hook.f., *Illicium griffithii* Hook. f. & Thomson, *Lagerstroemia minuticarpa* Debberm. ex P.C. Kanjilal, *Magnolia pealiana* King, *Pittosporum eriocarpum* Royle and *Taxus wallichiana* Zucc are endangered and *Aquilaria malaccensis* Lam., *Cephalotaxus mannii* Hook.f., *Dalbergia latifolia* Roxb, *Dipterocarpus retusus* Blume, *Elaeocarpus prunifolius* Wallich, *Gleditsia assamica* Bor, *Ixonanthes khasiana* Hook.f., *Magnolia mannii* (King) Figlar, *Picea brachytyla* (Franch.) E. Pritz. *and Ulmus wallichiana* Planch. are vulnerable tree species of IHR.

- A book entitled 'Tree Diversity of Western Himalaya' has been developed and released during the Annual day function (September 10, 2016) of the institute.

- Review of lietrature on the biotic and abiotic stress responses of medicinally important plants of Himalayan region was conducted. Analysis of the data reveals that there are only a few papers published on the physiological work on the Himalayan plants particularly with the abiotic stress. The study concluded that more work is required in these aspects so that authentic dataset on the physiological responses of the Himalayan plants could be created and utilized while developing strategies for conservation.

- Assessment of floristic diversity and microbial association of the Birch – Rhododendron forests in Himachal Pradesh, North Western Himalaya, was carried out. The soil properties from the rhizosphere of populations were analyzed and it varied within the different populations. The pH of the *B. utilis* rhizosphere soil ranged from 5.58 - 6.76; electrical conductivity 23.5 – 99.0 µS; moisture content 17.97 - 55.36%; organic carbon 2.6 ±0.01- 3.2 ±0.001%; and organic matter 4.5 ±0.01-5.4 ±0.001%. Soil NPK also showed variations at all populations. Available N, P and K ranged between 10.3 ±1.6 to 184.8 ±2.5, 0.011 ±0.001 to 1.15 ±0.035 and 320.4 ±1.3 to 420.1 ±2.5, respectively.

- Total 26 populations of *B. utilis* from three sites i.e., Rohtang Pass, Hamta Pass and Solang valley were assessed. Total 175 species (11 trees, 24 shrubs & 140 herbs) were recorded. In the populations, total tree density ranged from 180-1430 ind. ha^{-1}, sapling density 20- 860 ind. ha^{-1} and seedling density 10-820

ind. ha^{-1}; shrubs 310-2460 ind. ha^{-1}; herbs 17.15- 92.95 ind. m^{-2}; and species richness ranged between 16 -45.

- Species Diversity (H') of trees ranged from 0-1.67, saplings, 0.0-1.51, seedlings, 1.09-1.32, shrubs, 0.00-1.74 and herbs, 2.3-3.6. Concentration of dominance (Cd) for trees ranged from 0.22-1, saplings 0.26 to 1.0; seedlings 0.28-1.00; shrubs 0.17-1.00 and herbs 0.12-0.2.

- Climatic variables and their impact on environmental flow in the River Sutlej basin in Himachal Pradesh were assessed. The WQI (water quality index) of the River Sutlej water during post-monsoon, winter and pre-monsoon season in the selected sites were under good (39.56), good (46.54) and poor (54.78) respectively. WQI indicates for the present study region that water is not fit for drinking purpose.

- Water quality parameters like alkalinity as 200±25.11 mg l^{-1}, hardness 280±44.59 mg l^{-1} and DO 13± 2.11 were not found within their permissible limit in winter. On the other hand in pre-monsoon season, maximum pH raises to 8.89±0.30 which results in bitter taste to water, cause corrosion and affects mucous membrane and aquatic life.

- TDS and EC are more interrelated with correlation significant at the 0.01 level in all three seasons. Among all the parameters, electrical conductivity and total dissolved solids were highly correlated with significance level 0.01, R^2 (0.9811) along with regression equation.
- A trend of water quality parameters, namely, pH, D.O., B.O.D. and T.C. from 2006 to 2015 were analyzed for different seasons of the year. Among all TC shows a great decadal change in all sites / locations.

- Confluence point of the River Spiti and River Sutlej at Khab in Kinnaur is the control site chosen for the study. During a field survey in Tangling village, the respondents were not dependent, directly or indirectly, on the River Sutlej for their livelihood and other agricultural practices. In a survey, 55% of the villagers said that the fishes were found mostly a decade before in this basin; however, they are now rarely found due to construction activities like dams, tunnels, roads, etc.

- According to a questionnaire for a prioritize matrix, the most destructive activities that affect the environmental flow of the River Sutlej in the Himalayan villages are mainly road construction, dumping wastes into river water, tunnel construction and deforestation.

APPLICATION OF R & D OUTPUTS IN DEMONSTRATION AND DISSEMINATION

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

Ministry of Environment and Forests (MoEF&CC), Government of India entrusted the responsibility of Integrated Action Oriented Research, Development and Extension Programme (termed as Integrated Eco-development Research Programme - IERP) in the Indian Himalayan region (IHR) to the Institute in 1992. The Institute funded R&D projects under two broad thrust areas [namely, Technology Development and Research (TDR) for Integrated Eco-development, and Technology Demonstration and Extension (TDE)] up to 2006-2007. 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

- A grant-in-aid of Rs. 200 lakhs was received from National Mission on Himalayan Studies (NMHS) to strengthen IERP activities in the IHR.
- An advertisement requesting for project proposals for funding support from IERP-NMHS was published in National dailies. A total of 58 project proposals were received.
- The Project Evaluation Committee (i.e., 19th meeting of IERP-PEC) held at HQ GP Pant Almora and based on the experts opinion and recommendations the PEC members, a total of 13 new projects were sanctioned for execution in 3 States (namely, Assam, Nagaland and Uttarakhand) of the IHR.
- At present thirty nine IERP projects are on-going in 7 States (namely; Assam, Arunachal Pradesh, Himachal Pradesh, J&K, Sikkim, Uttarakhand and W.B.) of the IHR. A total of seven projects were completed in the reporting year.

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

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

Objectives

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

Achievements

- The Centre has compiled the quantitative and qualitative databases on various aspects of Himalayan Ecology. These include, ENVIS Centre Publications [ENVIS Newsletters Vol. 13(1-4), 2016-17; ENVIS Bulletin Vol. 24, 2016; State at a Glance: Series of Indian Himalayan States, Nagaland Vol. 1(6), 2016, Mizoram Vol. 1(7), 2016, Manipur Vol. 1(8), 2016, and Meghalaya Vol. 1(9), 2016]
- For improving the outreach of ENVIS Centre's publicaitons this year all publications in various scientifice agencies/libraries/etc. have been indexed. These include, Directory of Research Journals Indexing (DRJI); Eurasian Scientific Journal Index; Impact Factor Services for International Journals; CiteFactor
- State Specific Statistical Databases were developed, which covers the temporal trends across important segments, e.g., demography, literacy, land, water, agriculture, horticulture, forest cover, protected areas, weather profiles, etc., which would help in crucial decision-making and policy planning proactively of Indian Himalayan states.
- Regular upgradation and maintenance of ENVIS Centre's website (http://gbpihedenvis.nic.in).

Central Laboratory Services

Institute has strengthened the facilities of physico-chemical, biological, heavy metal analysis of drinking, raw, waste water and quantification of volatile compounds of soil and plant samples. The heavy metals in the water and soil samples are detected through Atomic Absorption Spectrophotometer (Make- Varian AA280Z, equipped with graphite tube atomizer). Quantification of aromatic and volatile compounds are carried out using Gas chromatograph (make- Chemito, Ceres 800 plus). Institute is also having the facility of analyzing carbon, hydrogen, nitrogen and sulfur through CHNS-O analyzer (make- Elementar, Vario EL-*III*). Facility of UV-Vis spectrophotometer (make- UV 5704, Electronics Corporation of India Ltd.) is available for soil, water & plant analysis. The Institute has extended these services for other organizations (NGOs and other Government Organization) on payment basis. In the financial year 2016-17, Institute has collected Rs.1.30 lakh as a central laboratory service charge from 15 organizations (4 - Govt. Organization, & 11 - NGOs). Apart from this, the Central Lab has also facilitated Institute research work (In-house and external funded projects) in the form of sample analysis using AAS, GC & CHNS. Figure 34 depicts month-wise samples analysed for Institute as well as other organizations

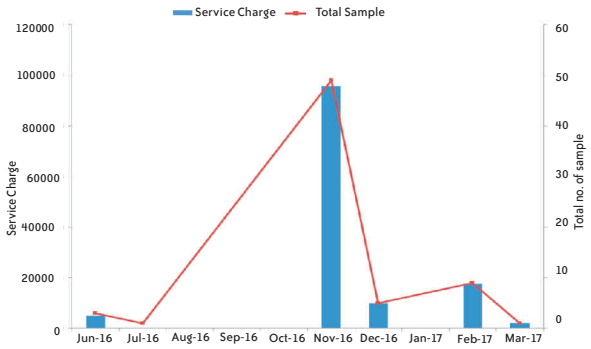


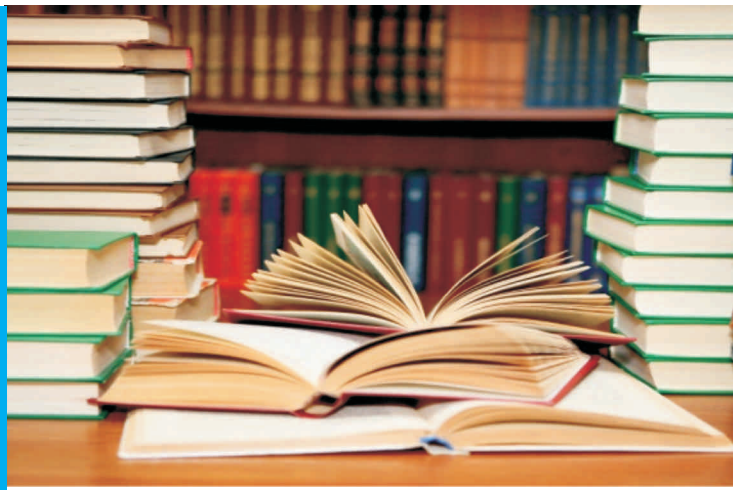
Fig. 34. Graphic representation showing total samples analysed in Central Laboratories

Strengthening and Maintenance of the Central Library at HQ

The Central Library of the Institute at its headquarters, at the end of financial year 2016-2017, has 16,737 books. The library is subscribing a total of 83 periodicals (44 Foreign and 39 Indian). For management of Library and Information Centre, a network version of the software PALMS developed by the Scientist of this Institute is being used. As a result, the Library is providing a number of services such as Article Alert, Current Awareness, Selective Dissemination of Information, Reprography, Reference, Indexing, Bibliography, Web Services (Online Journals) etc., for the development of the human resources. The Library of the Institute is accessible through the Institute's web site (http://gbpihed.gov.in).

During the reporting year, 123 new book titles were added to the Library. R & D achievements of the Institute were disseminated through its regular in-house publications, namely Hima-Paryavaran – a biannual newsletter and Institute Annual Report to various academic and scientific institutions, Government departments, NGOs, policymakers, planners and individuals working on various aspects of mountain environment and development.

MISCELLANEOUS ITEMS



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ANIL SHALINI & ASSOCIATES
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anilshaliniandassociates@gmail.com

INDEPENDENT AUDITOR'S REPORT

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

We have audited the attached Balance Sheet of **G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT AND SUSTAINABLE DEVELOPMENT** which comprise the Balance Sheet as at March 31, 2017, 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 give true and fair view of financial position, financial performance and cash flow and are free from material misstatement, whether due to fraud or error.

Auditor's Responsibility

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with the Standards on Auditing issued by the Institute of Chartered Accountants of India. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgement, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error .In making those risk assessments, the auditor considers internal control relevant to the Societies preparation and fair presentation of the financial statements in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of the accounting estimates made by management, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Opinion

In our opinion and to the best of our information and according to the explanations given to us, the financial statements of **G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT AND SUSTAINABLE DEVELOPMENT** for the year ended March 31, 2017 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 2017.**

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

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

Emphasis of Matter

We Draw attention to
Financial Statement, Point no. 4 of Significant accounting policy point no 4. Depreciation on fixed assets has been provided on straight line method as per the rate prescribed in the company's Act irrespective of days of use in first year depreciation is charged for whole year. In place of Income Tax Act 1961 and Income Tax Rules,

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: 04.07.2016

Place: Almora

For Anil Shalini & Associates
(Chartered accountants)

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

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
BALANCE SHEET AS ON 31ST MARCH 2017

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
LIABILITIES			
CORPUS / CAPITAL FUND	1	154562559.99	135850950.71
RESERVE AND SURPLUS	2	436363145.07	405080954.23
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	880498907.66	413012327.03
TOTAL		**1471424612.72**	**953944231.97**
ASSETS			
FIXED ASSETS	8	436363145.07	405080954.23
INVEST. FROM EARMARKED/ENDOWMENT FUND	9	143122867.99	122648277.71
INVEST. OTHERS	10	0.00	0.00
CURRENT ASSETS , LOANS, ADVANCES ETC.	11	891938599.66	426215000.03
MISCELLANEOUS EXPENDITURE			
TOTAL		**1471424612.72**	**953944231.97**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES & NOTES ON ACCOUNTS	25		

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

(Anil Kumar Shukla)
FCA PARTNER
M.NO.075418
FRN : 009960C

DATED : 04.07.2017
PLACE : KOSI- KATARMAL, ALMORA

(DR. P.P. DHYANI)
DIRECTOR

(DR. ANITA PANDEY)
D.D.O

04/7/17

(SURYA KANT)
FINANCE OFFICER

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
INCOME & EXPENDITURE A/C FOR THE YEAR ENDED 31ST MARCH 2017

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
INCOME			
Income from Sales/Services	12	308855.00	300163.00
Grants/Subsidies(net off exp)	13	224820366.32	218714275.6
Fees/Subscriptions	14	0.00	0.00
Income from Investment	15	0.00	0.00
Income tfr from Fixed Assets fund	-	27741768.16	25236908.15
(to the extent of depreciation & WDV of asset sold)		0.00	0.00
Income from Royalty, Income from Inv. Publication etc.	16	0.00	0.00
Interest Earned	17	15209306.28	15650959.02
Other Income	18	5369448.00	6591032.00
Increase (decrease) in stock of Finished goods and work in progress)	19	0.00	0.00
T O T A L (A)		**273449743.76**	**266493337.76**
EXPENDITURE			
Establishment Expenses: a) Institute	20	115752311.00	80322648.00
b) Projects		25741179.70	18402083.00
c) F.C (Projects)		3059539.00	4781177.00
Administrative Expenses :a) Institute	21	46344732.62	34786153.59
b) Projects (As per Annexure)		20229044.00	44973260.00
c) F.C (Projects)(As per Annexure)		6428951.00	15614243.00
Expenditure on Grants, Subsidies etc.	22	7264609.00	19834711.00
Interest			
Depreciation (Net Total at the year-end-as per Sch. 8)		27741768.16	25236908.15
T O T A L (B)		**252562134.48**	**243951183.74**
Balance being excess of Income over Expenditure (A - B)		**20887609.28**	**22542154.02**
Transfer to special Reserve			**0.00**
Transfer to/ from General Reserve			**0.00**
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Other Income)		**7339145.00**	**13202673.00**
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Corpus Interest Income)		**9594659.28**	**9339481.02**
BAL.BEING SURPLUS TRF.TO NMHS- PMU (Interest Income)		**3953805.00**	**0.00**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	25		

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

(Anil Kumar Shukla)
FCA PARTNER
M.NO.075418
FRN: 009960C
DATED : 04.07.2017
PLACE : KOSI- KATARMAL, ALMORA

(DR. P.P. DHYANI)
DIRECTOR

(DR. ANITA PANDEY)
D.D.O

(SURYA KANT)
FINANCE OFFICER

G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
RECEIPTS & PAYMENTS A/C FOR THE YEAR ENDED 31ST MARCH 2017

RECEIPTS	CURRENT YEAR	PREVIOUS YEAR	PAYMENTS	CURRENT YEAR	PREVIOUS YEAR
I. Opening Balances			**I. EXPENSES**		
a) Cash in hand	130098.50	50404.04	**a) Establishment Expenses**	85049117.70	84125313.00
			I) Institute		
b) Bank Balances			**b) Administrative expenses**		
			a) Institute	29900117.62	25720446.00
i) In current accounts		0.00	b) R&D(Rev) expenses	15770508.00	9366753.00
ii) In deposit accounts (Corpus Fund)	21602229.71	29321.71	c) Payments for current liabilities(gratuity/leave)	0.00	0.00
iii) Savings accounts	122457182.15	71844063.98	**C. Capital expenditure**		
c) Advances & Others	275228785.78	27119163.35	a) Purchase of Fixed Assets	12560030.00	7548754.00
(As per annexure Attached)			b)Expenditure on Capital Work in Progress	10900000.00	0.00
F.C. ACCOUNT			c) Acquirement of land (Lease money)		
A) Cash in hand	4305.33	19624.33	**II Payments made against funds for various proj.**		
b) Cash at bank	7967378.44	3595548.37	**Expenditure State govt. projects**		
c)FC Advances	12928662.89	12870109.82	a) Capital	30566691.00	17036110.00
II. Grants Received			b) Revenue:		
a) From Government of India	180000000.00	126250000.00	Establishment exp	25665744.00	17896975.00
i) Institute & IERP			Administration exp	18776178.00	44981070.00
			Expenditure FC projects		
b) From Other agencies	507242377.00	380026253.00	**a) Capital**	540220.00	405884.00
c) From other sources [from FC]	11690326.87	24629679.77	**b) Revenue:**		
III. Income on Investments from			Establishment exp	3264994.00	4588871.00
a) Corpus Fund(Received from Institute)	11026673.00	9081520.00	Administration exp	6428951.00	15614243.00
IV. Interest Received			**IERP grant released**	7264609.00	2025610.00
a) On Bank deposits savings a/c	9807255.00	6639530.00	**III Investments and deposits made**		
b)On term deposits a/c	1645126.00	5411765.00	Corpus Fund	37600000.00	19800000.00
c) Loans, Advances etc.	181218.00	368049.06	**IV Refund of Surplus money/Loans**		
			a) To the Government of India	953567.00	2864858.00
V. Other Income			b)To Others/ security/ caution money)	40922.00	155674.00
(As per annexure Attached)	5329003.00	6891195.00	**V Other payments**		
VI. Amount Borrowed			Other Payment to Instt. FC`Proj.	704902.00	213686.00
VII. Any other receipts.			Unspent Balance (FC)	0.00	310519.63
			Payment of Current Libilities	2177900.00	
			Refund of EMD	0.00	0.00
			Fund transfar to Corpus fund	11026673.00	9081520.00
a) Other Receipt FC a/c	0.00	0.00	**VI Closing balances**		
b) Receipts Current Liabilities	0.00	0.00	**a) Cash in hand**	65695.72	130098.50
c) IERP grants refunded by grantee Org.			**b) Bank Balance**		
d)Construction Fund			i) In Current account		
e) Corpus Fund FDR'S	39348801.00	26672007.00	ii) In deposit accounts (Corpus Fund)	43332194.71	21602229.71
f) Caution Money	8000.00	4500.00	iii) In savings accounts	448145165.67	122457182.15
g) Security Deposit	401240.00	2000.00			
h) EMD	310675.00	541250.00	**C) Advances and others**	392976876.71	275228785.78
i) Royalty	0.00	0.00	**FC Project**		
j) Sales Tax / VAT	22714.00	8945.00	a) Cash in hand	36870.33	4305.33
k)Service Tax	2218.00	0.00	b) Bank Balance	8487057.27	7967378.44
			c) Advances and others	13127678.93	12928662.89
			Adjustment of previous year closing Advances	1971606.01	0.00
TOTAL	1207334269.67	702054929.43	TOTAL	1207334269.67	702054929.43

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

(Anil Kumar Shukla)
FCA PARTNER
M.NO.075418
FRN: 009960C
DATED : 04.07.2017
PLACE : KOSI- KATARMAL, ALMORA

(Dr. P.P. DHYANI)
DIRECTOR

(Dr. ANITA PANDEY)
D.D.O

(SURYA KANT)
FINANCE OFFICER

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
SCHEDULE FORMING PART OF BALANCE SHEET AS ON 31ST MARCH 2017

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	813804.00	135634.00	0.00	949438.00	3119588.00	3255222.00
2	**BUILDING:**										
	a) On Freehold Land	214751988.00	31095878.00	0.00	245847866.00	47187003.82	4007320.22	0.00	51194324.03	194653541.97	167564984.18
	b)D.B.Manag.Centre(NMHS -PMU)	0.00	6570636.00	0.00	6570636.00	0.00	107101.37	107101.37	0.00	6463534.63	0.00
3	**PLANT MACHINERY & EQUIPMENT**										
	a) Scientific Equipments	211431231.11	23637469.00	0.00	235068700.11	117542572.65	10807285.98	0.00	128349858.63	106718841.48	95691937.17
4	**VEHICLES**	12475231.30	0.00	1005264.00	11469967.30	10373028.22	975396.73	1005264.00	10343160.94	1126806.36	2102205.08
5	**FURNITURE FIXTURES**	31391446.40	2328769.00	0.00	33720215.40	23137982.70	2134489.63	0.00	25272472.34	8447743.06	8253463.69
6	**OFFICE EQUIPMENT**	30974669.35	4288809.00	0.00	35263478.35	23386359.68	3350030.44	0.00	26736390.12	8527088.23	7588309.67
7	**COMPUTER/PHERIPHEARLS**	3115863.00	754533.00	0.00	3870396.00	317074.62	183843.81	0.00	500918.43	3369477.57	2138509.67
7	**ELECTRICAL INSTALLATION**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	**FIRE FIGHTING EQUIPMENTS**	60962.00	0.00	0.00	60962.00	57913.94	2895.70	0.00	60809.63	152.37	3048.07
9	**LIBRARY BOOKS**	117713762.50	7003435.00	0.00	124717197.50	60239103.56	5924066.88	0.00	66163170.44	58554027.06	56331658.94
10	**TUBE WELLS & W. SUPPLY**										
11	**OTHER FIXED ASSETS**										
	GLASS / NET HOUSE	3911549.00	0.00	0.00	3911549.00	3482998.48	113703.41	0.00	3596701.89	314847.11	428550.52
	TOTAL OF CURRENT YEAR	**629971367.89**	**75679529.00**	**1005264.00**	**704645632.89**	**286537841.66**	**27741768.16**	**1112365.37**	**313167244.46**	**391371287.07**	**343433528.22**
	PREVIOUS YEAR	**605072619.89**	**25020738.00**	**121990.00**	**630215347.89**	**261174230.40**	**25236908.15**	**0.00**	**286411138.55**	**343433528.23**	**343898389.50**
	B CAPITAL W I P										
	Acquirement of land (Lease money)	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CCU Delhi	**61647426.00**	10900000.00	27555568.00	44991858.00	0.00	0.00	0.00	0.00	44991858.00	61647426.00
	ASSET UNDER INSTAL/TRANSIT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	**691618793.89**	**86579529.00**	**28560832.00**	**749637490.89**	**286537841.66**	**27741768.16**	**1112365.37**	**313167244.46**	**436363145.07**	**405080954.22**

Anil Shalini & Associates
DELHI
FRN: 009960C
Chartered Accountants

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

STATEMENT OF OPENING & CLOSING BALANCES

PARTICULARS	OPENING AMOUNT	CLOSING AMOUNT
Grant in aid in transit (Biotech-XIII)	184000.00	184000.00
Cheque in transit: (HP Unit)	0.00	0.00
Cheque in transit: (G Unit)	0.00	925000.00
Cheque in transit: (Sk Unit)	0.00	0.00
Cheque in transit: (N.E. Unit)	0.00	0.00
Cheque in transit: (Core Grant)	0.00	10000000.00
Advances		
Electrecity Charges Recoverable	4575.00	4575.00
Income receivable form HP Unit	0.00	322436.00
NMHS- PMU Wages Surya Kunj receivable	0.00	40922.00
House Building Advance	442673.00	66678.00
Motor cycle/Car Advance	103975.00	120551.00
Festival Advance	40500.00	0.00
Computer Advance	0.00	0.00
Income tax deducted at source	191498.00	191498.00
Units of Institute:		
Sikkim Unit	-62552.83	-62552.83
HP Unit	7214.00	-155358.03
Garhwal Unit	57179.50	0.00
NE Unit	235459.00	41820.00
FDR (Margin Money/LC A/C)		
Institute	0.00	0.00
DST NMSHE TF 3	60078.00	2687676.00
DST SERB JCK H. P. Unit	0.00	0.00
SAC S. Trafdar G. Unit	0.00	0.00
TOTAL:	**1264598.67**	**14367245.14**

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

Brought forward	1264598.67	14367245.14
Due Staff/ other IC A/c		
Sh. Chandra Lal	0.00	10000.00
Dr. I. D. Bhatt (L.T.C)	0.00	0.00
STUP Consultant	(7435.00)	(7435.00)
M/S International Trade Links, Mumbai	34328.00	34328.00
LICOR INC USA	0.00	0.00
Tuder Rose UK (Instt.)	0.00	0.00
S.K. Diesel Sales (Instt.)	0.00	0.00
Wipro GE Health Care (Instt.)	0.00	0.00
Adv. a/c of Airport Handling Service (SERB JCK H. P. Unit)	18371.00	18371.00
VPKAS Almora (Instt.)	26560.00	26560.00
Adv. to NIH Roorkee	100000.00	100000.00
Post Master G.P.O Almora	0.00	0.00
Employment News	48287.00	48287.00
Sigma Aldrich Chemicals	10590.00	10590.00
Siltap Chemicals Ltd (Biotech -III)	408.00	408.00
DST (LMS) ILTP NRSA Hyderabad	48000.00	48000.00
NRSA Hyderabad	35300.00	35300.00
R.K.Nanda & Sons	28517.00	28517.00
NICSI New Delhi	35106.00	35106.00
Security Deposit CET Sikkim Unit	11000.00	11000.00
NRSA Hyderabad (NNRMS Proj.)	222000.00	0.00
NRSA Hyderabad- Grant in Aid (NNRMS Proj.)	638441.00	638441.00
NRSA Hyderabad (ISRO GBP SSS)	350000.00	350000.00
NRSA Hydrabad (DST-KK-I)	7400.00	7400.00
Vankta Enterprises (MOE&F NBA RSR)	7100.00	7100.00
CCU New Delhi	10123178.00	5666158.00
NRSC Hyderabad (SERB GCSN)	200000.00	200000.00
Security Deposit NE Unit	1750.00	1750.00
Adv. a/c of NRSC Hydrabad (Snow & Glacier KK)	0.00	0.00
EE R.E.S. Almora (MOE&F (BG) RSR	3402000.00	3402000.00
EE R.E.S. Almora Insitute	1571000.00	1571000.00
WWF New Delhi (UNDP-CEF-GOL) NE Unit	(31930.00)	(31930.00)
Adv. a/c of M/s Mahindra & Mahindra Mumbai	0.00	0.00
E E R.E.S. Almora (HRDI I.D.B. Project)	59000.00	59000.00
Adv. a/c of Chief Secretry Nagaland (Mountain Division)	0.00	0.00
Adv. a/c of Meteorological Department	8000.00	8000.00
Adv. a/c of Chief Coservator Eco Toursm D. Dun (Mountain Division)	500000.00	0.00
Adv. a/c of NRSC Hydrabad (Project No. 04)	24000.00	24000.00
Adv. a/c of of FRI Dehradun MoE&F (NNRMS)	1465104.00	0.00
Adv. a/c of Contrution Division II Pay Jal Nigam (MoE&F Botanical Garden	2493000.00	2493000.00
Adv. a/c of TATA Motors Ltd.	2836.00	2836.00
Adv. a/c of Director M. S. Sawaminathan (NNRMS)	1644000.00	1644000.00
Adv. a/c of Partners NMHS enclose **Annexure 'X'**	253285620.00	361706220.00
Adv. a/c of Ms. Poonam Mehta	198.00	198.00
Adv. a/c of NRSC Hydrabad (NMHS IHTP S. Sharma)	0.00	200000.00
Adv. a/c of Indian Institute of Technology (NMHS-ST)	0.00	530000.00
Adv. a/c of D. F. O Almora (NMHS-ST)	0.00	187740.00
Adv. a/c of Mahila Haat New Delhi (NMHS-DSR)	0.00	239000.00
FC Advances to Units	(2397541.89)	(695312.93)
TOTAL	**275228785.78**	**392976877.21**

FC Advances:		
ICIMOD RSR (LOA-I)Director, Wild Life Dehradun	729000.00	729000.00
ICIMOD RSR (LOA-III)Director, Wild Life Dehradun	270250.00	270250.00
ICIMOD RSR (LOA-I)M/S TATA Motars N. Delhi	177.00	177.00
ICIMOD India Day Workshop Habitat World N.Delhi	70000.00	70000.00
ICIMOD India Day Workshop The Energy Resources instt. N. Delhi	75000.00	75000.00
E.T.& T.N.DELHI(INDO-CANADIAN SUMMER)	2880.00	2880.00
NRSA HYDERABAD(PARDYP)	32274.00	32274.00
GBPUA&T, Pantnagar, PDF-B-GEF	265750.00	265750.00
XSPUH &F Solan, PDF-B-GEF	150956.00	150956.00
Uttrakhand State Biodiversity Board ICIMOD-RSR (LOA-I)	3202704.00	3956449.00
Adv. a/c of VPKAS PDF B GEF	268410.00	268410.00
Adv. a/c of Dr. R. S. Rawal (ICIMOD RSR KSLCDI	0.00	0.00
Adv. a/c of Dr. G. C. S. Negi (ICIMOD RSR KSLCDI	0.00	0.00
Adv. a/c of Uttarakhand Forest Deptt. ICIMOD RSR KSLCDI	3494000.00	3494000.00
Adv. a/c of Himalayan Gram Samiti ICIMOD RSR KSLCDI	982100.00	982100.00
Adv. a/c of U. SAC Dehradun (Main -New)	885500.00	1403000.00
Adv. a/c of Himalayan Seva Samiti (Main - New)	102120.00	102120.00
Adv. a/c of EE Construction Div. II Pay Jal Nigam	0.00	630000.00
FC ADVANCES TO UNIT	2397541.89	695312.93
	12928662.89	**13127678.93**

INSTITUTE SUPPORTING STAFF

HEAD QUARTERS

Mr. Anil Kumar Yadav	Administrative Officer
Surya Kant Langayan	Finance Officer
L.M.S. Negi	Office Superintendent (Admn.)
Sanjeev Higgins	Technical Gr. – III (3)
Mahesh Chandra Sati	Technical Gr. – IV (1)
Sarita Bagdwal	Stenographer
Jagdish Kumar	Stenographer
Mamta Higgins	U.D.C.
Heera Singh	U.D.C.
K.K. Pant	U.D.C.
Hema Pandey	U.D.C.
Suraj Lal	L.D.C.
Jagdish Singh Bisht	Technical Gr. – II (2)
Chandra Lal	Driver
K.N.Pathak	Technical Gr. – I (3)
Pan Singh	Group-C
Nathu Ram	Group-C
Ganga Joshi	Group-C
Kanshi Ram	Group-C

GARHWAL UNIT

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

HIMACHAL UNIT

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

SIKKIM UNIT

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

INSTITUTE FACULTY

HEAD QUARTERS

P.P.Dhyani	Director	Plant Physiology; Restoration Ecology
Kireet Kumar	Scientist-G	Environmental Engineering; Hydrology
S.K. Nandi	Scientist-G	Plant Physiology; Biochemistry
R.C. Sundriyal	Scientist-G	Plant Ecology; Rural Ecosystems
Anita Pandey	Scientist-G	Microbiology
D.S. Rawat	Scientist-F	Settlement Geography; Rural Ecosystems
R.S. Rawal	Scientist-F	High Altitude Ecology; Conservation Biology
R.C. Prasad	Scientist-F	Library & Documentation
G.C.S. Negi	Scientist-F	Forest Ecology; Watershed Management; EIA
Subrat Sharma	Scientist-E	Agroecology; Remote Sensing / GIS
Paromita Ghosh	Scientist-E	Plant Science; Soil Science
I.D. Bhatt	Scientist-E	Plant Physiology; Phytochemistry
R.K. Singh	Scientist-D	Information Technology
Ranjan Joshi	Scientist-D	Ecology Economics; Resource Valuation
Rajesh Joshi	Scientist-D	Mathematical Modeling
K.C. Sekar	Scientist-D	Plant Taxonomy; Animal Taxonomy
Vasudha Agnihotri	Scientist-C	Soil Science; Plant Analysis; Instrumentation
Harshit Pant	Scientist-B	Forest Ecology
Sandipan Mukherjee	Scientist-C	Climate Change; Ecosystem Services
B.S. Majila	Tech. Grade IV (4)	Forest Ecology; Restoration Ecology
Subodh Airi	Tech. Grade IV (3)	Forest Ecology; Biotechnology

HIMACHAL UNIT

S.S. Samant	Scientist-G & In-charge	Plant Taxonomy; Conservation Biology
J.C. Kuniyal	Scientist-F	Development Geography; Waste Management
R.K. Sharma	Scientist-D	Policy Analysis; Environmental Management
Sarla Shashni	Scientist-C	Rural Entrepreneurship and Small Business
Vaibhav Eknath Gosavi	Scientist-B	Hydrology; Watershed Management
Kishore Kumar	Tech. Grade IV (I)	Zoology

SIKKIM UNIT

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

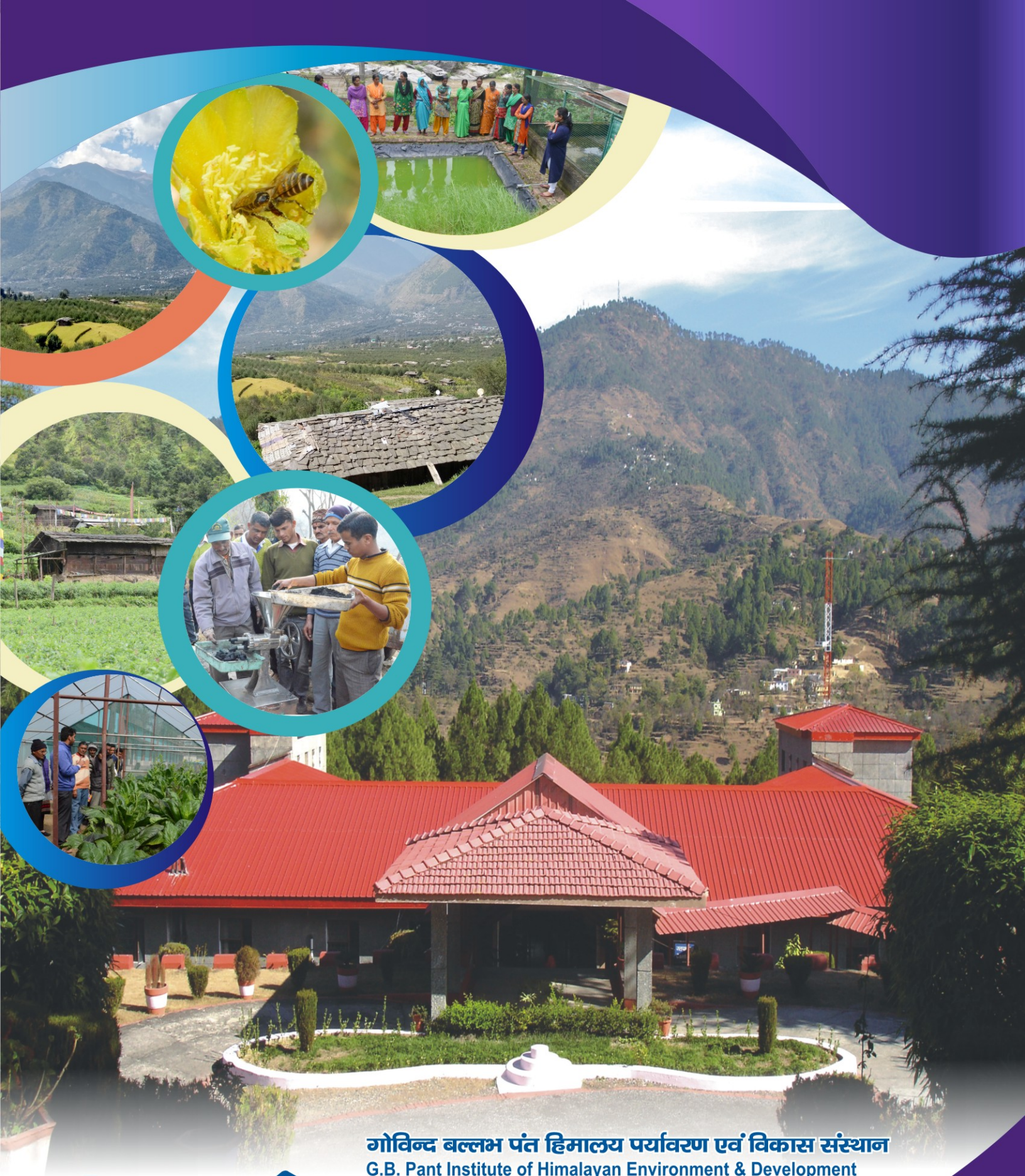
L.K. Rai	Tech. Grade IV (3)	Plant Taxonomy
Y.K. Rai	Tech. Grade IV (3)	Rural Ecosystems

GARHWAL UNIT

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

NORTH-EAST UNIT

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



गोविन्द बल्लभ पंत हिमालय पर्यावरण एवं विकास संस्थान

G.B. Pant Institute of Himalayan Environment & Development

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