GBPIHED

ANNUAL REPORT

2018-2019

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

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Climate Change
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Former Chief Secretary, Arunachal Pradesh
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Kashmere Gate, Delhi

Member Secretary
Director, GBPIHED, Kosi-Katarmal, Almora

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FOREWORD

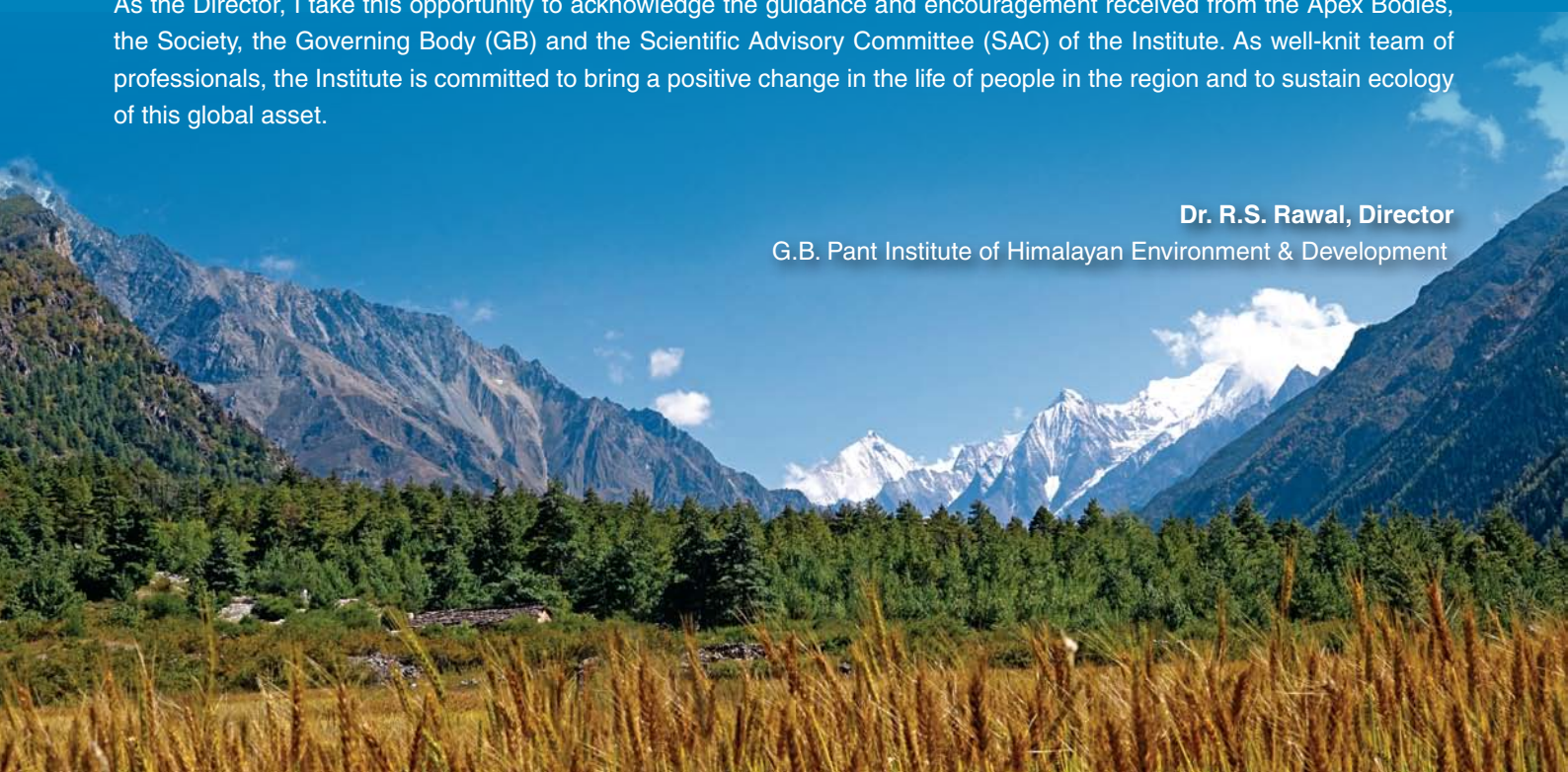
The Institute is dedicated to environmental conservation and sustainable development of the Indian Himalayan region (IHR). Therefore, the research and developmental programmes of the Institute are interdisciplinary in nature and multi-disciplinary in approach, which address contemporary issues pertaining to ecological, social and economic domains. Institute makes an earnest effort to implement the programmes in a manner to explicitly accommodate region-specific needs, and demonstrate efficacy of approaches on ground and disseminate information through knowledge products to diverse stakeholders.

During the reporting period (Year 2018-19), the Institute's expertise was recognized by way of inclusion in certain important initiatives of Govt. of India. For instance, the Institute was identified by NITI Aayog as a lead Institution for Working Group on "Data and Information Availability for Informed Decision Making by Multiple Stakeholders". Institute also became part of the NITI Aayog's Working Group on "Inventory and Revival of Springs in the Himalayas for Water Security" wherein the Institutional scientific knowhow of mountain springs and their linkages to Himalayan community was shared and documented. As a contribution to national skill building programme, the Institute organized 11 Green Skill Building Programmes for youths of the IHR states.

The Institute continues to bring advancements in achieving its R&D targets. In this context, major achievements include: estimation of discharges and sedimentation rates from Chipa and Khangri glaciers of Uttarakhand and Arunachal Pradesh; preparation of digital database of springs of Kali watershed and establishment of discharge gauging stations over Kali and Saryu rivers of Uttarakhand; establishment of five climate monitoring stations in Sikkim; long-term monitoring of surface O_3 and its precursors like nitrogen oxides, mean aerosol optical depth and black carbon at Kothi, Himachal Pradesh; monitoring of daily concentration of columnar ozone at Katarmal, Almora, Uttarakhand; discovery of *Meconopsis merakensis* var. *merakensis* as a new record for flora of India and *Gentiana urnula* and *Codonopsis thalictrifolia* as new record for flora of Arunachal Pradesh; promotion of nature tourism and strengthening of home-stays and rural tourism in 8 villages in Kedarnath valley of Uttarakhand; support to 346 households for various environment friendly income and livelihood generating activities across the IHR. Towards improving regional outreach and further strengthening R&D based conservation and development initiatives in the IHR, the Institute entered into a Memorandum of Understanding with International Centre for Integrated Mountain Development (ICIMOD). The Institute successfully implemented the action plan for three trans-boundary landscape conservation and development initiative facilitated by ICIMOD. The scientific excellence of the Institute is well reflected through ever increasing number of publications in peer-reviewed high-impact scientific journals of national as well international repute.

As the Director, I take this opportunity to acknowledge the guidance and encouragement received from the Apex Bodies, the Society, the Governing Body (GB) and the Scientific Advisory Committee (SAC) of the Institute. As well-knit team of professionals, the Institute is committed to bring a positive change in the life of people in the region and to sustain ecology of this global asset.

Dr. R.S. Rawal, Director
G.B. Pant Institute of Himalayan Environment & Development



MAJOR ACHIEVEMENTS (2018-2019)

1. Institute was identified by NITI Aayog as a lead Institution for Working Group on "Data and Information Availability for Informed Decision Making by Multiple Stakeholders" for Sustainable Development of Himalaya. The study report prepared by the Institute was released on August 2018 at NITI-Aayog, GoI, New Delhi.

2. A spring inventory map and gauging site location map of the Kali watershed was prepared to depict distribution of springs in the basin. In Dhauliganga (Uttarakhand), Parvati (Himachal Pradesh) and Sindh (J&K) rivers water quality parameters were studied and were found under the permissible limits.

3. Based on discharge dynamics over two years on two glacier systems (Chipa and Khangari) total loss of 0.275±0.017 km^3 volume for Chipa glacier and 0.21613±0.017 km^3 for Khangri glacier was estimated.

4. Ingredients used in the preparation of traditional cuisines for their nutritional and anti-nutritional properties along with mineral content were estimated. Total protein, carbohydrates, fat, fibre, ash and moisture were evaluated under proximate analysis.

5. Long-term monitoring of surface O_3 and its precursors like nitrogen oxides ($NO + NO_2$) at Kothi, H.P., daily concentration of columnar ozone at Katarmal, Almora (Uttarakhand), mean aerosol optical depth (AOD_{500nm}) and black carbon at Kothi and Mohal, H.P. served as an useful background data to relate vehicular pollution, biomass burning and forest fire across the western Himalaya.

6. Using restoration opportunities assessment methodology (ROAM) broad restoration opportunities were identified at Uttarakhand state, through a participatory process involving a range of stakeholders such as Van Panchayats, Gram Sabha, NGOs, state line departments, and active community members across Block and Distt. HQs in Pauri Garhwal and Pithoragarh districts and various bio-physical measures suiting to ecological conditions of the degraded forest landscape were suggested.

7. *Meconopsis merakensis* var. *merakensis* was discovered as a new record for flora of India and *Gentiana urnula* and *Codonopsis thalictrifolia* reported as new record for flora of Arunachal Pradesh.

8. Geographical distribution and status of plant resources (trees and shrubs, including lichens) were quantified and a herbarium has been established at Sikkim Regional Centre; 511 specimens of angiosperms and 321 specimens of lichens have been kept in the herbarium.

9. Along altitudinal gradient in Yuksam-Dzongri transect, West Sikkim, 5 climate monitoring sites were established and one year data recorded for tree line environment revealed a temperature lapse rate (–0.53 °C/100 m), which is the first report from this region.

10. Capacity and skill development of local people was affected in home stay accommodation, rural tourism, nature guides and tourism product development based on agro and wild bio resources. Thus, promoted nature tourism and strengthened home stay and rural tourism in 8 villages in Kedarnath valley of Uttarakhand.

11. To facilitate model village development, a participatory planning process was adopted and a 'Village Development and Action Plan' was prepared and priority actions and interventions were implemented in Bhetuli village (Distt. Almora). The district administration following this plan has identified 11 villages as 'Adarsh Gram'.

12. In view of abundance of chir-pine forests in the region that are susceptible to fire hazards, a chir-pine needle processing unit has been successfully set up (with the support of National Mission on Himalayan Studies) wherein paper, file folders, bags and handicraft items were prepared. Village community has been involved to supply raw material (chir-pine needles) that proves to be fire hazard in the forests of Uttarakhand.

13. Through various R&D projects benefitted 346 households for various income and livelihood generating activities by supporting protected cultivation, cash crop cultivation, fish farming, poultry farming, vermi-composting, bio-briquette making, and protected cultivation. A total of 24 trainings were organized at the Rural Technology Centre (RTC) for adoption of low-cost technologies along with 17 trainings in villages benefitting 1483 farmers.

14. Institute organized 11 Green Skill Building Programmes (GSBP) on various thematic areas and built skills of 238 youth (103 females and 135 males) across five states of IHR following the guidelines of Ministry of Skill Development and Entrepreneurship, GoI.

15. Under Swachh Bharat Mission 'Swachhta Hi Seva' a total of 910 citizens, students, teachers and common persons were involved in various cleanliness drives organized in different villages and townships across the IHR.

16. Various capacity building programmes were organized at HQs and four regional centres (Garhwal, Srinagar; Himachal, Kullu; Gangtok, Sikkim; Itanagar, Arunachal Pradesh) on various issues of forest resource management, climate adaptation/mitigation, home stay accommodation, agro-production system, bio-prospecting, tourism product development and livelihood enhancement.

Publications

1. Peer Reviewed Scientific Journals		
National	-	22
International	-	39
2. Chapters in Books/Proceedings	-	23
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EXECUTIVE SUMMARY

The G.B. Pant Institute of Himalayan Environment & Development (GBPIHED) mandated with environmental conservation and sustainable development of the Indian Himalayan Region (IHR) as the fundamental goal, addresses front-running environmental issues of physical, biological and socio-economic nature of the region in an integrated manner. Thus, the R&D mandate of the Institute is broad and covers all the facets of environment and development. Towards achieving this goal, in-depth knowledge generation through multidisciplinary R&D projects and integration of multiple subjects is the guiding principle. Further, emphasis is given on interlinking of natural and social sciences in all the R&D projects of the Institute. In this endeavour, special attention is placed on the intricate balance between fragility of mountains, indigenous knowledge and sustainable use of natural resources. Stakeholder's viewpoint and feed-back is always kept into consideration in designing and implementing R&D activities. Adequate efforts are devoted to address priority environmental problems, development and demonstration of best practices, technology packages and delivery systems for improved livelihood of the people in most of the programmes undertaken by the Institute. Also, conscious efforts are made to mobilize a variety of stakeholders (students, researchers, academicians, farmers, citizens, NGOs, policy makers, and others) to participate in our programmes through different initiatives. Therefore, training, education and awareness of a range of stakeholders are the essential components of all the R&D programmes. The R&D activities of the Institute are conceptualized, governed and executed through four centers of eminence and five regional centers. These are: (i) Center for Land and Water Resource Management (CLWRM); (ii) Center for Socio-Economic Development (CSED); (iii) Center for Biodiversity Conservation and Management (CBCM); and (iv) Center for Environmental Assessment and Climate Change (CEA&CC). The regional centers of the Institute are: (i) Himachal Regional Center; (ii) Garhwal Regional Center; (iii) Sikkim Regional Center; (iv) North-East Regional Center; and (v) Mountain Division Regional Center housed in MoEF&CC, New Delhi. A brief summary of R&D activities and achievements of different centers of the Institute during the reporting year 2018–19 is as follows:

1. Center of eminence

(i) Center for Land and Water Resource Management (CLWRM)

This center was created with the aim to work on integrated management and sustainable use of land and water resources with advancement of science-based solutions for their conservation. The focal areas of activities of the center are land and soil management, water sustainability, glacier system and climate and geo-hazard assessment. The vision of the center is to integrate land and water resources management to support sustainable development in IHR. The mission of the center include to develop action plan for land and water resource sustainability in IHR through intensive research on mapping of resource dynamics, hydrological and geological processes, and analyses of socio-ecological issues to provide sustainable solutions towards optimal resource use, participatory interventions, technological solutions, and policy recommendations. The centre aim to (i) conduct studies on water and related eco-sociological processes operational at watershed level including upstream- downstream linkages, (ii) develop tools and techniques of sustainable land management considering various developmental interventions, and (iii) provide inputs to government and other policy makers for bringing in mountain perspective in LWRM policies. During reporting year, center initiated activities on major in house project "Water Sustainability Mapping - Options, Issues and Impacts" with the aim to study the water sustainability in Kosi and Kali Watersheds in Kumaun Himalaya in the light of its availability to agriculture and household use, hydropower development potential, and its sacred value as pilgrimage/ religious tourism. In another study on Himalayan cryosphere in Uttarakhand and Arunachal Pradesh monitoring of two glaciers for retreat and discharge was carried out. To design and testing alternative intervention strategies for effective remediation and sustainable water management GIS based LULC maps were produced for 1999 and 2017 to identify major changes in the land use category for the Kosi-watershed (Kumaun Himalaya). Efforts were also made towards enhancement of the quality of livelihood opportunities and resilience for the people in the Indian Himalayas, through design of intervention strategies aimed at maximizing resource potential and minimizing risks in urban-rural ecosystem.

(ii) Center for Socio-Economic Development (CSED)

Sustainable development of rural ecosystem has been a challenging task in the Himalayan region in view of diverse environmental, socio-cultural or economic set up across the length and breadth of the IHR. Most mountain areas are facing problems related to unplanned development, degradation of natural resources, land use change, and sustained livelihood and migration, which has drawn wide attention in recent times. The Center for Socio-economic Development (CSED) has been engaged in diverse range of livelihood and natural resource management issues including documentation of mountain

specific indigenous knowledge on natural resource management, community livelihood, socio-economic database, and drivers of change. Its area of operation include, strengthening sustainable livelihood through promotion of on-farm and off-farm activities; demonstrating and disseminating specifically designed models and knowledge products; and strengthening entrepreneurial skills and self-employment opportunities through capacity building in rural areas. In the reporting year CSED has undertaken five projects with the focus to address priority problems and management of natural resources. To facilitate rural development by creating opportunities to upgrade income and livelihoods of rural communities a 'Model Village Development' approach was taken up in Almora district involving an innovative community-driven participatory planning approach. In a project on 'Livelihood improvement by integrated natural resource management' a total of 8 villages have been targeted for introducing innovative approaches and practical models for adaptive resource management. Under the Network Programme on convergence of traditional knowledge system for sustainable development' a total of 23 communities residing in six Himalayan states (viz. Arunachal Pradesh, Nagaland, Sikkim, Dajeeling district in WB, Uttarakhand, Himachal Pradesh) were investigated. In view of abundance of chir-pine forests in the region that are susceptible to fire hazards, a chir-pine needle processing unit has been successfully set up for manufacturing paper, bags and handicraft items. Village community has been involved to supply raw material (chir-pine needles) thus reducing the risk of forest fire. As an integrated farming approach three villages have been targeted for designing and demonstrating polythene lined fish ponds, a low cost poultry shed, and vegetable cultivation. CSED is extending training and capacity building support for establishment of rural bio-resource complex for economic empowerment of Himalayan communities. Besides, the centre has also extended technical support to state agencies, line departments, and district administration. Thus in the reporting year CSED targeted 14 villages (population 4045) and directly benefitted 346 households for enhancing their income generation and livelihood using various low-cost and environment-friendly technologies. Also, for adoption of low-cost technologies and income generating measures a total of 24 trainings were organized at Rural Technology Centre (RTC) thus benefitting 1483 farmers of 17 villages of the region.

(iii) Center for Biodiversity Conservation and Management (CBCM)

The center has been created to explore and assess, set conservation priorities and monitor Himalayan biodiversity elements using state-of-art approach, and transform data and information into knowledge that supports conservation and sustainable management of biodiversity. Collaborative and multidisciplinary research on *in-situ* and *ex-situ* conservation of biodiversity, forest ecosystem services and biotechnological applications are the focal areas of R&D activities of the center. The aim is to further strengthen science based understanding on Himalayan biodiversity to promote its conservation and to ensure sustained flow of its services for human well-being. The center envisages to (i) emerge as a core contributor for promoting integrative biodiversity science in the Himalaya to support decision making and foster science-policy-practice linkages, and (ii) act as a nodal referral and capacity building center on Himalayan biodiversity conservation and sustainable use. During the reporting year, CBCM succeeded in establishing one major long term ecological monitoring (LTEM) site to realize a major objective of in-house project "Long-term Ecological Monitoring in Western Himalaya and Knowledge Generation for Decision Making" so as to understand intensity and direction of on-going and potential changes on structure and functioning of biodiversity under the influence of climate change. Climate change impacts on forests of timberline zone of the selected locations of IHR are also being studied. Substantial efforts were put into exploration and assessment of biodiversity elements through continued field work in remote locations of IHR. Various *ex situ* and *in situ* conservation approaches were also employed targeting conservation of important species from the standpoint of loss of biodiversity. In this direction conservation of threatened plant species seeking participatory approaches of rural people is also implemented at several locations. To monitor the extent of distribution of high value plants in the alpine zone hyperspectral imaging technique is applied. Among the *ex situ* approaches for biodiversity conservation a genomic platform for apple varieties has been maintained. Also, quality plant production and promotion of cultivation of selected Himalayan medicinal plants for livelihood enhancement has been taken up among the rural people.

(iv) Center for Environmental Assessment and Climate Change (CEA&CC)

The fragile Himalayan ecosystem is under the pressure of developmental activities of various magnitude across the region. These activities has a definite amount of negative impacts on various components of our ecosystem those need to be understood and attempts need to be made for mitigation of the negative impacts. Therefore, appropriate R&D based strategies are required to address the adverse impact on our environment. In the recent decades, climate change (CC) has been the another challenge faced by these fragile mountain ecosystems. It has been projected that even with global warming of 1-2 ^{o}C, much less than the most recent projections during this century, most ecosystems and landscapes will be impacted negatively, thereby making the economy and survival strategies of people more vulnerable to risks. The implications of these impacts can be seen on the livelihoods of people who depend on a variety of natural resources. Thus it is important to assess the likely impacts of projected CC on IHR and develop adaptation strategies for both

conservation and management of natural resources and safeguard the livelihoods of people. The Center for Environmental Environmental Assessment and Climate Change (CEA&CC) successfully achieved its targets during 2018-19. The ongoing activities during reporting period were mainly conducted through 11 projects across the IHR. In these projects impacts were assessed in the areas such as, habitat degradation due to biotic pressure on sub-alpine and alpine grassland ecosystems,, vulnerability and adaptive capacity of forest ecosystems to climate change, impact of forest fire and prevention strategies, impact of changing environmental conditions on selected medicinal plants and understanding adaptation mechanisms, anthropogenic and climate change impacts on aerosols (i.e., gaseous pollutants, columnar aerosol including black carbon). In addition, efforts were also made on characterization of spatial attributes of timberline vegetation using remote sensing, clean energy development to mitigate impacts of climate change, preparation of coherent database for forest resources and plant diversity, monitoring of biodiversity in relation to changing climate, validation of climate model projections, sensitization and capacity building of inhabitants.

2. Regional Centers

(i) Himachal Regional Center

The Himachal Regional Center (HRC) caters to the need of entire Himachal Pradesh and Jammu & Kashmir state. This region falling under north-western Himalayan bio-geographic province is recognized for its unique natural resources manifested with ecosystem integrity, ecosystem services and human adaptations to tough terrain. Major thrust in this region was given on vulnerability assessment and conservation prioritization of biodiversity from anthropogenic pressure. Also, due to sprawling urban townships management of solid waste is another major thrust area. Himachal being rich in hydro-power projects, efforts were also devoted to understand the river hydrology and water resources. During the reporting period, studies have been conducted on solid waste management; population assessment of important plant taxa, standardization of propagation protocols and establishment (*ex situ* & *in situ*) of selected plants; identification of elite planting material of selected temperate medicinal plants, mass multiplication of elite plants, field demonstration and post-harvest processing; community based conservation of bee flora and pollinator; development of sustainable rural livelihood options utilizing locally available bio-resources through transformative rural technologies and vulnerability assessment of mountain ecosystems due to climate change. The HRC also devoted its efforts towards development of Peoples' Biodiversity Register of selected Panchayats in Kullu district; develop environmental assessment and management framework of Sutlej Basin; water quality assessment of existing water sources in the lower Parbati Basin; 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; and hydrological monitoring and modelling of river basins.

(ii) Garhwal Regional Center

Garhwal Regional Center (GRC) mainly caters to the regional needs of diversification of livelihood options in rural ecosystems, demonstartion of eco-friendly rural technologies and sustainable land use practices, water resources management and eco-friendly tourism practices. The R&D activities of the center focus on: (i) understand climate change impact in rural landscape and adaptation and livelihood strategies (agriculture, horticulture, pastoralism and traditional livestock husbandry, NTFPs including MAPs), (ii) identify sustainable tourism (nature/community based rural tourism, pilgrimage, etc.) and its environmental, economic and socio-cultural impacts, (iii) approaches for water resource assessment, use and management, (iv) appropriate technology interventions for sustainable development of rural ecosystem, and (v) development of plant propagation packages for conservation, management and large scale cultivation using biotechnological and microbiological tools. Some of the on-going R&D areas during the reporting period include: climate change impact, adaptation and coping strategies, tracer technique in spring recharge, bioprospecting of wild resources, promotion and cultivation of medicinal and aromatic plants, sustainable tourism, conservation and management of protected areas and eco-sensitive zones and reconstruction of disaster affected rural landscape of Kedar valley (Uttarakhand).

3. Sikkim Regional Center

Sikkim state supports rich floral and faunal diversity with a high proportion of endemic and threatened species covering diverse ecosystems and habitats that represent the uniqueness of biodiversity. Local people are largely depended on natural resources for their livelihood. However over-extraction and utilization of the natural resources demands immediate measure to reverse the trend of degradation. Besides, it also needs strengthening participatory management, enhancement of livelihood and self sufficiency and policy review/analysis and capacity building. Major thrust area of Sikkim Regional center include: (i) biodiversity safeguarding at ecosystems, species and genetic level, including ecosystem services, (ii) natural resource use and sustainability, (iii) enhance implementation of strategies through participatory planning and Policy analyses, and (iv) socio-economic improvement/extension and knowledge management through capacity building. During

the reporting period the center has initiated a major in-house project "Gridded biodiversity database for conservation and development in Sikkim Himalaya (focus: woody taxa)" for assessing and quantifying the geographic distribution, conservation status and phytogeographic aspects of plant resources of Sikkim Himalaya. Major efforts were also devoted to activities such as Khangchendzonga landscape conservation and development initiative, community based tourism by linking livelihoods with nature conservation, developing disaster resilience action plan for natural disaster risk reduction in Shillong and Gangtok and quantifying population and distribution of selected high value medicinal plants of Sikkim Himalaya.

4. North East Regional Center

North-east region of India is rich in both natural resources and cultural diversity. However, this region is confronted with several environment and development issues such as: Shortening of fallow cycle & changed practices; changes in land use pattern, land tenure and ownership pattern, and customary laws; lack of appropriate policy packages and technological intervention for soil conservation, soil nutrient management and yield enhancement; loss of agro-diversity & promotion of mono-cropping, lack of marketing opportunities for farm produce, depletion of traditional knowledge base and policy deficiency in promotion of alternative & innovative livelihoods. The remoteness and inaccessibility of this region has left a big scope for inventorization of biodiversity, sacred groves, community conserved areas, village forests, hotspots and keystone species to address the issue of biodiversity conservation. There is a great scope are alternative employment opportunities based on biodiversity based tourism. Therefore, strengthening of alternative and innovative livelihood options, conserving indigenous knowledge system, capacity building and human resource development are key areas to pursue R&D work. The major thrust areas of the Center is to study on (i) sustainable socio-economic development and livelihood security (focus on shifting cultivation), (ii) conservation of biological diversity and ecological security, (iii) adaptation/mitigation of Climate Change (CC) impacts, (iv) ecotourism, and (v) sustainable technologies and capacity building. During the reporting period the center initiated a project entitled "Enhancing eco-cultural livelihoods in biodiversity rich areas of Arunachal Himalaya". Various stakeholders' consultation workshops were organized and possible role of the community in project implementation and outcomes have been identified. In addition to this, through various R&D projects attempts are made for enhancing livelihoods in biodiversity rich areas of Arunachal Himalaya, assessment of floral biodiversity and resource utilization pattern in the high altitude wetlands, Landscape Initiative for Far-Eastern Himalaya (HI-LIFE), assessment of biochemical and phytochemical content of selected threatened and high value plants and anthropogenic impacts and their management options in different ecosystems of the IHR.

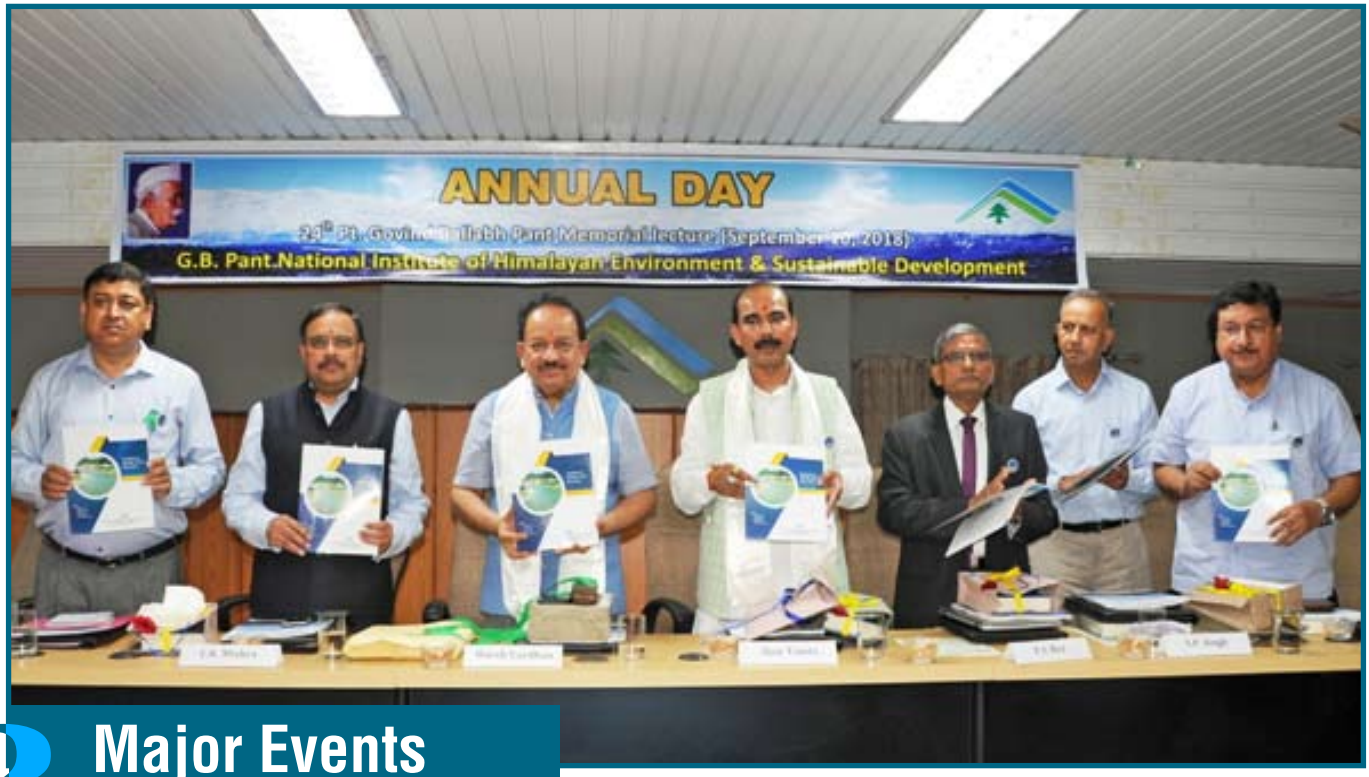
5. Mountain Division Regional Center

The MoEF&CC has established a dedicated unit as 'Mountain Division' within the MoEF&CC as fifth center of GBPIHED to address specific issues of the mountain ecosystem in an integrated manner through its Institutions, across the relevant key Ministries, and with NGOs and Academia to ensure conservation of mountain ecosystem and sustainable development of the mountain regions. The envisaged broad objectives of the Mountain Division are i) To contribute sustainable development of mountain ecosystems in integrated manner within divisions of the ministry and across the key ministries; ii) To sharpen focus on mountain issues by bringing in "Mountain Perspective" across policies, programmes, missions and schemes; iii) To foster linkages between upstream and downstream regions by influencing policy & planning based on mutual dependence; and iv) To develop a suitable framework of incentives for providers of ecosystem services. To achieve the objectives of the division the following project based studies are launched through Himalayan Research Fellows and Associates. The center through different fellowship projects has initiated to develop a GIS based land use modeling for studying the future projection and dynamic impact on IHR, understanding eco-physiology of selected medicinal plants with changing environment for better adaptation, and studying on the tradeoffs between conservation and livelihood outcomes in protected area management and assessment of alpine and sub-alpine ecosystems of Himachal Pradesh in relation to climate change and water quality assessment of existing water sources in H.P.

1 Introduction

During the year 2018-19, various R&D activities focusing on environmental conservation and sustainable development were executed by the Institute at different locations of the IHR through its HQs at Kosi-Katarmal (Almora) and five regional centers, viz., Himachal Regional Center (Kullu), Garhwal Regional Center (Srinagar-Garhwal), Sikkim Regional Center (Pangthang), NE Regional Center (Itanagar) and Mountain Division Regional Center (New Delhi). In all the R&D activities a major thrust has been to deal with issues of environmental conservation and sustainable development, develop region-specific approaches and demonstrate their efficacy in the field and disseminate information to various stakeholders. The diverse problems thus addressed through carrying out in-depth research on bio-physical and socio-economic aspects of mountain environment, devising R&D based strategies for natural resource conservation and management, documenting traditional practices of natural resource management, promote livelihood opportunities, develop approaches for biodiversity conservation, devise mitigation measures to the impact of climate change, biotechnological applications for conservation of important plant taxa, 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 funds R&D activities of various partner Institutions situated in different Himalayan states through Integrated Eco-development Research Programme (IERP) and National Mission of Himalayan Studies (NMHS). The Science Advisory Committee (SAC) of the Institute reviews the progress of existing projects and provides guidance to develop new R&D programmes. All these R&D projects are implemented through the four centers of eminence such as (i) Center of Land and Water Resource Management (CLWRM), (ii) Center for Socio-Economic Development (CSED), (iii) Center for Biodiversity Conservation and Management (CBCM), and Center for Environmental Assessment and Climate Change (CEA&CC), and the region specific issues are addressed by regional centers such as (i) Himachal Regional Center (HRC), (ii) Garhwal Regional Center (GRC), (iii) Sikkim Regional Center (SRC), (iv) North-East Regional Center (NERC), and (v) Mountain Division Regional Center housed at MoEF&CC.

During the reporting period, R&D work pursued on various projects across the IHR. Summaries of such completed projects are included at appropriate places in this report. In due course of time, relevant detailed documents will be published and made available for the various stakeholders. Particular thrust will be placed to bring out policy imperatives to handle front-running environmental issues of the region. In this report a brief account of academic and other activities, along with the statement of accounts for the year 2018–2019 carried out under various in-house and externally funded projects has been presented. 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 Major Events

Himalayan Researchers Consortium

The Himalayan Researchers Consortium (HRC) was organized by the Institute with an objective to share experiences, inspire researchers, build networks and take action on front-running environmental issues of the IHR such as conservation and management of Himalayan biodiversity, alternative livelihood options, skill development and capacity buildings for the conservation and management of natural resources. The Institute organized 1st HRC under the Chairmanship of Shri C. K. Mishra, IAS, Secretary, MoEF&CC, New Delhi along with other eminent invited experts and members at UCOST, Dehradun (26-27 April 2018). The Consortium brought together around 100 participants consisting of representatives from MoEF&CC, subject experts and Himalayan researchers and academia from eight different states of IHR. In this series, the IInd HRC was organized at Gangtok, Sikkim (26-27 November 2018) under the Chairmanship of Prof. G. K. Niraula Chhetri, Vice Chancellor, Sikkim State University, Gangtok, Sikkim along with other eminent invited experts and researchers. The Consortium brought together over 80 participants i.e. Subject experts and Himalayan researchers and academia from seven Himalayan States. Continuing the series, the IIIrd HRC was organized at GBPIHED HQs, Kosi-Katarmal, Almora, Uttarakhand under the Chairmanship of Prof. H.S. Dhami, Vice-Chancellor, Uttarakhand Residential University, Almora along with other eminent invited experts and members. This event was attended by 54 young Himalayan researchers.

Celebration of International Biological Diversity Day

International Day for Biological Diversity (IDB) 2018 focusing on this year theme: Celebrating 25 Years of Action for Biodiversity was celebrated at the GBPIHED HQs at Kosi-Kataramal, Almora and its four regional Centres located at Kullu (H.P.), Srinagar-Garhwal, (Uttarakhand), Pangthang (Sikkim) and Itanagar (Arunachal Pradesh) to mark the 25th anniversary of the entry into force of the Convention on Biological Diversity and to highlight progress made in the achievement of its objectives in the IHR (22-23 May 2018). At the Institute HQs, IDB celebration was inaugurated by Dr. R.S. Rawal, Director, GBPIHED in which 115 school students and teachers of various schools of Distt. Almora, Institute faculty and researchers participated. At this occasion a two-day's workshop was organized at Institute HQs in which school students organized a "Rally to beat plastic pollution" in the nearby Kosi town (Almora) and also staged a "Nukkar Natak". IDB was also celebrated by a team of Institute researchers at Narayan Ashram (Distt. Pithoragarh) in which 90 people / farmers from local villages and 80 students of local schools participated. At the H.P. Regional Centre, Kullu, IDB was celebrated in which 73 participants including Pradhans and Members of different Panchayats in Upper Kullu Valley and officials of Forest Deptt. and Wild Life participated. Shri B.L. Negi, Conservator of Forests, Kullu and Chief Guest addressed the participants. At the Garhwal Regional Centre IDB celebration was attended by about 60 participants including students and teachers. At the Sikkim and North-East Regional Centre, Itanagar IDB was celebrated with the school children and by organizing cleanliness drives.

Knowledge Sharing and Network Workshop

This workshop was organized by CBCM of the Institute under National Mission for Sustaining Himalayan Ecosystems (Task Force 3 -Forest Resources and Plant Biodiversity) (May 24-25, 2018). The objective of the workshop was to bring together young biologists, experts on relevant subjects; including Forestry, Ecology, Plant Biodiversity, Community Forestry, RS & GIS, Climatology, Ecological Modeling, etc., working in different universities and institutions of the region for discussion on possibilities of knowledge sharing & networking on 'Biodiversity-Forest Conservation and Management'. The workshop was organized into 5 sessions i.e. introductory session, presentations by young biologist, round-table discussion on 'Where do we stand?', brain storming session on what to do?, knowledge networking - concept to action and the valedictory session. The chief guest, Prof. M.P.S. Bisht (Director, USAC, Dehradun), underscored the need for consolidation of the available scattered information on various aspects of 'Forest Resources and Plant Biodiversity' for database development; which could be vital for climate change adaptation planning and biodiversity conservation in Himalayan region. Among the resource persons this workshop was attended by DR. S.D. Tewari (Kumaun University, Nainital), Dr. G.C. Joshi (Regional Ayurveda Research Institute, Ranikhet), Dr. Kiran Bargali (Kumaon University, Nainital), Dr. A.K. Yadava (Head, Forestry Dept. Kumaun University Campus, Almora), Dr B.S. Adhikari (WII, Dehradun), Dr. S.S. Phartiyal (HNB Garhwal University, Srinagar), Dr. Gajendra Rawat (USAC, Dehradun). Dr. R.S. Rawal, Director, GBPIHED in his concluding remarks urge for a deep understanding of subject knowledge before being a part of any research project. With this he provided sincere thanks to all the participants and experts. A total of 51 researchers (20 boys and 31 girls) and 11 experts from seven different institutions / organizations participated in the workshop.

World Environment Day

The GBPIHED participated in the World Environment Day (WED- 5 June 2018) organized at Vigyan Bhawan, New Delhi by MoEF&CC. In this event Hon'ble Prime Minister of India, Shri Narendra Modi was the chief guest. On this occasion the welcome address was given by Dr. Mahesh Sharma, Hon'ble Minister of State (MoS), MOEF&CC. During his address,

Dr. Harsh Vardhan, Hon'ble Minister, MoEF&CC mentioned that "Protecting mother earth is not just our political or social obligation, it is our moral responsibility." The Institute stall exhibited 3-D visual about "Kedarnath - Disaster to Restoration" that received wide appreciation by the MoEF&CC officials and participants of WED. At HQs of the Institute (Kosi-Katarmal, Almora, Uttarakhand), WED was inaugurated by Shri J. S. Mehta, Retired State Sliviculturist, Uttarakhand Forest Department in which 125 school students, researchers, scientific Faculty and staff of GBPIHED participated. Dr. R.S. Rawal, Director, GBPIHED highlighted the importance of such campaigns focusing on school children so that this message will be disseminated to larger number of people. On this occasion the Garhwal Regional Center organised a programme in which about 80 participants including students and teachers from different schools participated. On this occasion a two-days programme on waste management was organized in Gorkhey - a forest village in West Bengal (3-4 June 2018) on the WED theme of "Beat Plastic pollution". The Sikkim Regional Center, Pangthang, Gangtok organized environment related Quiz and painting competition for the students of Sikkim Government College, Tadong and Burtuk. Plantation drive was also organized in the campus of the centre to celebrate the WED. The North East Regional Center, Itanagar, celebrated the WED jointly with Zoological Survey of India, Arunachal Pradesh in the form of a workshop on "Plastic pollution and its impacts on Environment including Biodiversity and Society – The Arunachal Pradesh perspective" which was attended by students of about 10 schools of Itanagar.

National Coordination Committee for TBL Initiatives in the IHR

The First Meeting of National Coordination Committee (NCC) for Transbounday Landscape (TBL) Initiatives in the IHR was held on 19 June 2018 at the MoEF&CC, New Delhi. In this meeting a Memorandum of Understanding was signed by Dr. R.S. Rawal, Director, GBPIHED and Dr. David James Molden, Director General, ICIMOD for execution and implementation of various activities between the two institutions in the IHR for next 10 years. During the meeting, Dr. Rawal, briefed the house that Government of India has approved participation in three transboundary landscape initiatives that are being facilitated by ICIMOD, and identified national/state agencies in the IHR. He informed that the two TBL initiatives; namely, Landscape Development Initiative for Far-Eastern Himalaya (Hi-LIFE) and Khangchendzonga Landscape (KL) Conservation and Development Initiative (KLCDI), are in implementation phase whereas the Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI), has completed its first phase of implementation.

Awareness Program on Climate Change and Biodiversity Conservation

The North-East Regional Center, Itanagar of GBPIHED organized two awareness programs on 'Biodiversity conservation and climate change impact in high altitude areas' at Govt. Residential School, Melonghar village, New Lumla and Govt. Higher Secondary School, Jang of Tawang district (1-2 August 2018). Dr. K.S. Kanwal, Scientist of the Institute appraised the students and teachers about the status of biodiversity in Himalayan region, issues and challenges of biodiversity conservation and emerging threat of climate change particularly in high altitude areas. He further highlighted the significance of high altitude wetlands (HAWs), status of HAWs in the state, biodiversity of wetlands, major challenges in wetland conservation and management and issues related with pollution and waste management in high altitude areas. Ms. Yangchin Tsomu, Headmaster of Govt. residential school, Melonghar felt that student would be benefitted by this awareness program and will share the environment conservation message.

Annual Day Celebration

Annual day of the Institute and 24th G.B. Pant memorial lecture was organized at Institute HQs Kosi-Katarmal, Almora on September 10, 2018. Dr. Harsh Vardhan, Honorable Minister of MoEF&CC was the Chief Guest of the function. Mr. Ajay Tamata, State Minister of Textile Ministry presided over the function. Prof. P.S. Roy, NASI Senior Scientist Platinum Jubilee Fellow, delivered the G.B. Pant memorial lecture. Mr. C.K. Mishra, Secretary, MoEF&CC, Shri Hem Pandey, Former Secretary, MoEF, Govt. of India Prof. S.P. Singh, former Vice Chancellor of HNB Garhwal University, Srinagar and delegates from Nepal, Bhutan, Myanmar, various officers from different departments, various members of legislative assembly, local senior citizens and representatives from line agencies and R&D organizations were present during the function. On the next day a Brainstorming-cum-Policy forum was organized in which participants from three trans-boundary landscapes i.e. The Landscape Initiative for the Far-eastern Himalayas (Hi-LIFE); Kangchenjunga Landscape (KL) Conservation

and Development Initiative; Kailash Sacred Landscape (KSL) Conservation and Development Initiative, and officials from the landscapes participated. Before the Annual Day function, a nature camp for school students were organized at Surya-Kunj- Nature Interpretation and Learning Center of the Institute (September 8-10, 2018) in which 25 students and teachers participated. At the Garhwal Regional Center of GBPIHED a popular lecture on changes in Gangotri glacier and its surrounding environment was delivered by Prof. Harshwanti Bisht, renowned environmentalist and mountaineer that was attended by around 120 participants. The day was celebrated in all other regional center (Kullu HP; Pangthang, Sikkim, and Itanagar, AP)

Institute Governing Body Meeting

The 40th Governing Body meeting of GBPIHED was held on September 10, 2018 at the Institute HQs (Kosi-Katarmal, Almora). This meeting was chaired by Shri C.K. Mishra, Secretary, MoEF&CC (Chairman) and attended by Prof. R.K. Kohli, Vice-Chancellor, Central University of Punjab (Member), Shri R.S. Negi, Chairperson, DCPCR Delhi (Member), Shri M.C. Beniwal, Under Secretary, Representative of AS&FA, MoEF&CC (Member), Dr. R.S. Rawal, Director, GBPIHED (Member Secretary) and Shri Surya Kant, Finance Officer, GBPIHED (Special Invitee).

Celebration of Wildlife Week

Wildlife Week (2-8 October, 2018) under the theme for the year 2018 (Big Cats: Predators Under Threat) was celebrated by the GBPIHED across a number of locations in the IHR. This weeklong event was inaugurated by the Director of the Institute on 2nd October by flagging off a team of 44 researchers (41 young researchers and 3 scientists) to the Binsar Wildlife Sanctuary, Almora. Officials of the Binsar Wildlife Sanctuary (BWLS), Almora explained the team of researchers about the BWLS and various wildlife present in the sanctuary. The researchers trekked about 8 km into the BWLS and listed various flora (119 plants and 28 Lichen species) and fauna present there along with notes on habitats and also interacted with the local people of buffer zone villages of BWLS (Kathghara etc.) about the objectives of the Wildlife Week. The Fauna group spotted many wildlife animals during the trek like Eurasian Jay, Black-headed Jay, Rock Agama, Goral, White throated Laughing thrush, Brimstone butterfly, Hanuman Langur, Red-bleed blue magpie, Grey Bushchat, Verediter flycatcher, etc. Finally, at the end of the day a Nukkar Natak- Street Play on Save Wildlife Theme was played by the researchers in the Dhaulcheena town located in the buffer zone of the BWLS. On this occasion three events (2-7 October) were also organized by a team of researchers in Chaudas (GIC Pangu and Sri Narayan Ashram) and Gori Valley of Pithoragarh district with the local people and students in the remote areas in which 296 students and 30 teachers representing 9 schools participated. In all these events a “Cleanliness Drive” was also organized in collaboration with the students and local citizens of these places.

Green Skill Building Programmes (GSBP)

Under the Ministry of Skill Development and Entrepreneurship guidelines the Institute conducted several GSBPs spanning from a range of certificate courses and building the skills of 238 people (103 female and 135 males) (Table 1). The Environmental Information System (ENVIS) center of the Institute organized a 21 days training on “Nature Interpretation” for 14 selected trainees from 7 different districts of Uttarakhand (1-21 August, 2018). In this series two Certificate Courses of two weeks duration (7-21 January, 2019 and 12-26 February 2019) were conducted on Preparation of People’s Biodiversity Register (PBR). In these trainings PBRs of 7 villages of Uttarakhand were prepared by the 30 selected trainees from 8 districts of Uttarakhand. Tie up with Uttarakhand Biodiversity Board was made for engagement of these trainees in PBR preparation.

Table 1: Summary of GSBP organized by GBPIHED (2018-19)				
S.No.	**Skill Building Event(s)**	**Duration (hrs)**	**Place (State)**	**No of Beneficiaries (F+M)**
Green Skill Building Events at HQs				
1.	Certificate Course on Nature Interpretation	1-21 August 2018 (160 hrs)	Kosi-Katarmal, Almora (Uttarakhand)	13 (6+7)
2.	Certificate course on Preparation of People's Biodiversity Registers (PBRs)	7-21 January 2019 (120 hrs)	Kosi-Katarmal, Almora (Uttarakhand)	15 (2+13)
3.	Certificate course on Preparation of People's Biodiversity Registers (PBRs)	12- 26 February 2019 (120 hrs)	Kosi-Katarmal, Almora (Uttarakhand	15 (2+13)
4.	Certificate Course on Monitoring of Environmental Parameters and Their Interpretation	26 Feb to 14 March, 2019 (120 hrs)	Kosi-Katarmal, Almora (Uttarakhand)	15 (7+8)
5.	Forest Resources and Plant Biodiversity	5 March - 20 March, 2019 (120 hrs)	Kosi-Katarmal, Almora (Uttarakhand)	24 (10 + 14)
Green Skill Building Events at Regional Centres				
6.	Skill Development for Strengthening Ecotourism Based Livelihood Options	21 Jan to 1 Feb 2019 (80 hrs)	Dzongu (Sikkim)	33 (19+14)
7.	Certificate course on Livelihood Generation from Natural Resources	21 Feb to 08 March 2019 (120 hrs)	Mohal Kullu (Himachal Pradesh)	25 (15 + 10)
8.	Training course on Vegetation Assessment and Livelihood Improvement for Biodiversity Conservation	7-18 March 2019 (80 hrs)	Pangthang (Sikkim)	16 (5+11)
9.	Training on Harnessing Bioresource Potential for Livelihood Enhancement and Natural Resource Management in Central Himalaya	11-18 March 2019 (60 hrs)	Srinagar (Garhwal)	30 (11+19)
10.	Certificate course on Nature Conservation and Livelihood	05-21 March 2019 (120 hrs)	Itanagar (Arunachal Pradesh)	15 (9+6)
Green Skill Building Events in Collaboration with partners				
11.	Certificate Course on Parataxonomy	9-19 March 2019 (110 hrs)	Bhadrewah (Jammu & Kashmir)	37 (17+20)
	11 Events	1210 hrs	05 States	238 (103+135)

Training and Capacity Building Programme

A two-day training and capacity building programme on "Harnessing bioresources potential for livelihood enhancement in disaster affected villages of Kedar valley" was organized by Garhwal Regional Center of GBPIHED at Rural Technology Center established at village Triyuginarayan (Distt. Rudraprayag, Uttarakhand, (5 October 2018). The objectives of the programme was to share experience and ideas among different stakeholders including scientists, officials of state government line departments, villagers, NGOs, and students towards restoration of livelihood of the disaster affected people of the region through introduction of potential hill specific technologies. The workshop identified the challenging issues of livelihood that the farmers are facing and suggested appropriate solutions of livelihood improvement as well as natural resource conservation.

Mega Science, Technology & Industry Expo 2018

Institute participated in the India International Science Festival (IISF) 2018 held on 5-8 October, 2018 at Lucknow, Uttar Pradesh. Shri Ramnath Kovind Hon'ble President of India inaugurated the IISF. Union Minister for Science and Technology, Dr Harsh Vardhan inaugurated Young Scientists Conference, Mega Science, Technology & Industry Expo and Global Indian Science & Technology Stakeholders' Meet. In this event GBPIHED made an exhibition of various knowledge products and audio-video relating to environmental conservation and sustainable development of the IHR mainly dealing with Himalayan endemic plants conserved in "Suryakunj", important medicinal plants of the Himalaya, environment-friendly training packages of Rural Technology Complex, Tree diversity of Western Himalaya and Butterfly diversity in Almora hills, Integrated fish farming in Himalaya, Plastic free awareness campaign (video) and Tree-line in Himalaya (video). During this event an exhibition of fiber products of fiber yielding plants of the IHR as well as handmade paper products of chir pine needles i.e. file cover, envelopes, hand bags, etc. were also made. In addition to this, the Institute made an exhibition of various knowledge products during a three-day Mega exhibition "Alluring Rajasthan- 2018" held at Udaipur, (July 18-20, 2018) which was inaugurated by Shri C.S. Kothari, Mayer Udaipur.

Scientific Advisory Committee Meeting (SAC)

The 24th Meeting of the SAC was held on 31st October and 1st November, 2018 at the Institute's Headquarters, Kosi-Katarmal, Almora. The SAC meeting was chaired by Prof. V.P. Dimri. Among the SAC members, Dr. Kishor Kumar (Member), Prof. A.R. Nautiyal (Member), Dr. B.S. Kholiya (Representative of Director, BSI), Dr. N. Bala (Representative of Director, BSI), Dr. R.S. Rawal, Director, GBPIHED (Convener) and Institute members Er. M.S. Lodhi (GBPIHED nominee) and Ms. Sarla Shashani (GBPIHED nominee) participated. During the meeting Institute Scientists presented their R&D progress and the SAC members suggested useful comments / inputs on the presentations for better R&D outputs of the Institute.

Training on Bamboo Crafts Making

With an aim to maintain and develop interest in making bamboo crafts among the local people and to uplift the livelihood and skills of local bamboo craftsmen and artisans, a training on commercial bamboo crafts under KLCDI-India was organized by GBPIHED, Sikkim Regional Centre in collaboration with local partner organization, MLAs, Dzongu (December 2018) at Lingdem, Dzongu. A total of six beneficiaries (craftsmen and artisans) were identified along with other interested participants. Training on making of commercial bamboo products viz. Bulb cover, Coffee pack, LED light cover, and Pen stand was given by resource person Ms Nimkit Lepcha, a professionally trained bamboo-based artisan. The locally available bamboo species *Dendrocalamus hamiltonii* Nees & Arn. ex Munro (Nepali: Choya Bass, Lepcha: Po Puli or Puli Mat) and Ruh (cane) were used to make these artifacts. These bamboo products have huge demand in the market and trained artisan are needed in order to fulfill the demands.

Celebration of International Mountain Day

International Mountain Day (IMD) was celebrated by the Institute by organizing a Workshop-cum-Brainstorming on "Himalaya Matters for Ecological and Economic Security" at Indian National Science Academy, New Delhi (11 November 2018). This event was inaugurated by Sri A.K. Jain, Additional Secretary, MoEF&CC. Welcome address to the dignitaries and other participants was delivered by Director, GBPIHED, Dr. R.S. Rawal. This programme was divided into three sessions namely (i) Addressing issues of migration and livelihoods, (ii) Harnessing critical resources: water and biodiversity, and (iii) Managing the waste. All the three sessions were chaired by eminent scientists such as Prof. K.G. Saxena, JNU, New Delhi, Dr. Jayanta Bandyopadhyay, Observer Research Foundation,

Kolkata and Dr. Rajendra Dobhal, DG-UCOST, Dehradun, respectively. The Way Forward session was chaired by Shri Hem Pande, Former Secretary, Govt. of India. This programme was attended by several eminent academicians and Govt. officials. Among these, Prof. S.P. Singh, FNA, Former Vice Chancellor, Garhwal University, Srinagar, Dr. J.R. Bhatt, Advisor, MoEF&CC, Dr. R. M. Pant, Director, NIRD, Guwahati, Dr. S. Banerjee, ICIMOD, Dr. A.K. Gupta, National Institute of Disaster Management, and Dr. Subrata Bose, MoEF&CC. The IMD was also celebrated by the GBPIHED at its regional centers at Sikkim where a lead lecture on "Mountain Specific R&D priorities of Sikkim" was delivered by Prof. S.S. Sharma, Head, Department of Botany, Sikkim University. The workshop was chaired by Shri. S.D. Dhakal, Secretary, Youth and Sports Affairs, Government of Sikkim and attended by about 30 people and other resource persons/delegates from BSI, GSI, Sikkim University, etc. At the Garhwal Regional Center of GBPIHED on the occasion of IMD a workshop on "Mountains Matters" was organized in which 60 participants comprising students from H.N.B. Garhwal University, Srinagar, local people, NGOs and other stakeholders participated.

Institute Society Meeting

The twentieth meeting of the G.B. Pant Society of Himalayan Environment and Development (GBPIHED) was held under the Chairmanship of Dr. Harsh Vardhan, Hon'ble Union Minister of MoEF&CC, Government of India, and the President of GBPSHED, on 19th November 2018. The meeting was also attended by Dr. Mahesh Sharma, Hon'ble Minister of State MoEF&CC and Vice President of GBPSHED. At this occasion Hon'ble MP Lok Sabha Dr. Ramesh Pokhriyal 'Nishank' was also present. Among the dignitaries those attended the meeting were Shri C.K. Mishra, Secretary, MoEF&CC, Shri A.K. Jain, Additional Secretary, MoEF&CC, Dr. S.C. Gairola, DG, ICFRE, Dehradun, Prof. N.C. Gautam, Vice Chancellor, Chitrakoot, Dr. K.C. Agnihotri, V.C. Himachal Pradesh Krishi Vishwavidyalaya, representatives from Ministry of Mines, Ministry of Water Resources, Indian Council of Agriculture Research, DST, ICSSR, Govt. of Meghalaya, Uttarakhand, Sikkim, Himachal Pradesh, Manipur, J&K and Niti Aayog.

Special session in International Conference

GBPIHED, NE Regional Center organized Himalayan special session on "Strengthening indigenous knowledge system and sustainable socio-culture development under changing climate" on 14th December, 2018 during the International Conference on Climate Change, Biodiversity and Sustainable Agriculture held at Assam Agricultural University, Jorhat (Assam) (13-16 December, 2018). This Session was chaired by Dr. D.C. Uprety, Emeritus Scientist, Division of Plant physiology, Indian Agricultural Research Institute, New Delhi and focused on Himalayan research on different issues. On this occasion, Dr. A.L. Singh from ICAR-Directorate of Groundnut Research, Junagadh, Dr. V.S. Rana from YS Parmar University, Solan HP, Dr. G.S Yonzone from Darjeeling Society for Education, Research and Development and Kamal Deka from Tata Institute of Social Sciences, Guwahati, Assam were present. Altogether, there were 2 Lead Talks, 7 Invited Talks, 23 Oral and 22 Poster presentations during the Session.

Workshop on Himalaya Matters for Ecological and Economic Security

A Workshop cum brainstorming meeting was organized by National Institute of Rural Development and Panchayti Raj (NIRDPR), NERC Guwahati and GBPIHED) (January 22, 2019). Dr. R.M. Pant, Director (NIRDPR) and Dr. R.S. Rawal, Director GBPIHED briefed about the objectives of this workshop. Chief guests of the workshop were Mr. Swapananil Baruah (IAS Rtd.) Govt. of Assam who mentioned issues and challenges of north east Himalaya. Other guest was Mr. C.K. Das (IAS Rtd.) who drew attention on development plans of the north eastern region and its developments. Three

themes of the workshop were selected which were Migration and livelihood, Water and Biodiversity and Managing waste. Three groups were divided on different themes and discussed the issues in different part of the Himalaya.

Training on Low-cost Rural Technologies

The NE Regional Center of GBPIHED organised a Training Programme on Low-Cost Rural Technologies at Rural Technology Center (RTC) at Dera Natung Government College, Itanagar, Arunachal Pradesh (February 4, 2019). This programme was inaugurated by Chief Guest Dr. N.T. Rikam, Principal DNG College, Mrs. Amum Tamuk, Associate Professor, Dept. of Botany, DNG College, Dr. P. Nanda, and Associate Professor, Department of Zoology, DNG College and others. During the programme the resource persons and Institute scientists delivered lectures and training on various low-cost rural technologies those are demonstrated by the Institute. The session was followed by field demonstration and hands-on training to the participants on different low-cost technologies, viz. Vermi-composting, weed composting, Bio-briquette, Zero-Energy Cool Chamber, Plastic film technology, Pitcher irrigation, Trellis systems and Green House. The program was attended by a total of 40 participants including students and faculties of Botany and Zoology Departments of DNGC, Itanagar.

National Seminar-cum-Monitoring & Evaluation Workshop

A four-day National Seminar-cum-Monitoring and Evaluation (M&E) Workshop was organized at GBPIHED HQs, Kosi-Katarmal, Almora, Uttarakhand (4-7 February 2019). The Seminar was chaired by Professor V.K. Gaur, Emeritus Scientist, Indian Institute of Astrophysics, Bengaluru. Members and experts of the National Mission on Himalayan Studies (NMHS) Monitoring, Learning and Evaluation (MLE) Panel conducted the assessment and evaluation of all the 103 ongoing demand-driven action research and demonstrative developmental NMHS Projects and provided valuable comments and recommendations for further improvement.

Swachh Bharat Abhiyan

A one-day training programme and stakeholders consultative meeting on Swachh Bharat Mission was organised by Garhwal Regional Center of GBPIHED on12th February 2019 at village Nala, Guptakashi, Rudraprayag. The prime objectives of the programme were to interact with the villagers on how to make the village clean in terms of safe drinking water, sanitation, open defecation and garbage disposal. Secondly, motivate and generating awareness among the villagers towards various health and ecological problems raised by careless management of waste. About 80 participants comprising students from Junior High School and Primary School of Nala village, representatives of NGOs, SHGs and Mahila Mangal Dal who were engaged in various social activities at village level. The subject experts made participants aware about various diseases caused by ill management of garbage and open defecation in villages premise and highlighted different success stories adopted by the villages to make clean their villages in Uttarakhand. All participants and office staff collectively cleaned the temple area and village premise and collected garbage and waste material and installed dust bin in Temple area.

Workshop on Himalayan Timberline and Prospects of Conservation & Development

A three days workshop was organized by the Sikkim Regional Center during 18-20 February, 2019 at Gangtok, Sikkim under the auspices of GBPIHED and the Indian Himalayan Timberline Project (IHTP) supported by National Mission of Himalayan Studies (NMHS). The aim and objectives of the workshop were to (i) highlight the findings of IHTP and generate a wider debate among domain experts across the country so that the value of Himalayan Timberline could be widely appreciated, (ii) share key outcomes of Research & Development activities at GBPIHED Sikkim Regional Centre, and to strengthen Institutes' linkages with other agencies in Sikkim State, and (iii) identify front-running environment and development priorities that require evidence based interventions for planning and policies in the region. More than 70 participants and some eminent domain experts from Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Gujarat, Telangana, Sikkim, and Nepal participated in the workshop. During the workshop, deliberations were held on pertinent issues of Himalayan Timberline and Climate Change, thrust areas of studies on Himalaya timberline, institutional collaboration and strengthening linkages and front-running environment and development priorities of Sikkim.

State Level Coordination Committee under Landscape Initiative

The North-East Regional Center, Itanagar of GBPIHED in collaboration with Department of Environment & Forests, Govt of Arunachal Pradesh and ICIMOD, Nepal organized the 1st State Level Consultation Committee (SLCC) of Landscape Initiative for Far-Eastern Himalaya (Hi-LIFE) on 18th April, 2018 at the PCCF's office at Itanagar. SLCC Chairman, Shri. Omkar Singh (PCCF & PS, Dept of Environment & Forests, Govt of Arunachal Pradesh) highlighted the biodiversity significance of the project area at Namdapha National Park cum Tiger Reserve and expressed hope that the meeting would help in addressing problems and opportunities for Hi-LIFE programme implementation in India. Other dignitaries who spoke during the meeting include Mr. BMS Rathore, Chief Policy Avisor, ICIMOD, Mr. Nawraj Pradhan Hi-LIFE India Coordinator and Er. M.S. Lodhi, Scientist-Incharge, GBPIHED, NERC. Other participants in the meeting were diverse stakeholders including representatives from line departments of Government of Arunachal Pradesh, RFRI, Jorhat, Zoological Survey of India, Itanagar, Botanical Survey of India, Itanagar, Rajiv Gandhi University, Itanagar, WWF-India and SEACOW an NGO from Miao, Namdapha.

Research And Development Programmes

Center for Land and Water Resource Management (CLWRM)

Land and water resource management has remained as one of the main R&D activities of the Institute right from its inception and pursued under core programme of 'Land and Water Resource Management' during the period 1991 to 2005, and as 'Watershed Processes and Management & Knowledge Products and Capacity Building (WPM-KCB)' and 'Watershed Processes and Management, Environmental Assessment and Management, & Environmental Policy and Governance (WPM-KCB-EAM)' Group Programmes in the later years. The geological fragility & high landslide susceptibility of Himalaya, acute water scarcity & low agricultural productivity of Himalayan mountains, and the ecosystem service benefits of Himalayan waters for North Indian plains in terms of growth of settlements/agriculture/hydropower/industries makes it imperative that the land and water resources of IHR be properly harnessed, conserved and utilized by - devising optimal technological solutions at the local level, promoting participatory action for conservation, improving allocation and

resource use efficiency, and providing policy solutions at state and regional levels. In last few decades, the global warming and climate change have exacerbated the prevalent water scarcity in the high and mid altitude regions of IHR. Melting of glaciers and extreme events induced threats have aggravated the vulnerability of - human settlements, agricultural growth & sustainability, developmental infrastructure etc., to waterborne and drought related climatic hazards and disasters, which calls for development of suitable adaptations strategies and resilience to combat such changes and challenges.

Over the years the institute has gained widespread experience in mountain hydrology and water resource augmentation works, glacier retreat and glacial discharge studies, land & landslide restoration, catchment area treatment, and soil and water conservation technologies. These experiences alongwith the expertise of the Institute is now being utilized through the dedicated 'Center for Land and Water Resource Management' for a more focused R&D and in-depth understanding of complex issues and processes of mountain hydrology, glacier dynamics, geo-tectonics and hazards, etc., for providing decision support for land-use optimality & management, policy prescriptions at state and regional levels, and development of suitable technologies to suit various requirements of land and water resource management in the IHR.

Objectives

- To conduct studies on land and water and related eco-sociological processes operational at watershed level including upstream- downstream linkages.
- Develop tools and techniques of sustainable land management considering various developmental interventions.
- Provide inputs to government and other policy makers for bringing in mountain perspective in land and water resource management policies.

Water Sustainability Mapping - Options, Issues and Impacts (In house, 2017-20)

The Indian Himalayan Region (IHR) is called the water tower of India as the IHR is rich repository of water resource containing large quantity of ice and snow in its mountains and glaciers. All the major rivers that flow through the North India and their tributaries originate from IHR providing enough water for survival/ subsistence, growth of settlements/ agriculture and industry in areas lying along their course in IHR and in the plains of North India. The lakes, wetlands, springs, and streams are the other sources of water in the region that also cater to most of the household, agricultural/ industrial, and municipal demands of the IHR's people and settlements. But several pockets of this region, particularly those in high and mid altitude region, face acute shortage of water due complex topography and drainage patterns, and variability of rainfall across complex mountain terrain. The availability of water for household also varies with seasons. In many rural areas during lean period, everyday people have to travel long distances to fetch water to make up for the shortfalls. Over the years, deforestation related to growth of settlements, construction of roads, mining, etc. have also disturbed the underground water regimes and led to disappearance/ drying of several water streams and springs, such effects are further exacerbated by the climate change. The global warming is also causing melting of glaciers affecting the season/ annual discharge patterns of snow-fed rivers, and availability of water in future. The climate induced extreme events also pose flash floods threat to water based infrastructure made to cater to subsistence and developmental demands in the region. The Himalayan Rivers are considered sacred and have ritualistic significance which supports pilgrimage and religious tourism in the region providing income and livelihood to many people directly and benefitting a larger number through multiplier spin-offs. Increasing urbanization/ urban proliferation, and population also resulting increase in water demands which also needs to be looked into for demand-supply management. In view of the above, the present study intends to assess the water sustainability in Kosi and Kali Watersheds in Kumaun Himalaya in light of availability water for agriculture and household use, hydropower development potential, and sacred value as pilgrimage/ religious tourism.

Objectives

- To study the mountain hydro-dynamics in selected micro-watersheds to map the water sustainability at micro level delineating the status of water resources, zones of over exploitations and quality degradation
- To assess the water sustainability at macro level by analyzing the cumulative impacts of hydropower development in IHR and suggest a policy framework for optimization of hydropower development
- Estimation of the sacredness and recreational value of water as pilgrimage and tourism, its multipliers, and contributions to local economy
- To evolve a suitable framework for water stock augmentation and efficient resource allocation/use and suggest options/ solutions for water sustainability at micro and macro level

Achievements

1. The flow and water discharge of the two rivers viz. Kali and Saryu was monitored regularly from 1st of July 2018 on daily basis, and sediment analysis from samples collected at 10 days intervals was carried out. The hydro meteorological data from Central water commission, NHPC and UREDA was obtained for model calibration. Rating curves were prepared for both the rivers for discharge estimation (Fig. 1a).

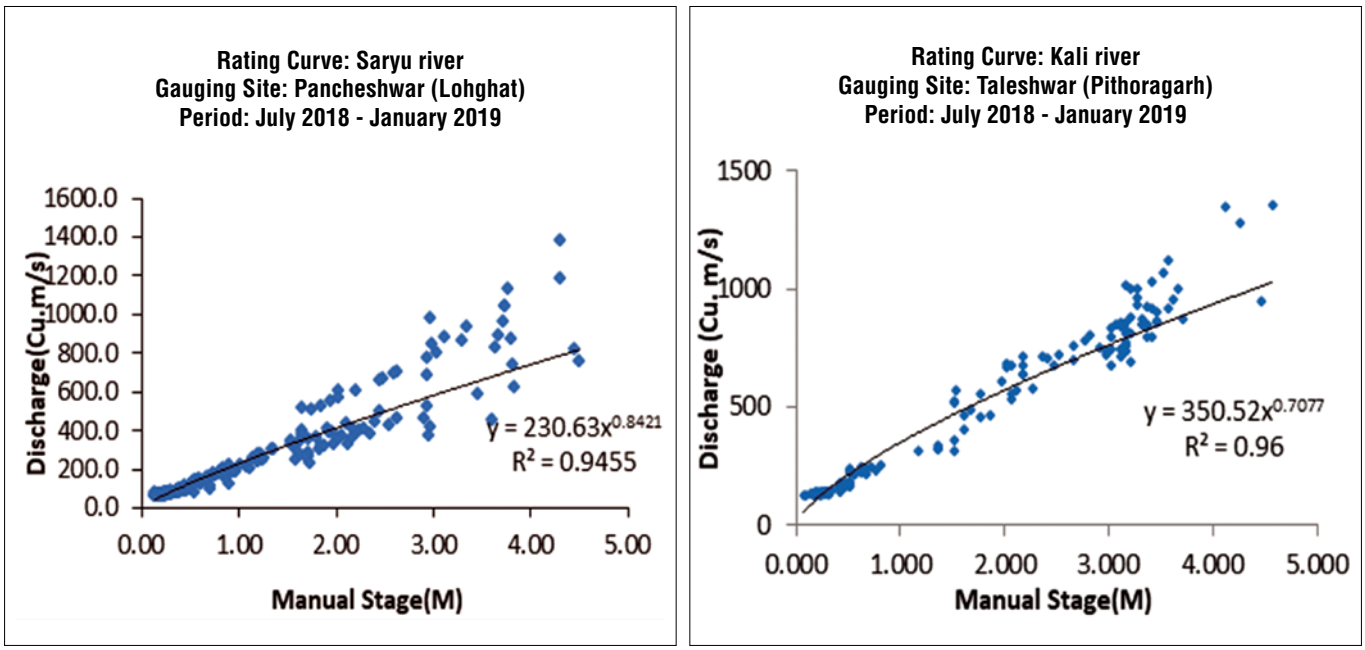


Fig 1a. Rating curves for Saryu and Kali rivers for discharge estimation

2. Household survey for water use in 36 villages (12 in altitude range 500-1000 m, and 24 in 1000-2000 m) of the 2-blocks of Pithoragarh district was carried out, and 80 springs in these villages (66 perennial and 14 are non-perennial) were geo-tagged.
3. The spring inventory map and gauging site location map of the Kali watershed were prepared (Fig. 1b) to depict distribution of springs in the basin. Reconnaissance surveys in the Kali watershed, for the installation of automatic rain gauges at Jauljibi, Pancheshwar and Jhulaghat sites, were completed. A macro analyses of tourism trends and observations on seasonal drying of water bodies were analyzed in terms of threats and impact on tourism prospects.

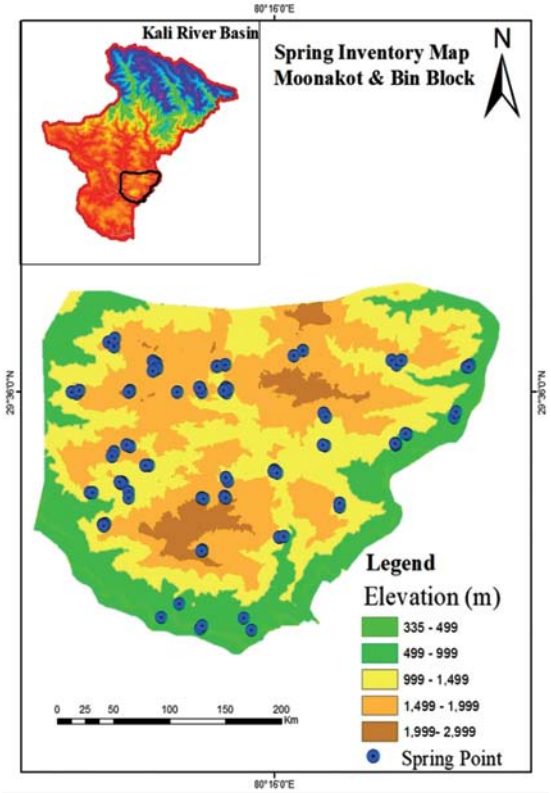


Fig 1b. Spring inventory map of Moonakot and Bin Block of Kali river basin

Integrated Studies of Himalayan Cryosphere in Uttarakhand and Arunachal Pradesh (SAC – ISRO, Ahmedabad, 2017-2019)

Glaciers across the world play a critical and vital role in the complex interactions of geological, cryospheric, atmospheric, hydrological and environmental processes that bear special significance for the earth's biodiversity, climate, and water cycle which in turn have a direct impact on human life. Himalaya, which is the youngest mountain system on earth, have 17% of its area covered by glaciers. These glaciers are the main source of water and origin point of the most of the perennial rivers that emanate from the Himalaya. Today, most of the glaciers in the Himalayan region are retreating due to accelerated global warming causing gradual and long-term loss of natural freshwater storage. This project on integrated study of Himalayan Cryosphere seeks to understand glacier dynamics and mass balance of the glaciers of the Himalayan Region. Consequently, the Institute is working on both field and space based inputs for two glaciers i.e. Chipa Glacier located at the elevation of 3500 masl in Dhauliganga Basin (Uttarakhand) in central Himalaya and the Khangri Glacier located at 4900 masl in Tawang Basin (Arunachal Pradesh) in eastern Himalayan region.

Objectives

- GPS measurement of elevation on glacier for mass balance estimation using geodetic method.
- Measurement of glacier ice thickness using GPR.
- Velocity of ice derived from optical and SAR data and its validation on ground.
- Monitoring of snow line at the end of ablation season of selected glaciers.
- Water discharge measurement of selected glaciers.
- Mapping and change detection in selected glaciers by using high resolution data.

Achievements

1. Stakes were setup in Chipa and Khangri glaciers by using DGPS and handheld GPS, and snout monitoring in Chipa Glacier was accomplished; the retreat rate was found out to be 6 m for year 2017-18 and 5.89 m for 2018-19.
2. The results of discharge study of Chipa Glacier revealed higher average discharge of 5.9cu.m/sec in year 2018 compared to 5.63cu.m/sec in 2017. In Khangri, the average discharge for year 2018 was 3.39cu.m/sec. The volume estimation of Chipa and Khangri glacier calculated through DEM differencing approach using SRTM DEM (2000) and ALOS Palsar DEM (2008), revealed total loss of 0.275±0.017 km^3 volume for Chipa Glacier and 0.21613±0.017 km^3 for Khangri Glacier
3. Land cover extracted area was found to be 74.04 km^2 of which 21.692 km^2 was total estimated area of snow in Chipa Glacier, and Khangri Glacier coverd 178.25 km^2 area of which 53.4 km^2 was covered by snow in October 2018 (Fig. 2 & 3).

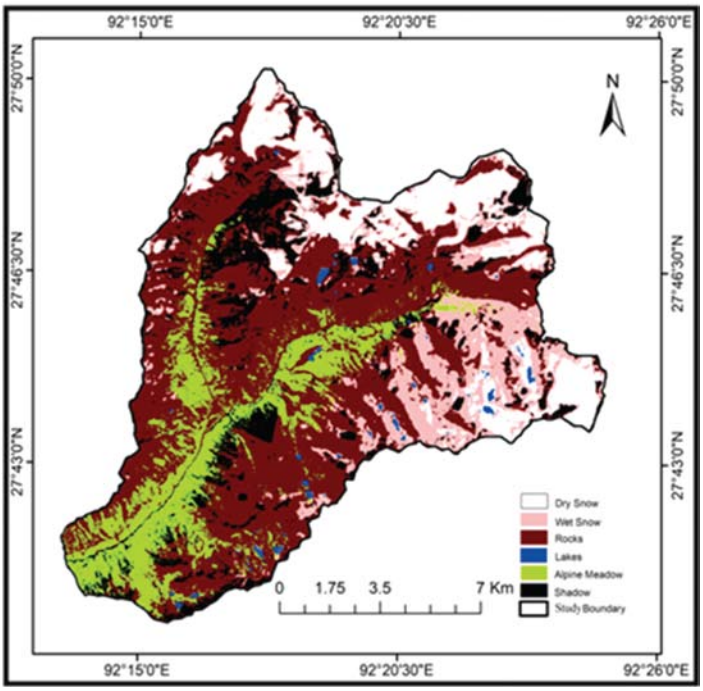


Fig 2. Classified image of Khangri Glacier using MLC method

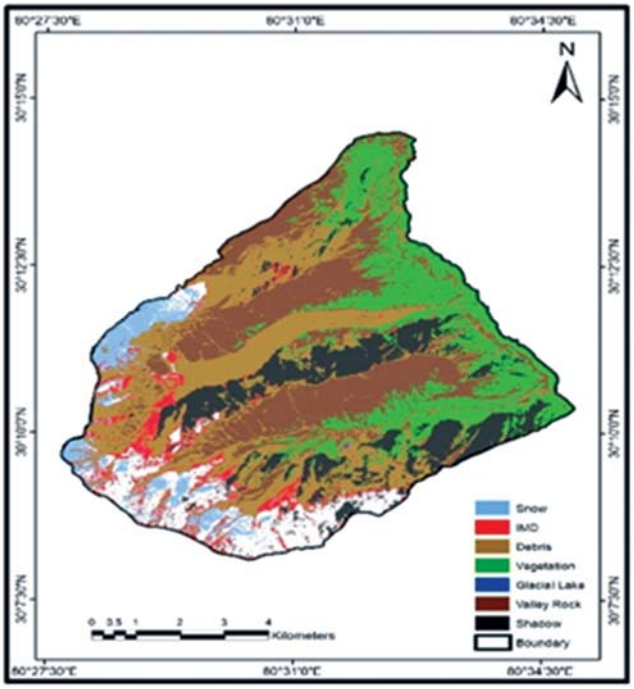


Fig 3. Classified image of Baling Glacier using MLC method

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 modelling 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 satisfactorily collapse the energy, momentum and tracer spectra in a wave number 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

- Evaluation of the atmospheric surface layer scaling parameters, kinetic energy dissipation at the CBL, surface friction layer height and dissipation velocity (ε_o, z_s and u_ε) and comparison with the traditional scaling parameters.
- Collapse of SFL velocity spectra of u, v and w component of wind at the wave-number axis using scaling parameters of CDS approach.

Achievements

1. Mathematical relationships between aerodynamic roughness length (z_o), representing distribution of surface elements, and wind direction; drag coefficient (C_D), representing resistance by surface elements, and wind speed were evaluated for convective atmospheres over complex terrain of Himalaya during post monsoon and monsoon period using observations from two different locations.
2. A nonlinear curve fitting optimization technique was used to derive numerical relationships between wind speed and C_D for turbulence observations made over two different types of surface conditions. Subsequently it was noted that surface elements of complex terrain have impact on mean wind speed for a convective atmosphere alike flat terrains of India (Fig. 4).
3. The numerical parameterization of C_D and wind speed, as developed for the complex terrains of Indian Himalayan region, are expected to be beneficial for understanding convective mixing and chemical transport modeling of atmosphere.

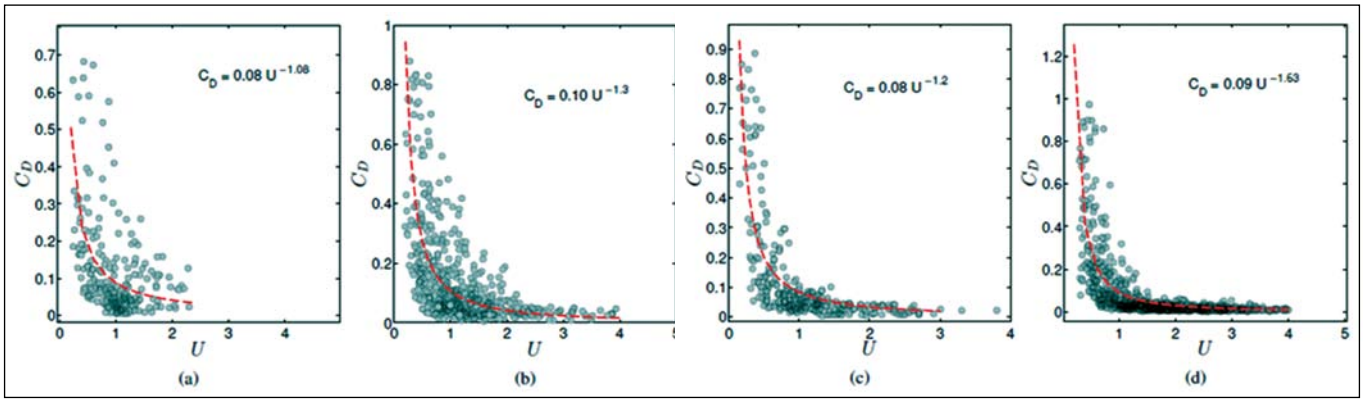


Fig 4. Variations in the drag coefficient (CD) with horizontal wind speed (U) are shown for the (a, b) post monsoon and (c, d) monsoon periods for observations made over (a, c) on-slope and (b, d) ridge-top sites. The red dotted line indicates the optimized non-linear curve fitted to observations.

Integrated System Dynamical Model to Design and Testing Alternative Intervention Strategies for Effective Remediation & Sustainable Water Management for two Selected River Basins of Indian Himalaya (NMHS, MoEFCC, Govt. of India, 2018-2021)

Rainfall and snow-melt are the major sources of water in the Indian Himalayas. Notable changes in terms of the quantity and space-time characteristics of rainfall and snow-melt over this region have been reported in recent decades. In addition, shift in the cropping systems, urbanization and population growths add additional stress on the available freshwater. These changes significantly modify water runoff and the quality of available freshwater, in turn, disrupting the balance of the regional hydrological cycle through negative feedbacks. So it is the need of the hour to design actionable intervention strategies at policy level for maintaining a sustainable water budget over these regions for long term sustainability of ecosystem and environment. Here, an integrated System Dynamic Model to design and test intervention strategies at policy level to evaluate and remediate water stress over these regions at short-term through intervention strategies and long-term through adaptive measures is proposed to be developed. Therefore, two river basins, Kosi and Upper Jhelum, which have undergone major hydrological changes and affecting disaster vulnerability and livelihood of the people of Uttarakhand and Jammu & Kashmir states, respectively, are being selected. The Kosi River is experiencing drying up of

perennial streams (225.85km in 1960 to 41.9 km today), diminishing spring discharge, reduced summer flows and the rising water demands, subsequently, the river ecosystem have put the region under severe water stress. Likewise, the Upper Jhelum basin has also undergone major changes in terms of the hydrological cycle, flood vulnerability and rise in demands of water. Accordingly these basins are selected for such exercise with the expectation that (i) the outcome of this project will not only address a situation faced by large sections of humanity but (ii) also, because of their variegated texture, offer an approach that can be easily adopted for other basins along the Himalaya. Lastly, the high interdisciplinary S & T knowledge and capabilities created in the process as well as the array of instrumentation systems that alert us to adverse changes in the state of the ecological system would hasten the approach of data and knowledge guided approaches to sustainable management.

Objectives

- Development, testing and validation of a System Dynamics Model of the Upper Jhelum and Kosi Basins;
- Projection of water budget, forest and agro-ecosystem under different environmental and social scenarios;
- Assessment of the outcome of alternate policy and technological interventions for conservation of river and associated ecosystems;
- Capacity and awareness building of stakeholder for enhanced decision making on water management.

Achievements

1. GIS based LULC maps were produced for 1999 and 2017 to identify major changes in the land use category for the Kosi-watershed. The LULC maps were produced using LandSat-7 and LandSat-8 data having 30 m resolution, and comparison of areas under Level-I classifications of LULC (6 classes, i.e. agriculture, built-up, water body, fallow land, silt and forest) carried out (Fig. 5).

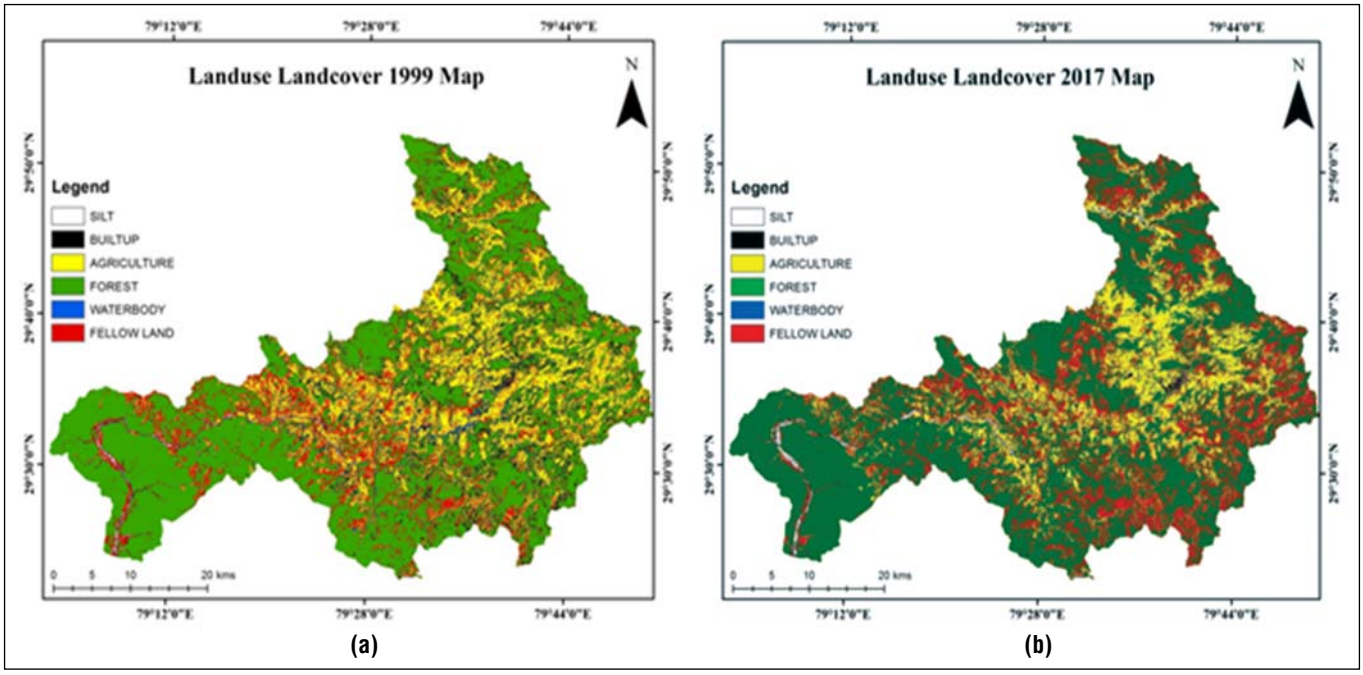


Fig 5. Landuse-Landcover over Kosi watershed for (a) 1999 and (b) 2017.

2. GIS based geomorphological and hypsometric maps (i.e. slopes, aspects, hill-shade, stream orders, village distribution, HRU distribution) of Kosi-watershed were prepared.
3. Village level survey for agricultural and fruits productivity, socio-economic structure, water demand and supply is completed for 18 villages having aprrox. 300 HHs to be used in System Dynamic model. Two crop fields (each at Sunari and Darimkhola village of Almora District) are permanently geo-tagged for wheat plant growth, yield, phytosociology, soil nutrient dynamics and field management practice monitoring.
4. A total number of 44 springs and streams of Suyal sub-watershed are geo-tagged and one time monitored for pH, EC and discharge data. This information would be used as baseline data. A total number of 6 geo-tagged springs across Kosi watershed is monitored at monthly interval.

Removal of Pharmaceutical and Personal Care Products (PPCPs) from Contaminated Water using Pine Needle Based Activated Carbon/ Biological Activated Carbon (DST-WTI, 2016-2019)

Pharmaceuticals and personal care product (PPCPs) are widely detected in natural surface and ground water, and have emerged as the environmental contamination with potentially widespread environmental effects. 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 material for removing these groups of compounds from wastewater. Target of 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 needle and microbes (in case of BAC)
- Estimation of AC/BAC efficiency for the removal of detergent metabolites, plasticizers pharmaceutical components from model fed system.
- Regeneration studies of AC/BAC.

Achievements

1. Total 324 activated carbon samples were prepared at various temperatures and impregnation ratios. Activated carbon samples, prepared through different chemical modification, have shown very high surface area equivalent to commercial activated carbon ranging from 900 to 1200 m^2 (determined through iodine method). Fig. 6 is showing significant increase in functional groups concentration (mmol/g) with activation duration at constant temperature ($p<0.05$).
2. The activated carbon was checked for the adsorption capacity of Bis phenol A. One of the impregnated carbons has shown the highest capacity of BPA adsorption 63.15% in 2 hours. Study is still under process.
3. The mineral media was optimized for bacterial growth using Box–Behnken design to visualize the effects of mineral salt concentration on growth of bacteria. 17 bacterial strains were screened for analyzing the degradation capacity of target compounds where best degradation was shown by CDB-02 for caffeine (93.2%), CDB-08 for bis- phenol A (97%), CDB-06 for estriol (79%) and CDB-04 for ibuprofen (59%) (Fig 7). Bacterial degradation capacity for caffeine, bis-phenol-A, estriol and ibuprofen was optimum at 25°C temperature and 7 pH at all the levels of concentration.

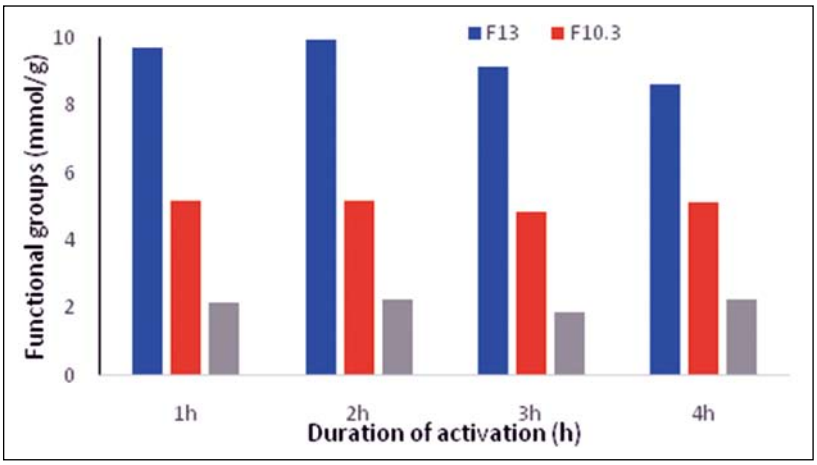


Fig 6. Effect of duration of activation on functional group concentration of activated carbon surface at 300°C

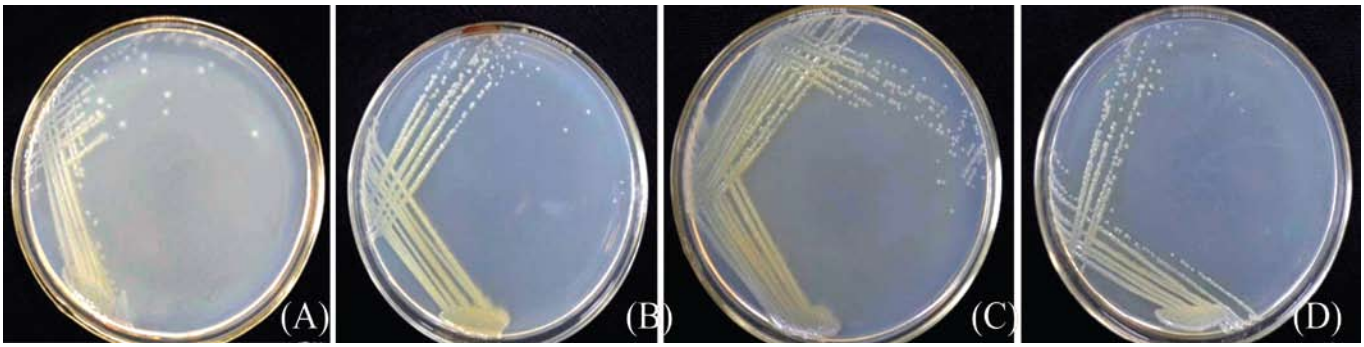


Fig 7. The bacteria showing growth in presence of the target compound (A) CDB-02 (B) CDB-04 (c) CDB-06 (D) CDB -08

Nutritional Status of Traditional Food of Uttarakhand Utilized by Scheduled Community (DST-NRDMS, 2016-2019)

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. Consequently, lifestyle of the people of Uttarakhand also differs from plain areas of the country. There are different types of traditional crops like cereals, millets, pulses, oilseeds and vegetables which have been grown in the region. But the people are taking less interest in their cultivation activities. 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 contents, which will definitely give importance to the nutritious food consumed by the community. Carrying out the proposed scientific evaluation would help in promoting the traditional recipes for better health and improved economic condition 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 demand for production of these crops which will 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. Ingredients used in the preparation of traditional cuisines were evaluated for their nutritional and anti-nutritional properties along with mineral content. Total protein, total carbohydrates, total fat, total fiber, ash and moisture were evaluated under proximate analysis.
2. Every spice has its own potentially beneficial nutritional value but *Curcuma longa* and *Syzygium aromaticum* were found to have the highest nutrient content and highest antioxidant activities among all the spices.
3. Among anti-nutrients, tannic content was found to be higher than phytic acid and oxalate content in all the grains and spices (Fig. 8). Qualitative test for amino acids in raw grains revealed presence of various amino acids. Horsegram was found to contain valine and arginine, ricebean - phenylalanine, and black soyabean - valine and leucine, whereas barnyard millet contained arginine as essential amino acids.
4. Cooked food analysis was initiated, and the preliminary study showed that in comparison to raw grains, the cooked food have high nutritional values due to the fortification or value addition of ingredients used in their preparations.

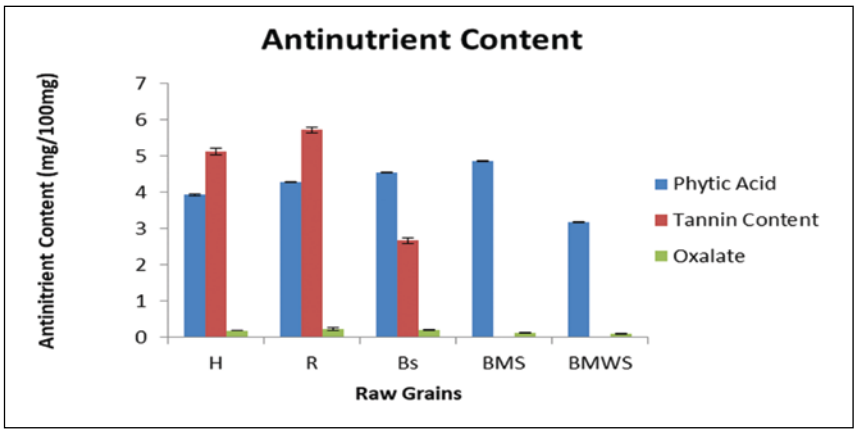


Fig 8. Antinutritional content of raw grains

Enhancement of the Quality of Livelihood Opportunities and Resilience for the People in the Indian Himalayas, Through Design of Intervention Strategies aimed at Maximizing Resource Potential and Minimizing risks in Urban-rural Ecosystem (NMHS, MoEF&CC, 2018-2021)

The traditional Urban-Rural Ecosystem of Himalaya was a closed, compact, and symbiotic system where villages in the vicinity of the small towns catered to urban demands and supplies and this created livelihood opportunities in production, marketing, and supply sectors in Urban-Rural ecosystem. The urban areas provided employment/ job opportunities in education, health, construction, transport, & service sectors and maintained a self-sustaining Rural-Urban Ecosystem Environment. The mutual dependence, small populations, and abundant forest resources supported this rural-urban ecosystem symbiotic which was sustained by reciprocal human-environment relationship protected by strong traditional institutions to safeguard the interests of natural and social environment. Later in the face of increasing craze for jobs,

outmigration, increased urban proliferation, market intrusions, globalization, climate change, and several other socio-economic reasons this symbiosis gradually disrupted resulting in threats to livelihood, the system sustainability and resilience. The water scarcity remained a limiting factor in hill agriculture and topographic barriers stalled the agriculture growth which adversely affected the urban-rural transactions and linkages forcing outmigration for jobs from the rural to urban areas in the region and outside. This scenario build-up, have implications for rural areas in terms of threat to their existence, loss of its agri-biodiversity/traditional landraces/ village industries and associated indigenous traditional knowledge. In urban sphere it is resulting in pollution, over-population, and congested growth. The outmigration and demographic changes are also resulting in weakening of institutions, environmental degradation, agriculture abandonment, and loss of opportunities in unorganized sectors in urban-rural ecosystem. The emerging situation have negative bearings in terms of contribution of rural sector to the economy, and increased dependence of urban areas on outside supplies, adversely affecting the rural livelihoods. Therefore, there is a need to sustain and conserve the co-existence of Urban-Rural ecosystems and their concomitant gains through contemplation of suitable strategies and policies for 'Protection of Urban-Rural Environment' and defining the limits of urban sprawl, forest area, etc. This collaborative project seeks to explore these possibilities through use of a set of system dynamical modeling in urban-rural ecosystems of the Himalayan states of Uttarakhand & J&K; this assignment pertains to Uttarakhand.

Objectives

- Development of strategies for resilient and sustainable urban-rural ecosystems to enhance sustained quality of livelihood of people.
- Test and validate the intervention strategies through development of a system dynamical model to enhance livelihood of the selected Himalayan habitats.
- Enhancement of human-natural resources management to achieve environmental and economic benefits whilst minimizing their carbon footprint.
- To provide policy options to achieve better quality of life for the selected habitats and their prototypes in a sustained manner.
- Capacity and awareness building through stakeholder interactions and design of viable intervention strategies for decision making and implementation that is also informed by the specificities of their traditional lifestyle.

Achievements

1. In Uttarakhand, the Almora Urban-Rural Ecosystem, comprising of Almora township and its surrounding villages in Kosi-Suyal wastershed was selected for the study. Secondary information on occupational status, land-use, urban-rural population, education/ literacy, landuse, occupational structure, etc. at Almora district level was collected and synthesized for understanding of changing urban-rural scenario in the region.
2. A review of population statistics reveals that 90% of the population of the district is rural; comparison of statistics for periods 1961 to 2011 shows compounded decadal growth of 10% in the district which is 18% for urban population and 9% for the rural. The change in composition of occupational structure for periods 1961 and 2011 is shown in Fig. 9. Which shows significant increase in non-worker population from 70,040 to 3,24,295 (18% to 52% of total population) and a decline in the ratio of cultivators' population from 35% to 21%, and marginal workers' population 37% to 16% of total population. Other workers population, though shows marginal increase as percent of total population, but has nearly doubled from 32798 persons in 1961 to 62201 in 2011.

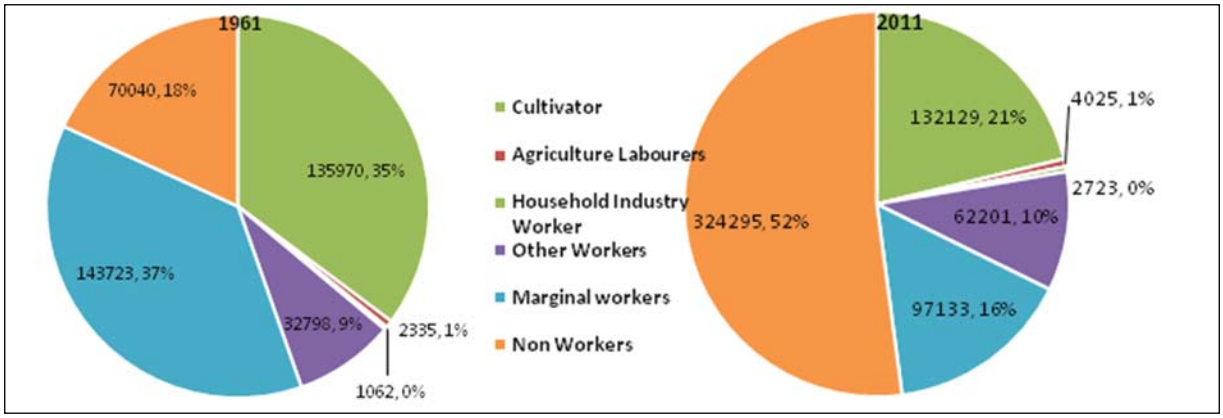


Fig 9. Change in the composition of workers and non workers in Almora district

3. Based on the economic linkages, 24 villages at varying distances from Almora town were identified for the study of livelihood opportunities, threats, related issues and problems. Survey of 241 households was completed for assessment of household income, livelihood options, natural/ social capital, migration, etc. The survey results of 12 villages with respect to household income, size of landholding derived from response of 146 households, and that of migration from villages are shown in Table 2. Data reveals that average landholding size is less than 0.31 ha, and 47% of the households are affected by outmigration. Further scrutiny suggests that outmigration affect is more pronounced amongst APL families.

Table 2: General rural scenario in villages near Almora town

Village	Average Household Income/ Yr	Average Landholding (Ha/ Household)	Households affected with outmigration
Sarsou/ Vishwnath N=19	Rs 251842	0.17	11 (57.89%)
Bukh, Mall N=22	Rs 246363	0.25	7 (31.82%)
Ujiyori, Matela N=16	Rs 191500	0.34	10 (62.5%)
Sounala N=13	Rs 173461	0.21	8 (61.54%)
Jagsoun N=22	Rs 178863	0.32	10 (45.45%)
Salla N=16	Rs 163552	0.21	6(37.5%)
Pilkha N=15	Rs 185937	0.27	7 (46.66%)
Railakot, Talla N=23	Rs 164300	0.31	10 (43.47%)

Center for Biodiversity Conservation and Management (CBCM)

Recognizing that the Himalaya is: (i) one of the hotspots for biodiversity, and (ii) provider of goods and services to large population in Indian subcontinent, biodiversity conservation and management deserves a major thematic thrust in the IHR. In keeping with these facts and realizing that: (a) biodiversity conservation and its sustainable use has emerged as one of the global priorities in the aftermath of Rio Earth Summit (1992), (b) the Conference of Parties to Convention on Biological Diversity (February 2004) has adopted 'Mountain Biodiversity' Programme of Work, and (c) India is among the selected countries in the world that have developed their own National Biodiversity Targets aligned with global targets (i.e., Aichi Biodiversity Targets), the Institute since its inception has identified Himalayan Biodiversity Conservation as a major thematic thrust. The R&D contributions, made over the years, by the Institute faculty and researchers have been recognized from local to global level, and as per the SCOPUS database the Institute ranks number one in the world w.r.t. number of scientific publications on Himalayan biodiversity and conservation. With this strong base, the Institute has established Center for Biodiversity Conservation and Management (CBCM) to play a more proactive role in Himalayan biodiversity sector. The aim is to further strengthen science based understanding on Himalayan biodiversity to promote its conservation and to ensure sustained flow of its services for human well-being under global change scenario.

Objectives

- Mainstreaming of Himalaya biodiversity knowledge in conservation decision making at local/state/national level
- Establishing representative long-term ecological monitoring sites/plots so that LTEM data becomes part of regional synthesis and long-term predictions
- Promoting partnership and collaboration for knowledge networking and capacity improvement to address issues of biodiversity conservation at local to sub-national level
- Standardizing protocols/approaches for sustainable utilization of bioresoures (i.e., harvesting, nutritional and therapeutic potential assessment, propagation and cultivation packages, etc.).

Long-term Ecological Monitoring in Western Himalaya and Knowledge Generation for Decision Making (In house 2017 - 2020)

Mountains have been recognized as important ecosystems by the Convention on Biological Diversity. This great wealth of biological diversity is attributed to the wide variety of environments in the Himalayan mountains, which is one among the 35 biodiversity hotspots of the globe having enormous ecological and economic importance that has sustained people through generations. However, we are loosing biodiversity owing to various natural and man-made drivers of change. In the recent years climate change has posed a new threat to biodiversity. The magnitude and consequences of which are still poorly understood. Arguably the future of biodiversity in the region would affect the well-being of local communities and downstream dependent people. Therefore, understanding intensity and direction of on-going and potential changes of climate change on structure and functioning of biodiversity becomes important. However, in absence of Long-term Ecological Monitoring Site(s) the region lacks mechanism for continuous flow of robust data-sets/information required for taking informed decisions. Also, the available data-sets on biodiversity are fragmentary. Realizing these gaps, with a focus on west Himalaya, the project broadly attempts to: (i) Establish Long-term Ecological Monitoring Site(s), along a representative altitude zone in four forest types in Gaula catchment (Distt. Nainital) for continuous monitoring and response studies to ensure effective flow of information for decision-making, (ii) Synthesize available biodiversity information to make it utilizable for effective conservation planning and suggesting sustainable use of biodiversity.

Objectives

- To establish long-term ecological monitoring site (s) for (i) continuous monitoring (structural and functional feature) of selected plant biodiversity components, and selected goods and services, and (ii) developing mechanisms for effective flow of information for decision-making on conservation and sustainable use of bio-resources at local and regional scales.
- To document response patterns of selected biodiversity elements for (i) enhanced understanding on change sensitivity, individually and collectively; and (ii) suggesting best possible options for long term conservation and livelihood promotion.
- To collect, collate and synthesize available biodiversity information to make it utilizable for (i) effective conservation planning (i.e., unique & threatened species, conservation areas, and sensitive habitats), (ii) suggesting sustainable use (i.e., medicinal plants, wild edible plants, and biodiversity based livelihoods options).
- To promote partnership for knowledge networking and capacity improvement for (i) effective flow and sharing of research and evidence based information/knowledge; (ii) better connected knowledge on biodiversity and ecosystem services with decision-making; (iii) enhance capacity of stakeholders to understand linkages between biodiversity and sustainable development in the region.

Achievements

1. Meteorological data was collected during July 2018 to March 2019. Mean atmospheric temperature during this period was found ranging from 11.07 (Mixed-Broadleaf forest, Patwadangar) - 14.86 °C (Sal forest, Ranibagh) and mean annual Relative Humidity from 72.8% (Oak forest, Kailakhan) - 96.2% (Oak-Conifer forest, Snow View, Nainital).
2. Phenological study revealed that leafing activity is mostly confined to spring and summer months in all the four forest types, whereas leaf drop was observed year-round in Sal and Pine forests. In the Oak and mixed forest both leafing and leaf drop activities were confined to spring and summer months. In all the forest types flowering and fruiting continues in the herb, shrub and trees year-round (Fig. 10 & 11).

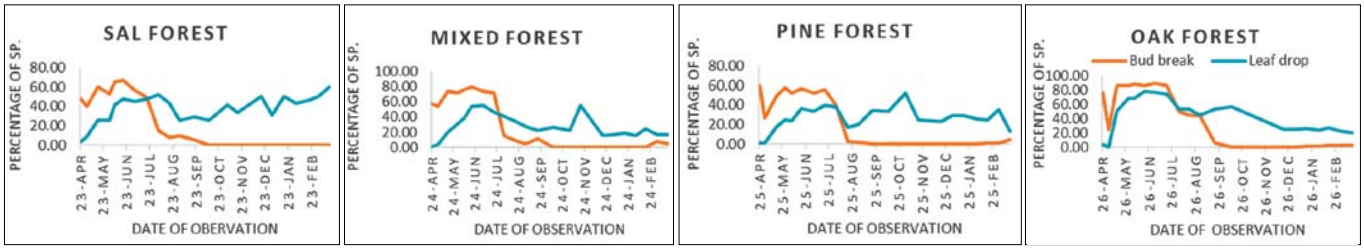


Fig 10. Periodicity of bud break and leaf drop in plant communities of LTEM plots

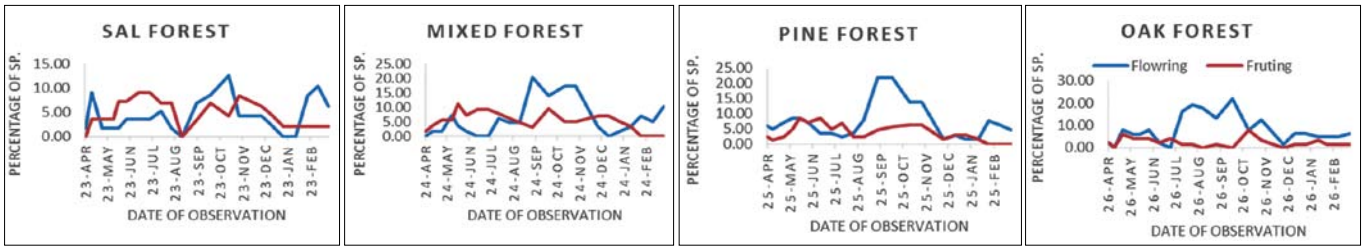


Fig 11. Periodicity of flowering and fruiting in plant communities of LTEM plots

3. In Sal forest a total of 45 species (45 genus and 25 families), total 67 species (57 genus and 33 families) in Pine forest, total 65 species (55 genus and 36 families) in mixed broad leaf forest and total 57 species (50 genus and 34 families) were recorded in Oak forest (during summer, rainy seasons). In the winter season, 90 new plant species (herbs and shrubs which belong to 48 families) were recorded from these forests.
4. Details of phytosociological analysis of vegetation of the LTEM plots in summer, rainy and winter seasons across the 4 LTEM plots is given in Table 3. In the forests adjacent to the LTEM plots phytosociological study in winter 2019 reveals that in Sal forest - *Shorea robusta* had maximum density (113 ind./ha) and total basal area (TBA) (10.83 m^2/ha), in mixed broad leaf forest *Pinus roxburghii* had the maximum density (54 ind./ha) and TBA (15.28 m2/ha), in Pine forest *Pinus roxburghii* had maximum density (146 ind./ha) and (TBA 7.68 m^2/ha). In Oak forest *Quercus leucotrichophora* had the maximum density (185 ind./ha) and TBA (25.80 m^2/ha).

Table 3: Baseline data of selected structural aspects of vegetation of LTEM plots and regeneration in 2018

Forest type (LTEM Plots)	Life form	Total density (ind./ha)	TBA (m^2/ha)	Dominant species	Regeneration status of tree species (Ind./ha)			
					Summer		Rainy	Winter
Sal forest	Tree	392	11.84	*Shorea robusta*	Seedlings	2,967	3067	3375
	Shrub	4,000	-	*Lantana camara*	Saplings	550	498	497
Pine forest	Tree	258	6.73	*Pinus roxburghii*	Seedlings	3,917	3783	3867
	Shrub	2,467	-	*Eupatorium adenophorum*	Saplings	158	158	108
Mixed broad leaf	Tree	275	8.78	*Myrica esculanta*	Seedlings	200	192	342
	Shrub	26,267	-	*Eupatorium adenophorum*	Saplings	125	108	150
Banj-Oak forest	Tree	325	13.81	*Quercus leucotrichophora*	Seedlings	133	183	217
	Shrub	13,760	-	*Eupatorium adenophorum*	Saplings	0	0	0

5. In eco-physiological study it was found that Oak forest with maximum light intensity reflected maximum stomatal conductance and maximum photosynthesis. In the mixed forest type both light intensity and stomatal conductance were minimum.
6. Soil organic carbon was found highest in Oak forest (5.46%) and lowest in Sal forest (0.48%). In the Oak forest, soil having high organic carbon and low bulk density depicts its high fertility and good porosity.The potassium and nitrogen content were found highest in the soil of Oak forest (N= 0.73%; K= 1.64%) and lowest in the Pine forest (N= 0.38%; K= 0.43%).
7. "Swach Bharat Abhiyan" was organized in two schools of Gaula catchment (i.e. J.H.S. Chopra, Nainital and G.I.C Dogra, Nainital) in which a total of 84 people participated.

Hyperspectral Imaging for Sharper Definition of Himalayan Ecosystem and Its High Value Plant Species under Climate Uncertainties (NMHS, MoEF&CC, 2018-2021)

Information on population status of high value plants in the diverse habitats of the Himalayan region is very crucial. However, population assessment of the high value species which are mostly rare and threatened is very difficult due to highly variable topography, harsh climate and inaccessibility. With the advent of modern remote sensing and GIS technologies it is now possible to detect and quantify the biophysical and biochemical parameters of different vegetation types for assessment of population using hyperspectral imaging technologies. Hyperspectral imaging provides spectral response in narrow and continuous bands with significant improvement when compared with broad band in terms of spectral resolution. The spectral profile obtained through radiometer can be used for creation of spectral digital library and subsequently used it for detection and monitoring of high value, rare and threatened plants. Hyperspectral remote sensing can be further used for

the estimation of phenolic contents as well as biophysical and biochemical parameters of the plants through forward and inverse modeling approach.

Objectives

- Detection and identification of the high value rare plants of medicinal and economic importance in relation to pedological and climatic conditions using hyperspectral spectroradiometer, AVIRIS next generation data and field observations in the Himalaya.
- Spectral library of the high value, rare and economically important plants with the hyperspectral satellite and airborne data for large scale quantification.
- Development of forward and inverse models for the retrieval of biophysical and biochemical parameters from the economically important plants species using hyperspectral data.
- Fine scale space-time map of the selected species of high value medicinal plants in the Himalaya.
- Projection of the future distribution of high value medicinal plants in relation to the climate change uncertainties.
- Development of knowledge based management planning for sustainable harvesting and conservation of the high value, rare medicinal plant species in the Himalaya.

Achievements

1. A review of all studies has been conducted on the medicinal plants in the study area i.e. Pindari area in Uttarakhand.
2. Based on intensive literature review eight species of high value, threatened and economically important species, namely *Rhododendron campanulatum* D. Don, *Podophyllum hexandrum* Royle, *Jurinea macrocephala* DC., *Delphinium brunonianum* Royle, *Rheum webbianum* Royle, *Arnebia benthamii* (Wall. ex G. Don) I.M. Johnst., *Dactylorhiza hatagirea* (D. Don) Soó and *Angelica glauca* Edgew. have been identified for creation of the hyperspectral library in Uttarakhand Himalaya.
3. Using the web of Science database and complete review of the biochemical properties of the selected eight species has been conducted for selection of parameters.

Creating a Genomics Platform for Apple Research in India (DBT, Govt of India, 2018-2020)

Biotechnological tools (various DNA markers) have proven immensely useful in genetic analysis of many crops including the tree species. Molecular methods especially those based on DNA markers/polymorphisms have become routine for estimation of genetic diversity, DNA fingerprints based unique Molecular IDs of individual genotypes/ cultivars, construction of linkage map, identification of molecular tags/markers linked to economic traits (including resistance to biotic and abiotic stresses) bringing in new dimensions and impetus to plant genetic improvement programs. Realizing this, the present long-term network project for 'Creating a genomic platform for apple research in India' was initiated in 2010 and in 2017-18 phase II of this project was approved. It is expected that the successful completion of the project will help realize the DNA markers/molecular tags based molecular breeding in apple programs for bringing acceleration, directionality and more efficiency in achieving the desired genetic improvement. Simultaneously, it is also hoped that the germplasm repositories that are being established, will serve as a ready fully characterized resource to meet the demands of different stakeholders, from researchers to orchardists. Also, the proposed studies will help in providing important information about the inheritance pattern/genes(s)/functional basis of some of the important traits, especially related to the fruit quality/quantity/self life.

Objectives

- Establishment and maintenance of clonal F1 mapping orchard and germplasm repository at Horticulture garden Chaubatia and Suryakunj, respectively
- Phenotyping of the clonal F1 mapping population based on standard pre-flowering/ pre fruiting morphological characters
- Transfer/exchange of scion wood of apple germplasm to Baderwah campus (Jammu University), Zakura campus (Kashmir University, Srinagar) in J&k and YSPUHF, Solan (HP)
- Providing inputs/data for the development of database on apple germplasm

Achievements

- Scion wood of a total of 140 genotypes of mapping population received from Kashmir University have been grafted and

planted at Horticulture garden Chaubatia. Of the total 140 genotypes, only 94 genotypes survived. Morphological data of the 94 grafted genotypes in triplicate have been collected.

- Phenotypic of mapping population i.e. stem and leaf characters have been collected. Initial results reveals that in active growth period maximum individuals attained height of 60-80 cm tall, with 10-20 leaves. Most of leaves were serrate while in few plant leaves were biserrate.
- Germplasm collected and planted during the first phase of the project have been maintained in two different sites (Govt. Horticultural Garden, Chaubatia and Suryakunj, Kosi-Katarmal, Almora).

Timberline and Altitudinal Gradient Ecology of Himalayas, and Human Use Sustenance in a Warming Climate (NMHS, MoEF&CC, 2016-2019)

The timberline of the Himalayan region needs to be investigated thoroughly because (i) it is an effective indicator of climate change, (ii) it is different from timberlines of the other regions (e.g., highest in the world and used by local people), and (iii) of the confusing and contradictory reports on its responses to climate change (e.g., upward movement of timberline) and other anthropogenic factors. Besides being an effective indicator of climate warming, structural and functional changes in timberline have implications to decline in biodiversity, wildlife habitats, provisioning of ecosystem services, such as medicinal plants, grazing sites for migratory livestock, recreational use, etc. In the Western Himalaya, regeneration of forest species is poor along the timberline ecotone and several species might have no space to migrate upwards due to disturbance and spread of invasive alien species with adverse impact on biodiversity and ecosystem balance. Also, almost no reliable information is available on even basic parameters such as impact of air temperature rise on phenological responses of plants, tree water relations, snowfall and snow melt on composition and functions of various forest ecosystems, timberline resource use, etc. This is a multi-site and multi-partner project involving six leading organizations working in the Himalayan region with a team of a dozen Investigators on the following objectives:

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
- To study relationship between tree ring growth and past climatic changes in different climate regime across IHR
- To understand the impact of depletion of snow-melt water on growth of tree seedlings, grasslands species composition and selected functional processes
- To promote participatory action research (Citizen Science) on innovative interventions to improve livelihoods, women participation in conservation and management of timberline resources

Achievements

1. In Chopta-Tungnath timberline ecotone (altitude, 2955-3700 m asl) 5 forest stands (viz., *Abies spectabilis, Betula utilis, Quercus semecarpifolia, Rhododendron arboreum* and *R. campanulatum*) were marked for phenological observations of major phenophases and studies on leaf area, leaf mass, leaf number per shoot of these species from May 2018-March 2019. The timberline species are characterized by a delayed bud-break and leafing, a slow leaf expansion, a short steady-state period in leaf mass, lower shoot growth, higher leaf density per shoot and lower leaf N concentration compared to the mid-altitude forest tree species of the western Himalayan region.
2. Data (May 2018-March 2019) for atmospheric temperature, atmospheric humidity, soil moisture and soil temperature for the 5 marked forest stands at Tungnath was measured at monthly interval. Minimum difference between air temperature and soil temperature was recorded during July-August and the maximum during November (Fig. 12).
3. Vegetation assessment along the altitude gradient in three altitudinal transects at Tungnath revealed that the patterns of tree density did not follow an uniform trend with the altitude, while the species richness decreases with increasing the altitude.

4. In the Tungnath area along an altitudinal gradient of 2000 m to 3700 m asl a total of 108 Lichen species represented by 41 genera and 15 families were reported. Maximum species were reported at 2500 and 2600 m altitude belt (62 species) while minimum species were reported at 3700 m (16 species).
5. Total length of timberline was computed 2,612 km in Jammu & Kashmir (2612 m-4080 m amsl), 3,257km in Himachal Pradesh (2426m-4262 m amsl), and 730 km in Sikkim (2621 m-4390 m). Distribution of total timberline length along the elevational gradient showed a bell-shaped pattern with peak (accounting for over one-third of the length) at 3200-3600m in Jammu & Kashmir, 3400-3600 m in Himachal Pradesh and 3600-4000 m in Sikkim.
6. A synoptic view of timberline ecotone was developed and characterized its various spatial attributes for three detail sites Sinthan watershed (40.16 km^2 area) in Jammu & Kashmir, Tungnath watershed (24 km^2 area) in Uttarakhand, and Dzongri watershed (143.73 km^2 area) in Sikkim.

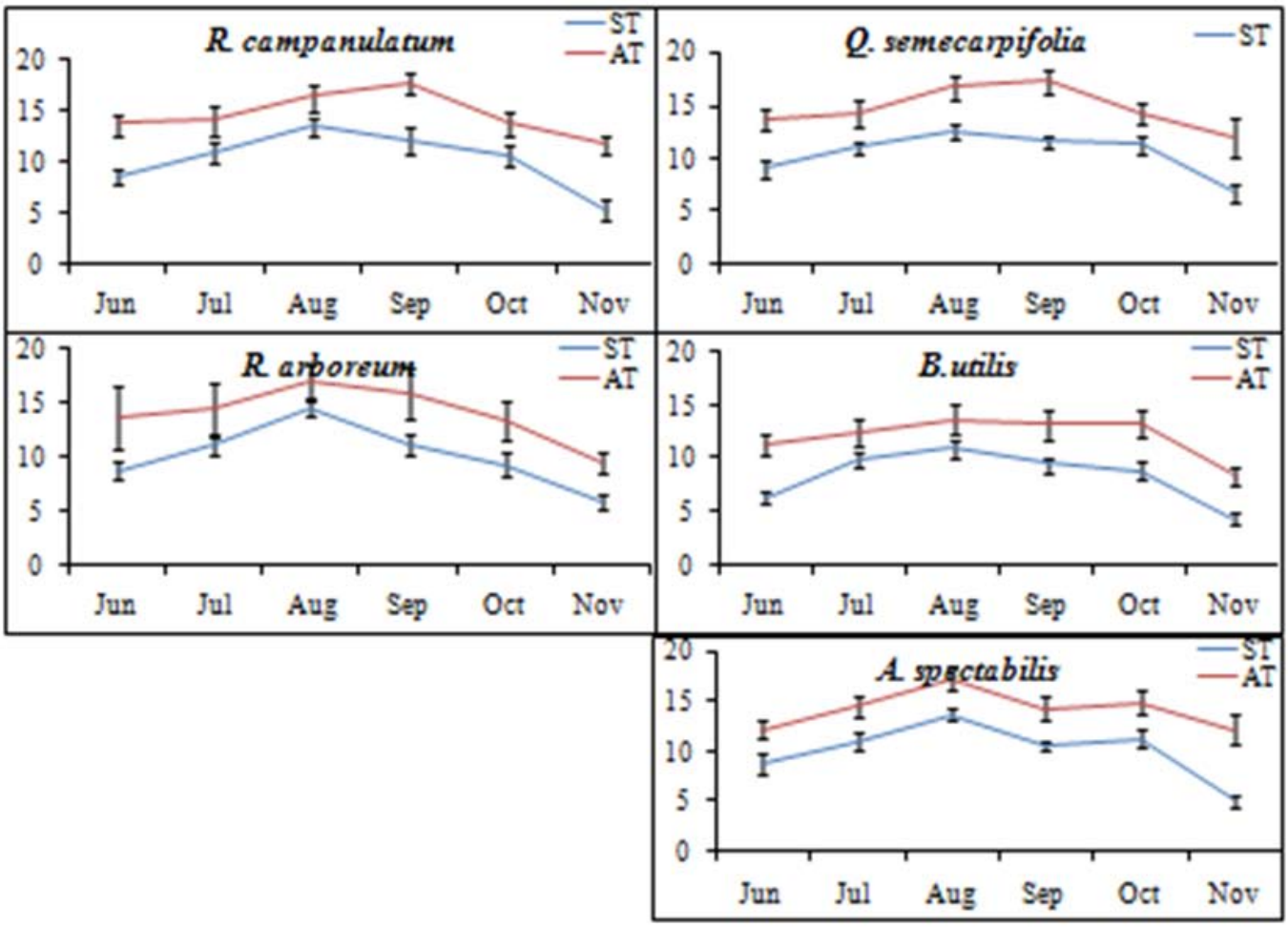


Fig 12. Mean values of micro-climatic data observed across five forest sites in timberline of Tungnath (ST= Soil temperature; AT= Air temperature) (2018).

Multidisciplinary Studies in Floristic Assessment, Ecological Analysis, Ecosystem Services, Conservation and Sustainable Management of Selected National Parks in Western Himalaya (NMHS, MOEF&CC, 2016-2019)

The Article 8 of the Convention on Biological Diversity stresses in-situ conservation of biota in a holistic manner and to fulfill 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 centres of endemism of plant diversity in Western Himalaya. Due to scenic beauty, diversity

of colorful 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 and training about the plant diversity and sustainable plant utilization

Achievements

1. Floristic diversity was documented in Valley of Flowers National Park where a total of 614 taxa (609 species, 3 subspecies and 2 varieties) belonging to 277 genera and 70 families have been recorded and 72 plants were enumerated as additions to flora of Valley of Flowers National Park (VoFNP). Among 614 taxa, 585 are Angiosperms, 23 Pteridophytes and 6 Gymnosperms. Five species are endemic to the IHR. Of the total, 54 species were recorded under threatened categories of International Union for Conservation of Nature (IUCN), Conservation Assessment of Management Prioritization (CAMP) and Red Data Book. One species namely Cuscuta reflexa Roxb recorded as invasive in VoFNP. Similarly, in Great Himalayan National Park (GHNP) a total of 406 species belonging to 220 genera and 55 families were recorded. Of these, 51 species were recorded in different threatened categories.
2. Phytosociological study reveals that plant density was higher in lower altitude as compared to higher altitude in both the National Parks. For instance, in VoFNP at 3600 m - 70.33 Ind/m^2 and at 4500 m - 39 Ind/m^2. Similarly in GHNP, at 3600 m - 34.4 Ind/m^2 and 5100 m - 0.5 Ind/m^2.
3. One day workshop cum awareness campaign was conducted in GHNP regarding biodiversity conservation on 04th July 2018. More than 300 participants (about 100 villagers, 120 students, 30 researchers, 20 forest department people, 30 teachers including scientists) participated in the awareness programme. Villagers and students were exposed to the importance and conservation of threatened and medicinal plants of GHNP.

Quality Plant Production and Promotion of Cultivation of Selected Himalayan Medicinal Plants for Livelihood Enhancement (Uttarakhand council of Biotechnology, 2016-2019)

The 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, due to increasing demand for medicinal plants in the pharmaceutical industries, there has been a large scale and uncontrolled collection from the wild. Thus, in the absence of organized cultivation, pressure in their natural population is increasing. As a result, many of these species have fallen into the list of different threatened categories. In such circumstances, there is a need to develop approaches for conservation and sustainable utilization of these plants. 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 with the following objectives. The selected species under this project 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. A large number of quality plant material of *Valeriana jatamansi* and *Hedychium spicatum* have been produced through *in vitro* propagation and vegetative means for the promotion of cultivation in farmers field.

2. Results of phytochemical attributes like, total phenols, flavonoids, tannins and antioxidant activities revealed the comparative amounts of content in tissue culture raised and mother plants of *V. jatamansi*.
3. Among different seasons, summer season is considered as the optimum harvesting time for harnessing higher bioactive compound like velerenic acid in *V. jatamansi*.
4. Among the physiological responses in *Vaeleriana jatamansi* in PPFD 200 and 700 CO_2 shows higher photosynthestic rate under nursery and nethouse conditions.

Promoting Conservation of Threatened Plant Species in West Himalayan region - A Participatory Approach (NMHS, MoEF&CC, 2018-2021)

Conservation and ensuring optimal use of high value plants species has emerged as one of the priority agenda of research and development after realizing the fact that it can serve the basic needs of human being together with maintaining the biodiversity. However, over the years the number of plant species has decreased at an unprecedented rate, which has put biodiversity under considerable threat. Considering the high rate of disappearance/ depletion of plant species in their natural habitats it would be pertinent to adopt multiplication and conservation measures, both *in situ* as well as *ex situ* for conservation and sustainable utilization of medicinal plants so as to improve their availability for end users and release pressure of exploitation from their natural habitats. In addition, it is pertinent to establish germplasm repositories so as to fulfill the need of planting material while reintroduction and cultivation activities taking place. In this context, this project has been undertaken with the following objectives:

Objectives

- To develop species specific protocols for recovery/reintroduction of threatened species.
- To establish demonstrations of threatened Himalayan medicinal plants at different altitudes.
- To promote cultivation of threatened medicinal plants at farmers field
- To develop market linkages for selling of cultivated produce
- To sensitize diverse stakeholders group towards promoting conservation of threatened medicinal plants

Achievements

1. Species specific protocols for medicinal plants i.e. *Cinnamomum tamala*, *Paris polyphylla*, *Allium strechii* have been developed and over 50000 plants of *Cinamomum tamala* have been produced through seed germination.
2. Demonstration of threatened medicinal plants at farmers field and Sri Narayan Ashram (Distt. Pithoragarh) have been established. All the target species (7 No.) are growing in the demonstration center of Sri Narayan Ashram (Fig. 13).
3. Awareness program and training provided to 500 farmers of Chaudas area and a total of 134 farmers of 9 villages were agreed for cultivation of the target species.
4. A total of 3000 stakeholders have been sensitized towards promoting conservation of threatened medicinal plants through organizing various meeting at village and block level.
5. A medicinal plants buyers and sellers meet was organized at Rung Community Hall, Dharchula for marketing of cultivated produce at project site.

Fig 13. Demonstration of medicinal plants and exposure of diverse stakeholders group at Sri Narayan Ashram

Mainstreaming Landscape Approach for Biodiversity Conservation, Improved livelihoods and Ecosystem Health in Kailash Sacred Landscape Part of India (NMHS, MoEF&CC, 2018-2021)

The fundamental philosophy of the Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI) considers that conservation and sustainable use of natural resources at the landscape scale is determined by ecosystems rather than administrative boundaries. Therefore, having adopted a landscape approach, the Kailash sacred landscape is being worked out for long term conservation and development through transboundary cooperation approach. The landscape approach seeks to identify, understand and reconcile various interests, values and needs of different stakeholders to achieve shared objectives, considering dependencies and reducing impacts of human activities on biodiversity, ecosystem services and climate change. Hence the project proposal is linked to pilot experiences of biodiversity conservation and its value-added use in "transboundary landscapes" by a consortium of partner agencies that include State Biodiversity Board, Govt. of Uttarakhand (SBB), G.B. Pant Institute of Himalayan Environment & Development (GBPIHED), Wildlife Institute of India (WII), Uttarakhand Space Application Centre (USAC), Central Himalayan Environment Association (CHEA), and Uttarakhand Forest Department (UKFD). The International Centre for Integrated Mountain Development (ICIMOD), as facilitating agency for KSLCDI, will act as technical advisory agency. The GBPIHED is involved in Objective No. 2 of this multi-partner project. The project builds on existing pilot learning, expertise and core competence of partnering institutions, and fosters strengthening of convergence and cooperative mechanisms amongst planning and implementing agencies while establishing communication, outreach and policy dialogues for long term networking amongst key stakeholders.

Objectives

- To develop and promote Incentive Based Mechanisms (IBM) for biodiversity conservation and benefit sharing
- To strengthen community institutions and establish convergence for restoration of degraded habitats and management of ecosystems
- To harness heritage value of cultural and biological diversity (i.e., wild and domesticated) for livelihoods promotion and biodiversity conservation
- To identify critical ecosystems/habitats, biodiversity corridors and suggest evidence based management plans
- To develop and institutionalize landscape level biodiversity knowledge network and create a data and information centre for strengthening science-policy-practice linkages

Achievements

1. One day block level synergy building workshop was organized at Gangolihat (Distt. Pithoragarh) which was attended by officials from various line departments, project partners and village representatives and village people. Various activities of the project were discussed and the degraded lands in the target sites were identified.
2. Hands on training regarding the restoration interventions was given to 04 village resource persons which are likely to act as resource persons/trainers in the future restoration activities in different areas of the Kailash Landscape.
3. Need assessment of communities in 9 villages (5 in Chandak-Aunlaghat Watershed and 4 in Hat-Kalika Watershed) was conducted and degraded land restoration proposals from the 4 villages of Hat Kalika Watershed were received with their restoration based needs.
4. One restoration site was developed on 1 hectare degraded land in Sunali hamlet of Jajut Van Panchayat (Hat Kalika Watershed) by planting more than 200 saplings of different plant species.

SUMMARY OF THE COMPLETED PROJECT

Assessing Landscape Restoration Opportunities for the State of Uttarakhand, India (IUCN, 2017-18)

Land degradation is a global problem caused by a variety of factors or processes which include soil erosion by water/ wind, deterioration in physical, chemical and biological properties of soil and loss of its productive potential. Worldwide about 2 billion ha land is under various forms of degradation. Land degradation is also a pressing problem in India owing to various reasons. Estimates of degraded land in India vary from 30-175 mha following various assessments methods and RS data used. Among Indian states, Uttarakhand, a predominantly mountainous state, ranks 20th in terms of area under wasteland, which has 23.91% land lying under degraded category following various reasons. ROAM (Restoration Opportunities Assessment Methodology) is a comprehensive assessment tool inclusive of all concerned stakeholders one way or the other in land restoration process. Realizing the urgent need of land restoration in India, IUCN is pilot testing ROAM through a sub-national assessment in the State of Uttarakhand, mainly due to the State's high potential of land based strategy for mitigation and adaptation towards addressing issues of climate change. GBPIHED undertaken this study for assessment of priority FLR (Forest landscape restoration) areas and to suggest most appropriate interventions in Uttarakhand. While broad restoration opportunities were identified at state level, districts of Pithoragarh and Garhwal (Pauri) were taken up for more intensive investigation. To make this participatory process representative, 11 consultations were held across a range of stakeholders such as Van Panchayats, Gram Sabha, NGOs, state line departments, and active community members across Block and Distt. HQs in Garhwal and Pithoragarh districts in 2017. Also, historical data of past 1-2 decades on restorations activities carried out by various departments and other related agencies were collected.

Achievements

During the consultation processes following drivers of land degradation (both natural and anthropogenic) were identified in order of priority: (i) Increasing frequency of forest fire, (ii) Invasion of alien plants (e.g. *Lantana camara*), (iii) Livestock grazing, (iv) Landslides and soil erosion, (v) Pressure on forests for fodder/fuel wood, and (vi) Increasing apathy of people towards agriculture and forest management. The ecological and socio-economic consequences of the land degradation were reported as: (i) Drying up of springs/ streams, (ii) Soil erosion and downstream flooding, (iii) Human-wildlife conflict, (iv) Declining natural resources and livelihood options, and (v) Increasing out-migration. Thus a vicious cycle between land degradation, diminishing natural resource based livelihood options and out-migration is discernible as a consequence of land degradation. In order to offer R&D based restoration opportunities three physiographic zones were identified in the target districts. In the high altitude region restorations of degraded land due to natural hazards (such as landslides) need to be handled in priority through bio-engineering methods using fast growing and soil binding species such as (*Alnus, Salix, Hippophae* etc). In the mid and low altitude areas issues such as: (i) Minimize forest fire including expansion of fire prone Pine forests (ii) Promotion of agri-horticulture, cultivation of medicinal, and aromatic plants, silvi-pasture promotion using MPTs for livelihood, (iii) Linking sacred groves/sites and VPs with people's livelihoods such as (eco-tourism). These measures are likely to enhance community participation in effective treatment of degraded land. It is expected that this comprehensive approach of FLR using ROAM would prove more pragmatic over the traditional approach of sectoral treatment of degraded land in Uttarakhand.

Center for Socio Economic Development (CSED)

The Indian Himalayan region (IHR), which extends to twelve states (ten fully and two states partially), covers an area of 591000 sq km with a population of about 486 lakh with over 170 ethnic communities that have distinct socio-cultural milieu, demographic setups, societal ethos, resource endowment and reliance. Despite of rich indigenous wisdom to manage resources the productivity of agricultural lands is low with minimal use of modern technologies. Rural communities face problems related to unsustainability, poverty, land use change, degradation of natural resources, livelihood and migration. There is lack of a proper understanding on rural poverty, diverse causes of natural resource degradation, socio-economic constraints, and other issues concerning Himalaya. The linkages of forest and agriculture, poverty and social capital are multifaceted and need more investigation with location-specific focus. The Institute since its inception has been working on location-specific problems, such as generating mountain specific knowledge on priority problems, management of natural resource, demonstrating appropriate land use models, promoting good practices through peoples' participation, undertakes policy advocacy, and ensuring capacity building of communities. The Center for Socio-economic Development (CSED) is working for economic and social development of communities along with environmental protection. The Centre significantly contributes to document mountain specific indigenous knowledge on natural resource management, community livelihood, socio-economic databases, and drivers of change; strengthen sustainable livelihood through promotion of on-farm and off-farm activities; demonstrate and disseminate natural resource management models, and appropriate knowledge products; develop and strengthen entrepreneurial skills and self-employment opportunities through capacity building. During the reporting year following research and development activities were undertaken by the CSED:

Development of Model Village through Technology Transfer for Livelihood Enhancement in the Central Himalaya (In house, 2017-2020)

The livelihood of Himalayan people is highly dependent on natural resources and communities possess rich indigenous wisdom to manage these resources. Agriculture is subsistence in nature with low productivity and minimal use of modern technologies. The forests supply diverse goods and services to millions of people living within and outside the region. Status of forests is strongly influenced by farmers' socio-economic status and on governance of formal and informal institutions. Mostly the people of the region are poor, marginalized and disadvantaged. Degrading of forests, abandonment of agricultural land, water scarcity, and growing animal-human conflicts are important concerns for all. Main challenge is to find solutions to improve quality of livelihood and human wellbeing within a village ecosystem. The development of the

region requires significant efforts, planning, and human and financial resources to reach to the level of a model village. The present project has been selected with similar target. A total of three villages have been targeted that represents different altitude of Almora district so as to consider the location-specific needs. The 'model village' development is a participatory and community-driven development approach that aims to upgrade community livelihood at village level by enhancing agricultural productivity, availability of biomass, and income; improving environmental and ecological restoration; strengthening village institutions and sustainable governance; and expanding community access to govt. run schemes, programmes and services.

Objectives

- To strengthen and transfer farm based technologies for enhancing livelihood.
- Capacity building through trainings/on site demonstration/field exercises of target villages to assess location specific needs
- To identify/develop linkage with development schemes for implementation of identified activities.
- To empower village communities, particularly women and weaker sections, through improved natural resource management technologies for income generation.

Achievements

1. Three selected villages of Almora districts are Bhetuli (>1800 m elevation, Takula Block), Jyoli (1200-1800 m elevation, Hawalbagh Block) and Malera (900-1200 m elevation, Hawalbagh Block). Bhetuli village comprises a total of 151 households (population 713; male 379, female 334); Jyoli village has 103 households (population 630; male 330, female 300), and Malera village has 19 households (population 93; male 41, female 52). The composition of scheduled caste (SC) population was 40% and 38% in Bhetuli and Jyoli, respectively; whereas no SC was residing in Malera village. The male and female literacy in these villages was 89.18 and 80.54% (total 85%), 88.78 and 90.33% (total 89.55%), and 80.49 and 78.85% (total 79.67%), respectively for Bhetuli, Jyoli, and Malera.
2. In all villages 79 to 97 % farmers were marginal having land holding less than 0.5 ha. The composition of working population in primary (cultivators and agricultural labors), secondary (self-employed persons), and tertiary (government and private services) sectors for Bhetuli, Jyoli and Malera villages was 54, 10, 36%; 53, 5, 42%; and 52, 11, 37%, respectively. The data clearly shows that still majority of the population is engaged in on-farm activities.
3. During the functioning of the project activities a total of 7 training programmes were conducted at Rural Technology Complex of the Institute, out of these, five training programmes were on Bio-briquetting and two training programmes were on Low cost technologies and Integrated Fish Farming respectively (Fig. 14). In the trainings total 364 persons were trained which included 127 males and 237 females covering 55 villages from the districts for the awareness about project activities as well as future references.

Fig 14. Different low cost technologies adopted by villagers for income generation

4. On farm training programmes were also conducted at study villages. These programmes were on poultry farming and pre plantation techniques. In the training programmes a total of 90 people participated which included 54 males and 36 females.
5. A total of 114 families were benefited through field demonstrations of polyhouse, polytank, vermi-compost pit and chick birds for poultry farming. Under the plantation activities a total of 2730 fruits, medicinal, bamboo and other plants were distributed and planted in the target villages benefiting 127 families. Survival rate of the species was 83% after one year. A total of 21 training programmes were conducted for the farmers of target villages under different subject round the year (Table 4).

Table 4: Training Programs within the study villages.

	Subject of Training	Bhetuli	Malera	Jyoli	Total
1	Village level interaction & issues identification	2	2	2	6
2	Technological information	2	1	1	4
3	SHGs issues	2	1	1	4
4	Capacity building in low-cost technologies (RTC)	2	1	1	4
5	Plantation Training	1	-	-	1
6	Poultry farming Training	1	-	-	1
7	Village Management Plan	2	-	-	1
	Total	12	5	5	21

6. Under project activities Swachh Bharat Campaign of Swachhta Hi Seva was organized in the target villages. It included students, parents and faculty members of three Inter Colleges in Almora district. A total of 910 persons participated in the campaign.
7. To undertake Bhetuli model village development, a two day workshop and participatory planning process was initiated, which led to identify many issues and concerns for village development. A 'Village Development and Action Plan' was finalized comprising vision and objectives, issues of concerns, statements about problems, and development potential of the village with the consent of the community. The document also comprises maps and diagrams to support and clarify various priority actions and strategies for the target community along with method and timeframe of implementation and cost.
8. The participatory approach to development planning at the village level seems to provide a new technique to encourage and empower village people to plan and implement development projects according to their needs and aspirations. The workshop also led to identify various developmental proposals in the form of actions, strategies and programmes (Table 5).

Table 5: Development proposals from village action plan workshops for Bhetuli village

Development Proposal	Frequency	%
Skill training on low-cost technologies	90	60
Capacity building on bio-briquette making	30	20
Development of abandoned agriculture land	9	6
Integrated fish farming	2	1
Polyhouse for vegetable cultivation	3	2
Water harvesting tanks	2	1
Producing vermi-compost and organic fertilizer	1	1
Backyard poultry development	15	10
Establish market value chain	2	1
Tourism & homestay	11	7
Horticulture development and orchards	127	84
Facilitate development of small industries	11	7
Village cooperatives and self-help groups	1	1
Government to provide loan, seeds and fertilizer	1	1
Milk and dairy development	3	2
Fodder development	5	3
Swachh Bharat campaign of Swachhta Hi Seva	125	83

9. Uttarakhand Government has been implementing 'Veer Shiromani Madho Singh Bhadari Integrated Village Development Program' to develop selected village clusters in each district. For Almora district 11 such villages have been identified. On the demand of district administration the project has been extending technical support to such villages; it is building capacity of concerned staff and nodal officers, and help in developing village development plans. It is expected that the approach will allow learning many new lessons for rural area development in the Himalayan region, and such efforts may lead villages towards achieving sustainable development.

Network Programme on Convergence of Traditional Knowledge System for Sustainable Development of Indian Himalaya (NMSHE-TF 5, 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 recedes 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 to 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 System (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
- 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. A total of 23 communities residing in 06 Himalayan states have been targeted and data analysis was done for identified sectors viz., land and soil management, water conservation practices, bio-resources and bio-processing.
2. Communities use wide variety of plant resources for their sustenance. An inventory of wild edible plant resources was made that comprised as many as 704 species used in Arunachal Pradesh, 107 in Nagaland, 456 in Sikkim, 452 in West Bengal Hills, 1226 in Uttarakhand, and 323 species in Himachal Pradesh by the different tribes.
3. Communities also possess huge indigenous knowledge about various types of fermented foods, beverages, recipes that are used either as local delicacies and/or during religious and customary rituals of the community, viz., Arunachal Pradesh (56), Sikkim (13) Uttarakhand (18) and Himachal Pradesh (38). Some of these dishes were found rich in proteins thus essential ingredients for a balanced diet.
4. A total of 826 species (AP-607 spp; SK- 49 spp; UK- 124 spp & HP-46 spp) were used for bioprospecting and 155 species (AP-58 spp; SK- 25 spp; UK- 54 spp & HP-18 spp) were used for agro biodiversity. A total of 40 landraces of rice were reported out of which only 47% are under cultivation from Bageshwar district of Uttarakhand.
5. Land and soil management practices are almost similar in North-East region. Soil and water management systems are interrelated with each other. Traditionally community knowledge on the soil and water management practices is done through agronomic and mechanical measures. A total 06 agriculture practices (Jhum, Echo, Zabo, Terrace rice cultivation and WRC etc.) from Arunachal Pradesh and Nagaland and 10 land use practices comprising 06 common agronomic and 04 mechanical measures have been identified from Sikkim and West Bengal hills.
6. Regional calendars of communities for taking up agricultural practices, rituals and festivals, which are in one or other way related to the nature and the natural resource systems, have also been created.

7. A record of traditions in terms of their eroding frequency is being prepared that may serve as an important tool to control the eroding factors behind.

A Sustainable Approach for Livelihood Improvement by Integrated Natural Resource Management in the Central Himalaya (NMHS, MoEF&CC, 2016-2019)

In IHR the foremost livelihood of rural people is mainly dependent 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 proposition. 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, 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 problems which need to be addressed for improving the status of natural resources and enhance the livelihood in the study area were ascertained through PRA, group discussion and questionnaire survey. In order to address these problems nine suitable low cost, eco-friendly and replicable technology packages were identified and successfully transferred to the stakeholders.
2. During the reporting period a total of 269 persons were trained on different livelihood enhancement technologies i.e. protected cultivation, waste land development, vermi-composting, bio-briquetting, etc.
3. The technologies transferred under on-farm sector include protected cultivation of vegetables, integrated fish farming, multipurpose tree plantation, yield enhancement of low productive agricultural lands through high value cash crops (ginger, garlic, turmeric, onion etc.), waste/abandoned land development through cash crop (ginger) cultivation, organic vegetable cultivation, poultry farming and vermi-composting. Off-farm technologies include bio-briquetting and making decorative items from pine needle and cone.
4. Abandoned/waste lands (2.5 ha) of 21 households have been rehabilitated through cash crop (ginger) production. The ginger crop was chosen as it is not damaged by wild and domestic animals.
5. Farmers have increased their income from technology adoption. Six farmers adopted protected cultivation of vegetables during the reporting period. The additional income of farmers from vegetable cultivation under polyhouses (10x30 feet) ranged between Rs. 7295 and Rs. 12620.
6. Two models of integrated fish farming have been demonstrated in the study area. Beneficiary farmer has earned up to Rs. 40,000 additional income in a year from integrated fish farming. Integration of fishery with poultry, vegetable and

vermi-composting etc., have increased efficiency of resource utilization. The average additional income of farmers from poultry farming ranges from Rs. 12500 to 17000 per year. This is also helpful for doubling farmers' income as planned by Government of India.

7. Low yield cultivated lands (6 ha) of 128 families have become profitable through adoption of high value cash crop i.e. garlic, onion, ginger, turmeric. Per unit production of cash crop on low productive land was higher than traditional crops.
8. About 0.5 ha waste land of 5 families is being developed through plantation of Tejpatta (*Cinnamomum tamala*), various citrus species and multipurpose fodder species such as Bhimal (*Grewia optiva*), Falyat (*Quercus glauca*), Quiral (*Bauhinia variegata*), etc. It has become a successful plantation as 90% plants have survived after two years of plantation.
9. Pine needles are being used to make various products. About 20% population is actively involved in bio-briquetting. Bio-briquetting from chir pine needle has provided an additional source of income to local people and helped to save surrounding pine forest from forest fire. Villagers are also generating income from bio-briquetting. 90 beneficiary families have earned Rs. 35,000 during project duration from selling bio-briquettes. Most of the beneficiaries are also using bio-briquettes at home for heating and cooking purposes.
10. Preparation of chir-pine needle based handmade paper was also initiated, and a total of 2200 files have been produced (Fig. 15).

Fig 15. Products made of Chir-pine needles

Ecosystem Services in Changing Biodiversity State: A Comparative Study of Western and Eastern Himalayan Forest Stands (MoEF&CC, 2016-2020)

The wellbeing of human is integrally linked to biodiversity ecosystem process and ecosystem services. It is now recognized that if the current rate of loss of biological diversity is continued the coming human generation are going to face problem in sustaining their livelihood, and some symptoms are visible now. Globally majority of the forests are undergoing increasing pressure from driver (such as land use change, habitat loss, degradation, overexploitation and unsustainable use of resource and invasive alien species) and excessive nutrient load and other forms of pollution. The biggest challenge is to decipher the impact of loss of biodiversity change on ecological processes and its services and its interaction. Loss of species and genetic diversity would lead to decreases in the resilience of ecosystem that will be ultimately effect quality of ecosystem services that are essential for human survival. Therefore, maintaining the species rich composition of communities is critical for sustaining ecosystem services and its interactions. The mountains have been recognized amongst most change sensitive ecosystems to climate change and anthropogenic stress and the local extinction of species may have more drastic ecosystem consequence. Present study investigates biodiversity status (species composition, species richness, distribution pattern, species diversity and regeneration pattern) of selected forest stands that are threatened under biotic pressure with relation to recent past.

Objectives

- To investigate temporal and spatial variation in vegetation cover at selected forest stands in Western and Eastern Himalayan region.
- To study species composition, richness, functional traits, regeneration and distribution pattern of the above selected forest stand under changing biodiversity state.
- To analyze dynamics of aboveground biomass, productivity, litter fall and forest floor nutrient pool, and carbon sequestration under changing biodiversity status for selected forest.

- To quantify various ecosystem provisioning services by the selected forest type and their dynamics of use of local residents.
- Quantify environmental vulnerability and directional change in selected ecosystem process and ecosystem services and suggest suitable conservation approaches.

Achievements

1. Forest structure were studied at Chorgaliya, Baldiyakhan, Kailakhan and Kilbury forest of district Nainital in Western Himalaya forest stands and analysis of temporal changes in species composition and forest structure in past three decades was observed. Data revealed that selected forests in Uttarakhand state are better managed leading to improve density, basal cover and species richness.
2. Tree biomass was estimated as 215.71 to 557.83 t/ha. Tree biomass in subtropical forest stands in western Himalaya increased leading to carbon accumulation; however it was decreased in temperate forest.
3. Carbon stock in selected forest stands ranged from 97.06 to 252.75 t/ha, maximum found in Sal forest followed by Pine forest, Banj-Oak forest, and minimum in mixed Oak forest
4. Litter fall dynamics was assessed with the help of litter trap method. Total annual litter fall ranged from 8.57-13.66 t/ha, which was higher as compared to earlier studies on same forest stands.
5. For the analysis of litter decomposition, in all forest stands separate leaf-litter samples of *S. robusta*, *Mallotus philippensis*, *Pinus roxburghii*, *Q. leucotrichophora*, *Q. floribunda*, *Q. lanuginosa*, and mix species were placed and being monitored on regular intervals.
6. Decomposition rate of all species was higher in rainy seasons, and leaf litter decomposition was fast for mixed spp. (*S. robusta* and *M. philippensis*). However it was much slow for *Pinus roxburghii*. A comparison with earlier data set litter decomposition rate was found higher in all species.
7. Soil sampling was taken at three depths from all forest stands and physical property of soil (WHC, soil moisture, soil texture) and chemical properties (pH, organic carbon, nitrogen, potassium, and phosphorous) were estimated.
8. The soil pH ranged from 5.91±0.09 to 6.61±0.04 in all forest stands. The soil of banj-Oak and mixed-Oak forests was more acidic as compared to Sal and pine forest. The soil moisture are maximum (26.61%) recorded in mixed Oak forest followed by Banj Oak forest (25.35%), Sal forest (18.55%) and minimum in Pine forest (16.25%). The maximum soil moisture was recorded in rainy season, followed by winter and minimum in summer seasons across all forest stands. Water holding capacity of soil ranged from 49.13% to 64.31%. Maximum WHC of soil was recorded in Banj Oak forest (64.31%), followed by mixed Oak forest (62.63%), Sal forest (53%) and it was minimum (49.13%) in Pine forest stands. On the basic of percentage of sand, silt and clay soil type varies in all forest stands. The soil of Sal forest was loamy-sand, in Pine forest it was sandy-clay and in the Banj-Oak and mixed-Oak forest it was sandy-loam.

Livelihood Enhancement of Small Farmers of Uttarakhand Hills through Integration of Simple, Cost-effective, Eco-friendly Rural Technologies (DST Women Scientist, 2017-2020)

A large number of natural resource based hill specific, low cost, eco-friendly technologies are available for wellbeing of poor hill farmers. However, majority of the farmers in the region are unaware of these technological interventions and do not realize employment and income generation potential of natural resources available in their surroundings. In the project, natural resource based technology-centric village development model(s), integrating interventions such as Integrated Fish Farming (IFF), off-season vegetable and mushroom cultivation, green fodder production; bio-composting/vermicomposting and bio-briquetting are introduced in three villages selected for the study. In such system different components are integrated in such a way that bio-products and waste of each subsystem become valuable input for another subsystem. As expected, the integrated approach is not only economical but also providing effective recycling of wastes, utilization of farm and forest biomass, energy saving and eventually helping in protecting environment in of the hills.

Objectives:

- To promote sustainable development of small hill farmers through technology centric eco-development model (s) integrating natural resource based simple, low-cost, eco-friendly appropriate technology packages.
- To enhance livelihood opportunities and nutritional security to the rural poor through efficient utilization of available resources.
- Capacity building and skill development of farmers on simple, cost-effective labour saving rural technology packages on participatory approaches.
- To evaluate, validate and improve integrated technological interventions for efficient management of the model (s).
- Documentation of successful case studies for wider circulation.

Achievements:

1. The project activities have been carried out in three villages in Almora district namely, Matela, Kaneli (Hawalbag block) and Kalon (Bhaisiyachhana block) located at mid elevation zone (1000-1800 m amsl).
2. Demonstration of three Integrated Farming System (IFS) models, comprising polyline fish pond (size 70-100 m2) a low cost poultry house at dyke of the pond, have been constructed at the selected sites. Fingerlings of Chinese carp species viz., silver carp (*Hypophthalmicthys molitrix* Valenciennes), grass carp (*Ctenopharyngodon idella* Valenciennes) and common carp (Cyprinus carpio Linnalus) at a density of 3/m2, were stocked into the ponds at all the sites during month of March. Fingerlings attained average size of 500-800 g within eight months at Kaneli and Kalon village (Fig. 16).
3. Chicken (3000 birds/ha) of coloured hybrid layer species of chick bird (Kuroiler), weighing approximately 40-50 g were integrated with fishery at each site. High survival (100%) and substantially high growth rate was recorded in chick birds, (0.950-3.25 kg) within 4 months. Besides, regular earning, farmers' family also got nutritional security.
4. During reporting period a total of 4 training programmes were organized and benefitted 330 persons (including 120 women). Technical help related to IFS extended to State Fishery Department. Besides, a technology package was finalized and published on IFS

Fig 16. Integrated fish farming at project sites (A= Kaneli, B= Kalon)

Study and Quantification of Non-timber Forest Products (NTFPs) and related value chains from the Western Himalaya (NMHS Fellowship, 2016-2019)

Non timber forest products (NTFPs) constitute an important source of livelihood for millions of people across the world by providing food, fodder, species, medicinal plants, dyes and income. In India, NTFPs are associated with socio-economic and cultural life of forest dependent communities inhabiting in wide ecological and geo-climatic condition throughout the country. In Himalayan region also communities fulfill their deserve subsistence needs from NTFPs. Access to forest products, goods and services is vital for the livelihoods and resilience of the rural and marginal households, acting as safety nets in different times. It is strong desire to investigate NTFPs diversity at use, traditional knowledge and their conservation status for improvising community livelihood and mitigating negative effects of climate change. The present study is taken up with such focus.

Objectives

- Inventorying NTFP species, diversity and management practices
- Status on marketing, value addition and enterprise development
- Governance, policies and regulations related to NTFPs and their impact

Achievement

1. A total of 354 NTFPs have been explored till date form Himachal Pradesh. 106 have been categorized as threatened species, 13 of them by IUCN while 93 species as per stakeholder perception. Continuous extraction of NTFPs from wild areas has, however, put high impacts on selected species, viz. *Aconitum heterophyllum, Angelica glauca, Gentiana kurroo, Nardostachys jatamansi, Saussurea costus, Lilium polyphyllum, Trillidium govanianum*, etc.

2. Maximum species are used for medicinal purpose (48%). Most of the plants belongs to family Asteraceae (30%), followed by Lamiaceae (21%). Most commonly used plant part was underground part (42.94%), followed by whole plant (21.47%). Dominant plant life form was herbs (68%), shrubs (14%), trees (13%), and ferns (2%). Climbers, grasses and mushroom were <2%.
3. The distribution of NTFPs along an altitudinal gradient revealed that maximum species were found in sub-alpine zone (2801-3300 m) (35.81%), followed by alpine (>3300 m) (20.16%), warm-temperate (1001-1800 m) (19.18%), temperate (1801-2800 m) (18.20%), and sub-tropical (<1000m) (6.65%).
4. An analysis of quantum of NTFPs harvested in the past six decades in Himachal Pradesh exhibited a decline trend by about 85% in past 43 years supposed to be due to depletion of resource base in their natural habitats as well as restriction in collection of species. Contrany, an increasing trend of revenue collection by issuing permits by Forest department was observed for past 68 years, it was more so in past three decades.
5. The species that grow in nearby forest areas are mostly collected by women and children and are comparatively low priced. Young male members collect species from high-hill regions and alpine pastures, which are high priced items. Average collection period of NTFPs in different districts ranged from 34 to 82 days annually.
6. A thorough review of government policies and regulations pertaining to harvest and management of NTFPs in Himachal Pradesh was accomplished.

Center For Environment Assessment and Climate Change (CEA&CC)

Different environmental factors including climate influence ecosystems, which has been further exacerbated by human induced perturbations. Changes in climate regime over the last few decades have already started affecting natural resources worldwide including mountain regions, subsequently, natural resources of the Himalayas are highly vulnerable. Different scientific reports and publicarions including the IPCC Reports (IPCC 2007, 2014) emphasize on impacts of climate change (CC) in the Himalayan region, which is amongst the 35 global biodiversity hotspots for its unique and rich biodiversity. Now it is known that CC is a major global environmental challenge that affect ecosystems in a variety of ways, e.g., warming could force species to migrate to higher elevations for their survival; it also interacts with other human stressors such as development, and cumulative impact may lead to dramatic ecological changes. Therefore, CC poses a threat to social and economic development in the Indian Himalayan Region (IHR) where natural resource dependency of societies is very high. The Centre for Environmental Assessment & Climate Change (CEACC) caters the Himalayan needs on these issues in tune with MoEF & CC and SDGs (Goal no 13) which requires "urgent action to combat climate change and its impacts". The broad approach for achieving these goals includes (i) identification and prioritization of climate sensitive sectors in the Himalaya for research and resource generation, (ii) development of indicators of Climate Change in the Himalaya in identified sectors, (iii) inclusion of Citizen Science Approach in Research, and Adaptation & Mitigation Strategies. Practice-Science-Policy connect through integration of community level experiences (acclimatization/adaptation/coping mechanisms) in Policy Framework, and (iv) collaboration with other Organizations/Universities on climate change projects

The objectives of the center are assess and monitor physical, biological and socio-economic environmental parameters for the development in IHRand design measures for climate change mitigation and adaptation by communities and developing ecosystem resilience to cope up with climate change risks.

Forest fire in the Central Himalaya: Environmental Impacts and Prevention Strategies (In house, 2019-2020)

Fire strongly influences carbon cycling storage in forests. On the face of global warming, frequency and intensity of forest fires are likely to increase globally while a dry winter and early rise of temperature coincide with leaf fall of trees resulting large scale fires in the Central Himalaya. However, fire events spread all across the Uttarakhand state and most of the events occurred in the zone of Pine (*Pinus roxburghii*) dominated areas. A general belief among people associates occurrence of

pine forests to large scale fire in the region, however sub-tropical sal forests along foothills are equally prone to such fires in changing environment. The fire-induced sequestration of carbon from the short-term biospheric to the long-term geological cycle due to the formation of black carbon may represent a significant sink of atmospheric CO_2 and source of O_2 possibly has influenced today's atmospheric oxygen content. On the other side, smoke from biomass burning suppresses warm rain processes. Forest fires release significant amounts of carbon dioxide into the atmosphere, but also convert a fraction of the burning vegetation to charred black carbon. Formation of this reserve, therefore, creates a long-term soil carbon sink. The project aims to develop mitigation strategies for preparedness and resource deployment during fire events using citizen science approach, and will demonstrate the approach for district Almora, as a pilot.

Objectives

- To document existing knowledge on forest fires of the Uttarakhand for knowledge gap and policy formulations.
- To analyze present extent and expansion of pine forests (last 25 years) to unveil history of forest fire events in Kumaun region (six districts of Uttarakhand State) and mapping of carbon sequestration potential for climate based fire prediction model.
- To find status of ambient air quality (particulate matters, black carbon, etc.) during pre-, between, and post forest fire seasons, and its radiative forcing.
- To demonstrate citizen science approaches (pilot demonstration) during forest fire seasons in (i) preventing fire events and spread of forest fire through effective monitoring, and (ii) preventing measures in district Almora (pine dominated district).

Achievements

1. Data collection on records of forest fire in the Kumaun region has been started (Fig. 17).
2. Ambient air quality in terms of particulate matter below 10 micron (PM_{10}), particulate matter below 2.5 micron ($PM_{2.5}$) and black carbon (BC) in the background site at GBPIHED campus, Katarmal is being monitored.

Fig 17. Forest fire occurrences in Almora district

Gaseous Air Pollution in the Background Sites of Sprawling Urban Environment in the North-Western Himalaya (ISRO, PRL, Ahmedabad, (2008-09 to Long term studies)

Surface ozone (O_3) as one of the greenhouse gases is an important air pollutant threatening human health, vegetation growth and increasing local temperature. O_3 is a secondary pollutant and is a key species affecting the chemical properties of the atmosphere where it is a precursor for the highly reactive hydroxyl radical. The relation between O_3 and its main precursors represents one of the major scientific challenges associated with gaseous pollutants. 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 local and regional level pollution. Nitric oxide (NO) is emitted from soils, natural fires, lightning, and is emitted from combustion processes such as vehicular 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 carbon monoxide (CO) 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 with gaseous pollutants, and analyze in the background of long-range transport sources.
- To suggest some feasible mitigating measures to fill up the gaps at policy level.

Achievements

1. Observation of surface O_3 and its precursors like nitrogen oxides (NO + NO_2) was carried out at Kothi (2500 m amsl). During a period from October 2017 to June 2018, it shows higher concentration in June (62.60 ± 7.21) and lower in December (39.45 ± 0.98). The daily concentration of columnar ozone at Katarmal, Almora (Uttarakhand) was found on March 15, 2019 (70.31 ± 2.03 DU) and minimum on March 29, 2019 (30.67 ± 2.24 DU)). This is because of increase in NOx precursor due to inflow of high influx of vehicles and strong solar irradiance.
2. Maximum concentration of NO shows higher concentration (3.2 ± 0.01) in December and lower (0.8±0.03) in May. While NO_2 concentration shows high in January (4.1 ± 0.15) and lowest in June (2.5 ± 0.17) (Fig. 18a). This is due to mainly a less concentration of pollutants in winter and less solar irradiance as a result NOx could not dissociate with O_2 in producing surface ozone.
3. During a reporting period, maximum concentration of CO_2 in June 2018 (394.06 ± 2.03 ppm) followed by May (374.65 ± 3.35 ppm) and minimum in March (350.58 ± 2.24 ppm). This is due to burning of firewood for cooking and heating at household level and biomass burning as forest fires.
4. The concentration of O_3 showed unimodal peak and reached maximum (72.79± 3.50 ppb) at 17:00 during afternoon. (Fig. 18b) It gradually decreased during night and showed minimum value (49.13 ± 1.8) in the morning 9:00 after sunrise (07:00 - 08:00 h IST), and attaining maximum concentration during afternoon (14:00 - 16:00 h IST).
5. Ozone shows positive correlation with solar flux, temperature, humidity and negative with wind speed. This increase in ozone concentration from early morning to peak afternoon was noted in all the months.

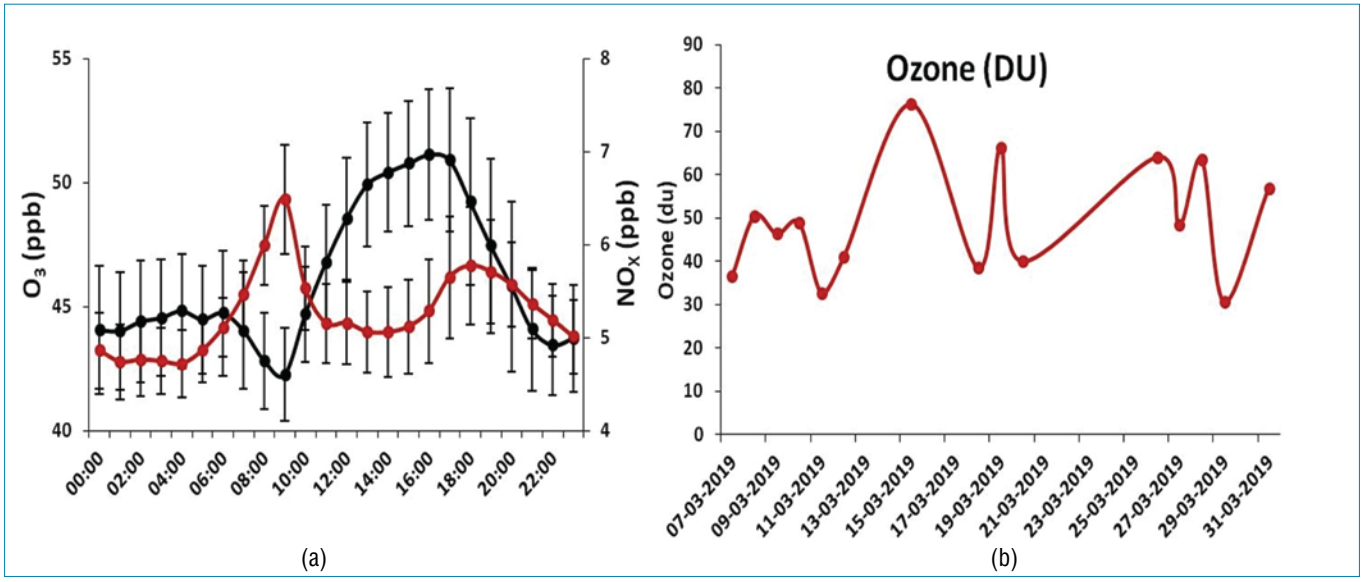


Fig 18. Monthly concentration of O3 and NOx at Kothi, and b - daily concentration of columnar O3 at Katarmal, Almora

Aerosols Climatology over the Northwestern Indian Himalayan Region (ISRO, SPL, Thiruvanthapuram, 2005-06 to Long Term Network Programme)

Climate change is one of the most important issues on the planet where aerosols play an important role. The Kullu valley- a famous tourist destination, suffers from anthropogenic emissions to a greater extent in recent decades especially due to tourists' influx and ever increasing native populations ultimately affecting the Himalayan climate and glaciers. Depending

upon the optical properties of aerosols, they cause cooling effect by scattering back solar radiation and warming effect by absorbing incoming solar radiation on the earth's surface and atmosphere. Upon interaction with atmospheric aerosols, there is extinction in solar radiation thereby imbalancing earth's radiation budget. Some of the aerosols such as sulphate reflect short wave solar radiation back to space and cools the earth's surface. Black carbon, which is produced from incomplete combustion of fossil fuel, biofuel and biomass burning, absorb shortwave solar radiations, warms the air and contributes to global warming. Also, black carbon aerosol if deposits on snow and ice, it darkens its surface and reduces albedo and melts faster snow, retreats the glacier and decreases snowpack along with 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. WHO has also recently recognized black carbon as the carcinogen. The present study unfolds the status of aerosols in the topographically fragile and ecologically delicate region of the Himalaya.

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 MicrotopsII sunphotometer.
- To obtain Black Carbon Aerosol concentrations on land and glaciers.
- To relate AODs with the meteorological parameters with the help of Automatic Weather Station installed at Mohal, and
- To estimate Radiative Forcing using different models.

Achievements

1. AOD in the Kullu valley is wavelength dependent; higher at shorter wavelengths and lower at larger wavelengths, indicating dominance of anthropogenic interferences in the surrounding environment. Figure 19 shows Multi-Wavelength Radiometer (MWR) set up for aerosol measurements at Mohal.

Fig 19. Multi-wavelength radiometer (MWR) set up for aerosol measurement at Mohal

2. Mean AOD500nm at Kothi (2500 m amsl) was observed 0.30± 0.11 in 2018 (Fig. 20a). It ranged from 0.10 to 0.59. On the other hand, mean AOD500nm at Mohal (1154 m amsl) was observed 0.32± 0.13 (Fig. 20b) ranging from 0.11 to 0.68.
3. Diurnal variation of BC in 2018 showed bimodal peak at Kothi (March – August) with its highest concentration in the morning and evening hours. At Kothi, peak was around 6:00 hrs IST in the morning with 3632 ng m-3 and around 19:00 hrs IST in the evening with 1946 ng m-3 (Fig. 20c).
4. At Kothi in 2018, radiative forcing solely due to BC was estimated to be +12.0 ± 0.2 Wm–2, -22.1 ± 0.6 Wm–2 and +34.2 ± 0.8 Wm–2 on top of the atmosphere (TOA), surface (SFC) and atmosphere (ATM), respectively (Fig. 20d). BC Radiative forcing at atmosphere (BCRFATM) upon translation gives equivalent heating rate of 0.96 K day-1.

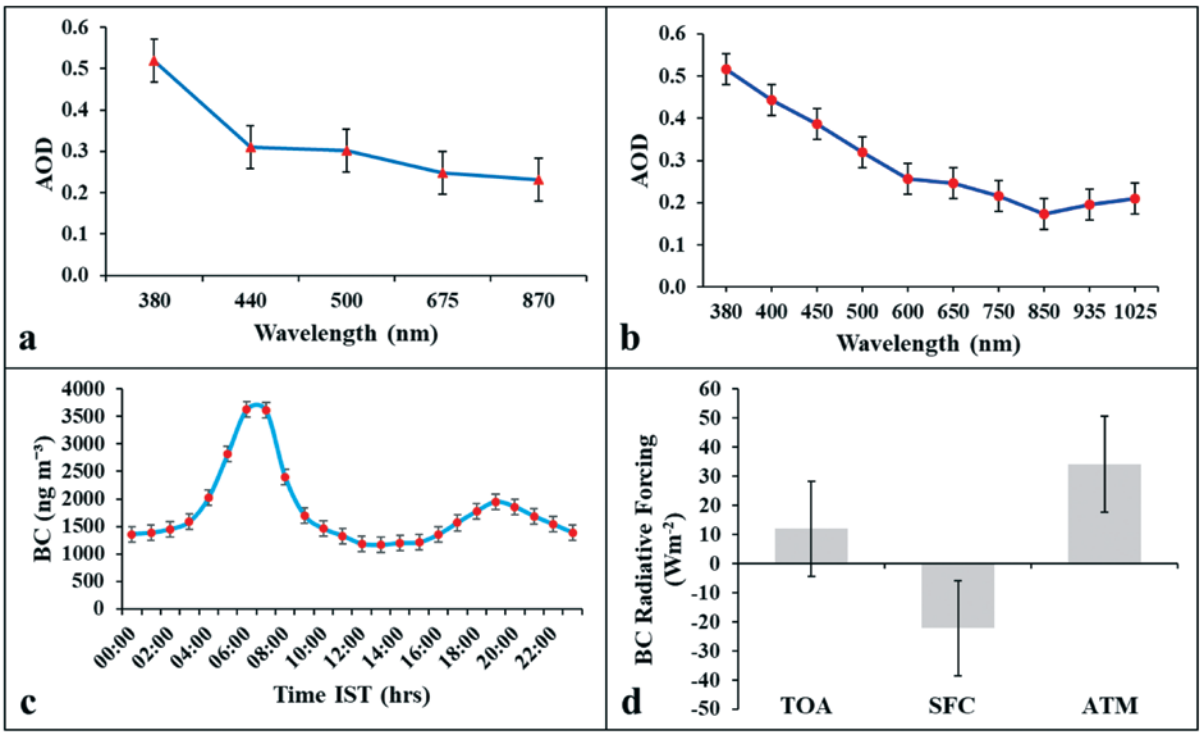


Fig 20. (a) AOD at Kothi, (b) AOD at Mohal, (c) BC concentration at Kothi, and (d) BC radiative forcing at Kothi

Anthropogenic Impacts and their Management Options in Different Ecosystems of the Indian Himalayan Region (NMHS, MoEF&CC, 2017-2020)

The Himalayan ecosystem as a whole is facing a variety of changes in terms of its current environmental scenario. Some of these changes include faster melting of glacier/ snow, erratic seasonal surface run-off, and its effect in downslope regions on existing developmental interventions in the form of mass tourism, hydropower projects, land use components, biodiversity, riverine aquatic life and above all livelihood options and well being of human life. As a result, two different parts of ecosystems such as snow and/or headwater regions on the top of mountains and riverine basins in downslope regions are going to be adversely affected from the northwestern to the northeastern Himalayan Indian Region (IHR). Knowing the primary status of these issues under present scenario is a difficult task without any data. As a result, monitoring of major impacts due to anthropogenic pressure within these ecosystems in the IHR for a long duration is imperativet from a viewpoint of management and sustainable development. The faster melting of the glaciers and snow causes erratic distribution pattern of surface run-off over and headwater environment to downslope riverine basin, changes in either of the ecosystem due to anthropogenic impacts including climate change and its inhabiting human populations within a geographical set up and their management options would be an important effort to address these issues. In some of the river basins, many developmental and economic activities are in full swing. Most of the activities are entirely dependent on water for drinking, irrigation, power generation, etc. If the water demand for a range of economic activities and land use practices could not be adequate and uniform, water situation could become erratic affecting adversely a variety of economic activities of the local communities in the downstream regions. Keeping these issues in mind, the objectives of the present study are as under:

Objectives

- To monitor snow melt and/or headwater contribution in total river water flow, their seasonal behavior and quality due to climate change.

- To assess the impacts due to erratic seasonal behavior of river/stream water flow on overall land use pattern, developmental projects such as HEPs and riverine aquatic biodiversity.
- To enhance capacity building of the stakeholders including women in terms of increasing their resilience and adaptive capacity due to climate change for their sustainable livelihood options.
- To suggest mitigating measures and management options due to anthropogenic impacts.
- To provide policy guidelines for strengthening existing polices

Achievements

1. Out of five study sites, installation of Automated Weather Tower (AWS) was completed in 3 study sites, namely; Parbati Basin, Dhauliganga Basin and Ranganadi Basin. In Dhauliganga Basin, average discharge obtained at two locations, viz. Dugtu (3189 m) and Sobla (1673 m) using AWLR and manual gauging, was 7.04 cumecs and 45.28 cumecs respectively (Fig. 21 a&b). Average silt loads at these two locations, Dugtu and Sobla, were 1132 tons/day and 4928 tons/day, respectively. The study indicates that silt load is increasing from headwater altitude to downstream locations.
2. Water quality results show increase in turbidity (avg. turbidity=20.158 NTU) in River Dhauliganga, increase in pH (pH=8 - 8.6) and hardness (TH=78 - 222 mg/l) in River Sindh. While in Parbati basin, pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were 8.05, 929 µs cm-1 and 234 mg l-1 respectively. All other parameters were found under the permissible limit (I.S. specified).
3. The Parbati Basin occupies an area 1765 km^2 where its outer length was 183 km and basin length was only 56 km. Total six stream orders (Nu) were identified in the basin. The first order stream has maximum 1245 stream segments, 2nd order stream 549, 3rd order 277, 4th order 182, 5th order 60 and 6th order 109 segments. The Sind Basin has a geographical area of about 1,558 km^2 having its course of about 100 km. There were 5657 streams identified; out of which 4373 belong to 1st order streams, 1013 2nd order, 209 3rd order, 45 4th order, 13 5th order, 3 6th order and 1 7th order.
4. Peoples' perception survey was conducted in different basins. Sindh Basin covered 385 households, Parbati basin 385 households, Dhauliganga basin 334 households, Ranganadi basin 170 households and Imphal basin 244 households. Climate variability, impacts of climate change, contribution of snowmelt in the overall river water, changing snowfall pattern, duration of rainfall, changing land use pattern, water demand for domestic and livestock purpose, sources of water and its seasonal scarcity, impacts of hydropower, livelihood option and areas of women skill development for livelihood options were major issues.
5. A capacity building training was organized in Parbati Basin (31 September 2018) to aware the people including women about 'Bee-Keeping' and its economic benefits. In total, 33 participants, mostly women, were trained.

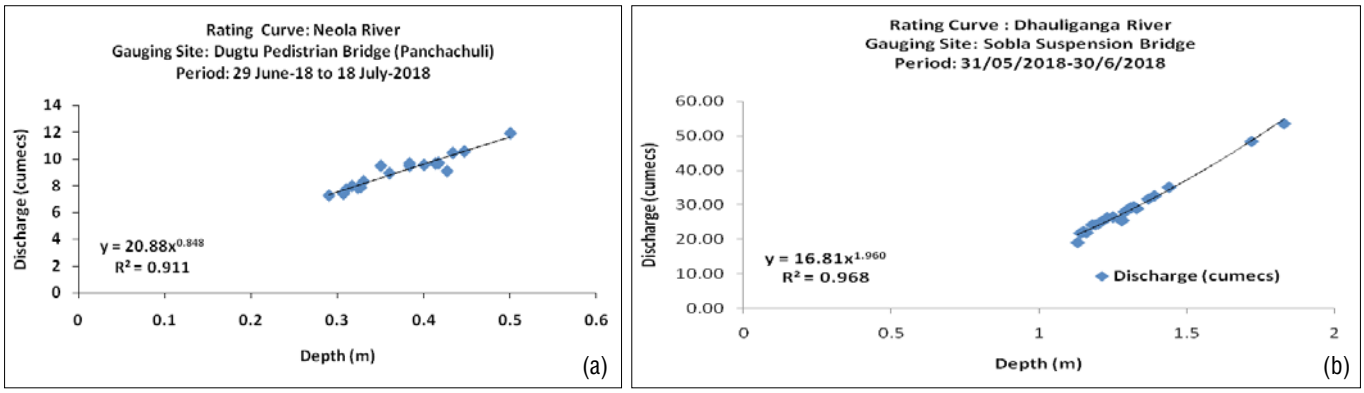


Fig 21. Water discharge of (a) River Neola, and (b) River Dhauliganga

Establishment and Conservation of *Ginkgo biloba* and *Taxus wallichiana* using Microbial technology: Field Evaluation (In house, 2017-2020)

Ginkgo biloba (English name: Maiden hair tree; Hindi name: Balkuanri; Family Ginkgoaceae; referred as the living fossil) and *Taxus wallichiana* (English name: Himalayan Yew; Hindi name: Thuner; Family Taxaceae) are medicinally important trees that grow under temperate locations of Indian Himalayan region (IHR). Mentioned in IUCN red list, both the species need attention for propagation and conservation in Forest sites. In this background, based on the rhizosphere studies conducted in the Microbiology laboratory of the Institute on *G. biloba* and *T. wallichiana*, the microbial formulations have

been developed for propagation of these plant species. In this project, *G. biloba* and *T. wallichiana* is raised using stem cuttings and microbial formulations in the net house of the Institute and examined for the microbial colonization pattern. The colonized plants then will be transferred to the field in collaboration with Forest Department, DRDO, ITBP and NGOs. The transferred plants will be evaluated with respect to their rhizosphere, plant growth and physico-chemical parameters.

Objectives

- To study the rhizosphere colonization pattern during field establishment of *G. biloba* and *T. wallichiana.*
- To evaluate the effect of microbial inoculation on rhizosphere, plant growth and physico-chemical parameters of the respective species.
- To demonstrate the benefits of this eco-friendly microbial technology in propagation and conservation of medicinally important plant species.

Achievements

1. Stem cuttings of the target species (*Ginkgo* and *Taxus*) have been planted in the net-house using microbial formulations (Fig. 22).

Fig 22. Establishment of target species in net-house: A. Ginkgo, and B. Taxus

2. Sampling from *Ginkgo* rhizosphere plants that were transferred at Kalika nursery in 2011 has been performed. Rhizosphere studies on *Ginkgo* roots showed enormous colonization by endophytic fungi (Fig. 23).

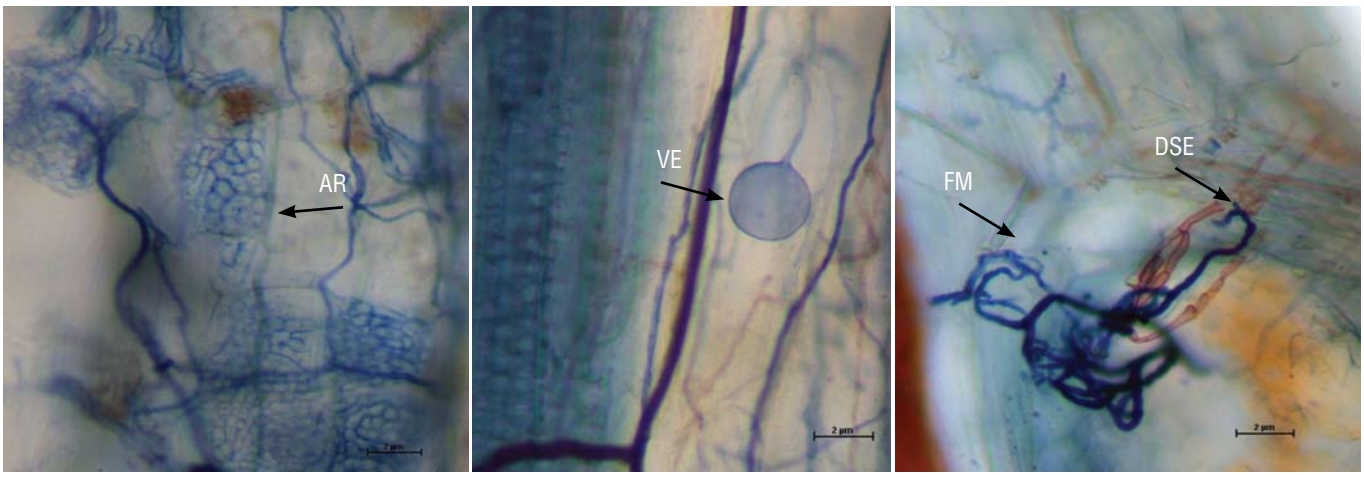


Fig 23. Colonization of *G. biloba* roots: Arbuscules (AR), Vesicle (VE), fungal mycelium (FM), and Dark septate mycelium (DSM)

Conservation and Sustainable use of Biodiversity with Particular Reference to Microbial Diversity (NMHS Fellowship, 2016-2019)

In this project a focused study entitled ''Plant microbe-interactions in *Taxus wallichiana* Zucc." has been designed with respect to microbial associates of *T. wallichiana* and their biotechnological applications. *Taxus wallichiana* (Zucc.) Pilger (English name: Himalayan Yew; Hindi name: Thuner; family Taxaceae) is recognized as a medicinally important evergreen

tree that grows under temperate locations of Indian Himalaya. The species has received considerable attention on account of its existing exploitation for the extraction of the drug (taxol) and also the removal of old forests. While the species is well recognized as source of anticancerous drug Taxol ® (paclitaxal) that is useful in treating various forms of cancers, it still needs attention in antimicrobial prospective. The present study is, therefore, based on the plant microbe-interactions with respect to *Taxus wallichiana*. Rhizosphere studies have been planned on the colonization of *Taxus* roots by plant growth promoting microorganisms and their subsequent use in *Taxus* propagation. The extract of *Taxus* plant parts (needle, stem and bark) will be investigated for their antimicrobial potential against bacteria, actinobacteria and fungi.

Objectives

- Understanding diversity of endophytic microorganisms associated with *Taxus baccata* spp. *wallichiana* roots and their biotechnological applications.
- Evaluation of bioactive compounds of *T. wallichiana* with particular reference to antimicrobial activity (bacteria, actinobacteria and fungi, in particular).

Achievements

1. Microscopic observations revealed colonization of *T. wallichiana* roots by endophytic bacteria and fungi. Prolonged dip treatment in distilled water helped in removal of melanin like substances from the roots and resulted in clarity with respect to structures (size and shape) of endophytes. Colonization of fungal mycelium was recorded up to 84%, followed by arbuscular mycorrhizae (52%) and dark septate endophytes (34%) (Fig. 24). The culturable bacterial species belonged to Bacillus and Burkholderia while the fungal species belonged to Aspergillus and Penicillium. These endophytes showed ecological resilience through their tolerance to wide temperature, pH, and salt concentration. Functionally, these endophytes possessed plant growth and biocontrol properties such as phosphate solubilization and antagonism. Such detailed studies will have implications in understanding the role of endosymbiosis in plant growth growing under low temperature environments.

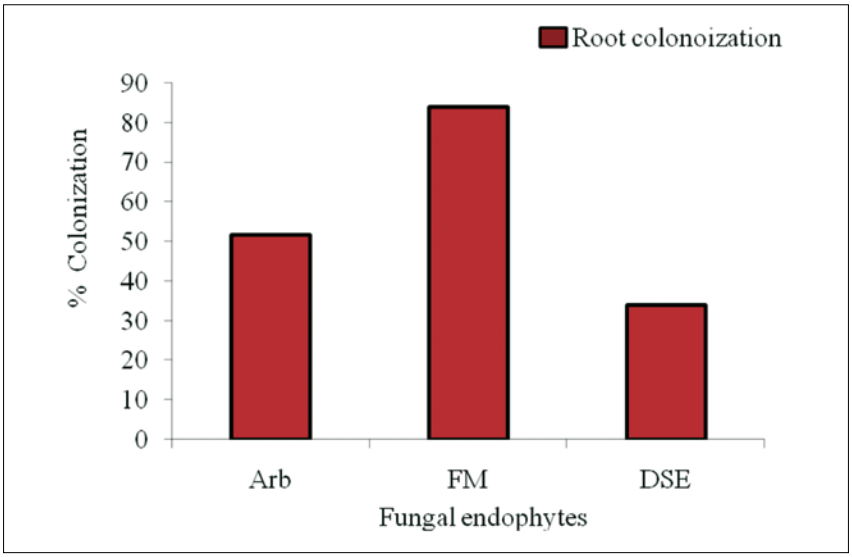


Fig 24. Fungal colonization in T. wallichiana roots; Arb= Arbuscules; FM= Fungal mycelium; DSE= Dark septate endophytes

2. Endophytic microorganisms produce a range of bioactive metabolites and support plant growth and their competitiveness. An endophytic, antagonistic and pigment producing bacterium (GBPI_TWL), isolated from the roots of *Taxus wallichiana* Zucc., has been characterized for antimicrobial metabolites. Following morphological, biochemical, and molecular characters, the bacterium was identified as *Burkholderia contaminans*.The bacterium produced diffusible and volatile antimicrobials against phytopathogens in plate bioassays. The bacterial pigment, extracted in four solvents (separately) viz., benzene, ethyl acetate, ethanol and methanol, was tested for production of antimicrobial metabolites against three groups of microorganisms (bacteria, actinobacteria and fungi). Methanol and ethyl acetate extracts were used for GC-MS analysis. Mass spectra results revealed the presence of the secondary metabolites of antimicrobial nature including hexadecanoic acid, methyl ester, 1,2-benzenedicarboxylic acid, nonacosan-14-one, tridecanedial, heneicosane, eicosane, phthalic acid, eicosanoic acid, methyl ester, E,E,Z-1,3,12-nonadecatriene-5,14-diol and methenamine (Fig. 25 A-D).

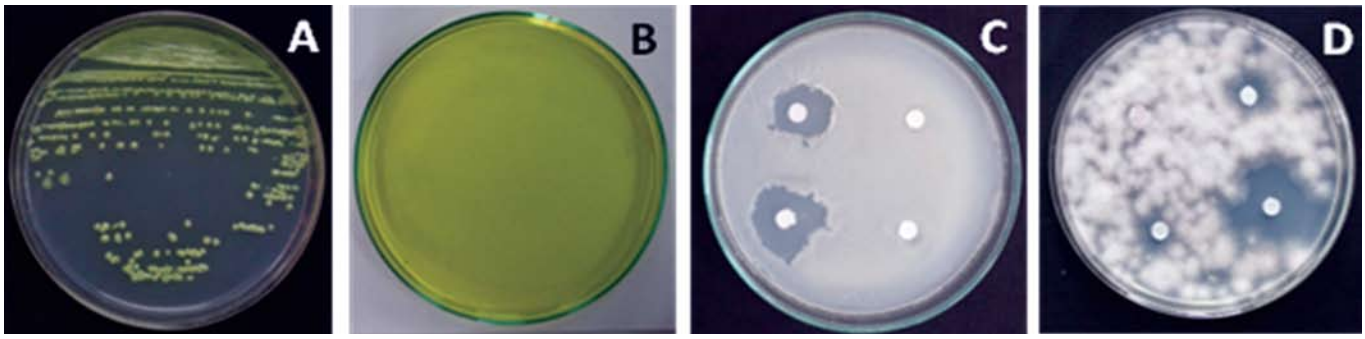


Fig 25. A. GBPI_TWL, B: Extraction of pigment, C: Antibacterial activity, D: Antifungal activity

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 in comparison to central India. Numerous bio-geographical factors are responsible for the vulnerability of western Himalayan mountain ecosystem to climate change, and these include (i) potential shifts in the species' bioclimatic envelop changing 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 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 ecosystems of the mountains. GBPIHED is establishing one of the LTERs 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: 2 new plots of 20 x 20 meter at two different locations were established at an altitude of 2850m and 3100m asl for long term monitoring with compilation of geo-spatial attributes, thus making a total 10 permanent sites. Vegetation in each plot was marked and measured for density of trees, sapling, and seedlings. These new plots had 6 tree species and 38 individuals, and 9 tree species 27 individuals. In total 11 tree species were noted and 4 were common in both the plots. Saplings were limited to few 6 species only.
2. Occurrence of woody patches (largely formed by *Rhododendron campanulatum* with or without tree species of timberline) in the alpine, using high resolution image of year 2015, was mapped in both the flanks (eastern and western) of Pindar valley (beyond timberline). Patches were distributed between altitude of 3238 m to 3950m asl, and area of a woody patch may range from 0.02 ha to 10.2 ha.
3. Above timberline, a total 98 woody patches was mapped in the river valley, and warmer flanks (western slopes) had higher number of woody patches (59%), however, total area of the patches was almost similar (Table 6).

Table 6: Distribution of woody patches above timberline in Pindar river valley

Size (ha)	East facing slope		West facing slope		Total	
	Area (ha)	Number	Area (ha)	Number	Area (ha)	Number
<1	9.30	34	11.24	52	20.54	86
1 to 5	6.55	4	9.09	5	15.64	9
5 to 10	14.87	2	-	-	14.88	2
> 10	-	-	10.28	1	10.28	1
Total	30.72	40	30.61	58	61.34	98

Clean Energy Development to Mitigate Impacts of Climate Change in the Indian Himalayan Region (NMHS Fellowship, 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 resides 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 (GHGs) mainly CO_2. There is a need to (i) analyze gap between pace of growth development and policy interface for clean energy development, (ii) document best practices/models for further promotion, and replication, (iii) 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. Document for clean energy best practices has been prepared indicating presence of off-grid electricity production systems including hybrid energy systems being implemented in the Indian Himalayan Region. Adoption of such mechanisms in schools, colleges and households was observed indicating preference of general population towards off-grid energy consumption.
2. Document on adoption and promotion of renewable energy was prepared which indicates renewable energy best practices like pine needle gasifiers to produce electricity, concentrated solar cooking systems and micro hydro community based projects were being adopted in many states of the Indian Himalayan Region; however Mizoram, Manipur, Arunachal Pradesh, Tripura and Nagaland still slagged behind due to lack of policy initiatives.
3. Document on relevant supportive legislative framework depicted absence of legislative framework in Nagaland, Tripura, Mizoram, Manipur and Arunachal Pradesh.
4. Document on situation analysis on the progress in different states suggested that projects which were based on community management were more beneficial as compared to government operated or privately operated projects due to faster response in case of electrical faults and provides employment and skills to the local population, further indicating the advantage that off-grid production had over grid connected technology.
5. A gap between peak demand and peak supply exists in the Indian Himalayan States equivalent of approximately 9% of total energy supplied which could be reduced by focusing on promotion of clean energy best practices and developing the legislative framework in the north–eastern states (Fig. 26).

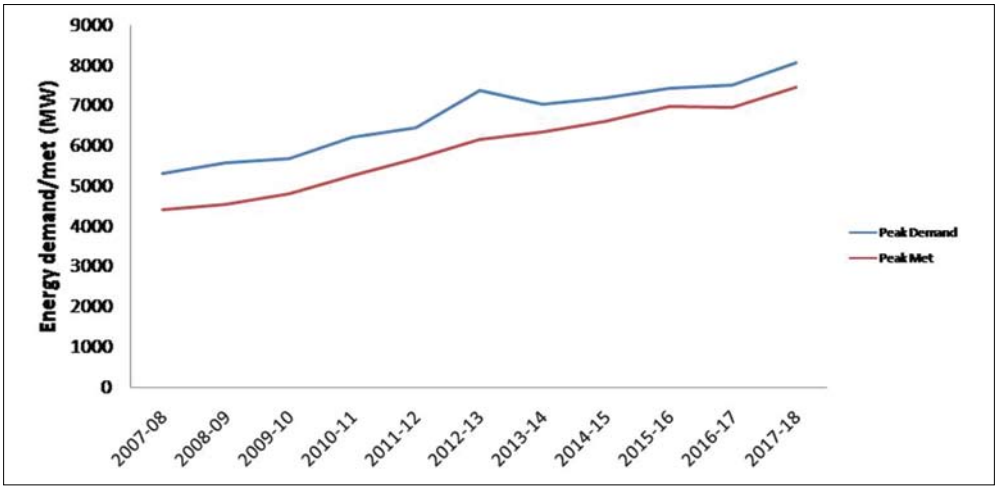


Fig 26. Current Scenario: Peak demand vs Peak met of electricity supply in IHR

6. The relationship between energy consumption (kg of oil equivalent per capita) and economic growth (Gross Domestic Product per capita) during the 24 year period of 1991-2014 of India was investigated and feedback hypothesis was confirmed or bidirectional causality was observed. Feedback hypothesis confirmed the interdependence between energy consumption and economic growth since both variables affect each other. This encourages the implementation of energy expansionary policies for long run sustainable economic growth.

NMSHE Task Force -3: Forest resources and plant biodiversity (DST Govt. of India, 2014-19)

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 mission among the eight National Missions. This mission envisages measures for sustaining and safeguarding the glaciers and mountain ecosystems. Considering the relevance of mandate, 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 include (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 1163 trees of Angiosperm (106 families and 413 genera), and 2017 shrub species (134 families and 615 Genera) of Arunachal Pradesh, Sikkim, Jammu & Kashmir, Himachal Pradesh and Uttarakhand of Indian Himalayan Region were prepared (Table 6). In general, Leguminosae was found to be dominant family for both shrubs and trees. Among shrubs, *Rhododendron* (76 species) and among trees. *Ficus* (41 species) were the dominant genera. A total of 346 tree species and 711 shrubs were native to the Indian Himalayan Region, while 26 tree species and 68 shrubs were endemic to the Indian Himalayan Region.

Table 7: Taxonomic description of Shrubs and Trees in the Indian Himalayan Region

States	Shrubs			Trees		
	Species	Genera	Family	Species	Genera	Family
Jammu & Kashmir	554	222	74	269	134	55
Himachal Pradesh	538	224	71	538	224	71
Uttarakhand	844	322	70	518	241	73
Arunachal Pradesh	1240	442	112	741	308	89
Sikkim	190	84	41	187	93	37

2. The altitudinal distribution of 2017 Shrubs of Trans, North Western Himalaya and North Eastern Himalaya revealed that the maximum number of species were distributed in the altitudinal range < 1800 m (1521 spp.), followed by 1801-2800 m (911 spp.), 2801-3800 m (500 spp.) and > 3800m (158 spp.).
3. Forest Vulnerability Index (FVI) was assessed for inherent vulnerability of community forests by integrating 12 indicators. The results of the study provided high vulnerability of low altitude forests compared to high altitude forests, attributed to high density of alien species (R^2=0.18, p=0.015), low moisture content (R^2=0.40,p<0.0001) and high anthropogenic disturbance (R^2=0.49,p<0.0001).
4. Tree ring chronologies for *Cedrus deodara, Pinus roxburghii, Betula utilis, Abies specabilies* and *Pinus wallichiana* were developed. Based on tree ring chronology, relative humidity was developed for the period 1707-2015.
5. Future temperature and precipitation trend up to 21th century was analyzed using climate model MIROC5 in Pithoragarh region. Temperature and precipitation data of two scenarios RCP 4.5 and RCP 8.5 showed increase in mean annual

temperature by 0.029^{0}C/year and 0.055^{0}C/year respectively. Under RCP 4.5 and RCP 8.5, pre-monsoon temperature is likely to be increased by 0.037^{0}C/year and 0.071^{0}C/ year, respectively.

6. The study suggests that radial growth of Cedrus deodara is projected to decrease by 0.004 mm/year under RCP 4.5 whereas *Pinus roxburghii* is projected to be increased by 0.0003 mm/year during 2006-2056. On the other hand, during 2056 - 21th century growth projection does not show any stationary trend and indicates productivity of *Cedrus deodara* under warming conditions may decrease whereas growth of *Pinus roxburghii* may increase.
7. Comparison of observed daily average net ecosystem exchanges (NEE) of the Central Himalayan Pine (*Pinus roxburghii*) and Oak (*Quercus leucotrichophora*) dominated vegetations for a period of 619 days indicates that average carbon sequestration rate of a Pine dominated forest (-2.04 micromol m^{-2} s^{-1}) is higher than an Oak dominated forest (-1.7 micromol m^{-2} s^{-1}) vegetation of the Central Himalaya. Different regional global climate models datasets were downloaded (including current climate data from World Clim, MODIS, NDVI, etc.) for climate scenario projection on climate sensitive taxa of Sikkim Himalaya.
8. Under capacity and sensitization component, 14 days Green Skill Building Course was organized between 5-18 March 2019 on 'Forest Resources and Plant Biodiversity'. A total of 24 students of master's level from 4 states (Uttar Pradesh, Haryana, Jharkhand and Uttarakhand) were participated in the programme. Hands on training were provided on biodiversity conservation, forest resource mapping, phytosociology, dendrochronology and long-term ecological monitoring (Fig. 27).

Fig 27. Green Skill Building Course under NMSHE TF-3

Garhwal Regional Center (RRC)

The major R&D activities of Garhwal Regional Center includes model demonstration on restoration of degraded lands through action research, forest and agro-bioresource utilization for sustainable rural development, water resource management through spring sanctuary development, protected area management and people conflict resolution, eco-tourism, skill development of stakeholders in simple technologies for natural resource management and livelihood enhancement, etc. Some of the on-going R&D thrust areas include climate change impact, adaptation and coping strategies, tracer technique in spring recharge, bioprospecting of wild resources, promotion and cultivation of medicinal and aromatic plants, sustainable tourism, conservation and management of protected areas and eco-sensitive zones and reconstruction of disaster affected rural landscape of Kedar valley.

The Major objective of the center are (i) empowering communities in social, and local governance on natural resource management.; (ii) Promoting environmentally sustainable income generating activities for livelihood enhancement and socio-economic development.; (iii) Model demonstration on innovative, improved and best practices and skill development of farming communities through on-site action research and training and (iv) Organizing an open and continuing dialogue between diverse stakeholders (local people, NGOs, scientists, educationists and policy planners) across societal strata for developing hill/mountain specific policies.

Reinventing Pilgrimage Potential for Tourism Development in the Sacred Landscape of Garhwal Himalaya, Uttarakhand (In house, 2017-2020)

The Devbhoomi Uttarakhand is one of the unique and sacred mountain landscapes, with high ecological, cultural, religious, spiritual values and rich in biodiversity and has a long history in attracting pilgrim's, nature lovers or eco-tourists. It is a land where traditions and culture blend and continue to live in harmony and has great tourism potential. However, many economic benefits of this industry do not accrue to local communities because they do not own and control the key assets. Pilgrimage tourism activities are often seasonal and characterized by unpredictability due to changes in demand, climate, and other external factors. The pressure of religious/pilgrimage tourism has been increasing in the region and 2013 "Kedarnath disaster" is a glaring example. Therefore, there is need of reinventing pilgrimage/ religious potential for tourism development in sacred landscape of Chardham. To ensure that the local population has a share in the economic benefits generated

by pilgrimage tourism, it is important that activities need to be community-based. First and foremost, pilgrimage tourism activities and entrepreneurial initiatives need to be developed in ways that benefit the most disadvantaged and initiate activities that includes capacity building and skills development training for local entrepreneurs and others who wish to work in the tourism sector. It also pays attention to a region's cultural heritage and unique assets, so that development activities integrate local knowledge and expertise and recognizes the varied and rich bio- cultures that local hill communities have developed over centuries or longer. With this in mind, there is an urgent need for activities that help diversify economies, provide alternative livelihood opportunities for locals, develop entrepreneurship skill among the locals to manage and operate tourism travel chain or tourism products, promote biodiversity conservation and over all address the issues related pilgrimage/ religious tourism in the Chardham sacred landscape that is now being connected with all weather roads.

Objectives

- To assess the status of pilgrimage/ religious tourism in Garhwal Himalaya and its contribution to the local economy
- To study the impacts of pilgrimage/religious tourism on carrying capacity of the important circuits, destinations and natural resources of the area and analyses of ongoing scenario in context of future planning and impact management
- To develop entrepreneurial skill and capacities of local communities particularly youth to manage religious/pilgrimage tourism while linking it with diverse livelihood options, employment/ income opportunities, better stewardship, and skill development
- To supplement/ strengthen pilgrimage tourism with other tourism forms i.e. heritage tourism, eco-tourism, nature tourism, rural tourism, agro-tourism, and effective circuit planning
- To create awareness and empowerment of stakeholders in all aspects of religious tourism at different levels of tourism chain for sustainable management.

Achievements

1. Impact assessment on environment, social and cultural aspects of tourism in upper Kedar valley landscape has been conducted.
2. In order to supplement pilgrimage tourism with other forms of tourism the centre developed rural tourism circuit to divert pilgrim tourist for exploring rural ecosystem and detailed trekking routes based on the inputs received from the diverse stakeholders (Fig. 28).

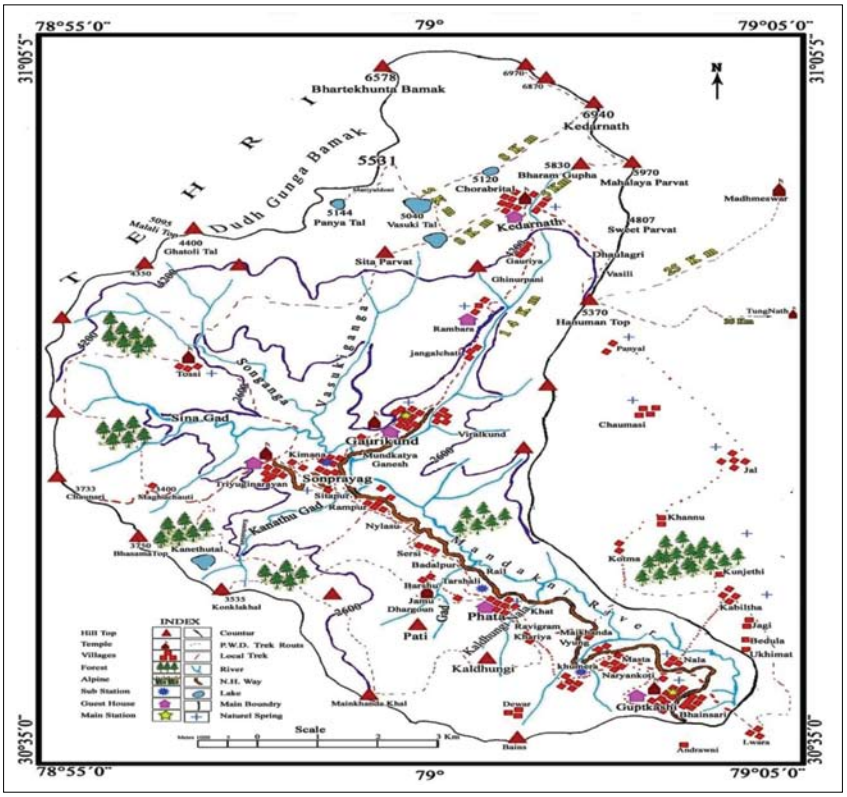


Fig 28. Important trekking routes to potential sites in the natural landscape in Upper Kedar Valley

3. Awareness campaigns were organized involving diverse stakeholders such as local people, travel, tour operators, guides and porters, hotel and shop owners, NGOs,Tourism and other line departments of state and central governments, educational, research and development institutions, and media in the field of naturalist guides, natural resource management, and conservation education, promotion of value addition in wild edibles, local food products and home stay accommodation so as to improve local economy.
4. Identified villages for promotion of rural tourism based on the unique selling points (USP) in consultation with the local people, representatives of village and van panchayats, panchayati raj institutions and block development office, local tour guides and tour operators (Table 8).

Table 8: Promoting villages having rural tourism potential in the rural landscape of the Upper Kedar Valley

S.No.	Village	Altitude (metres above sea level)	Distance (km) from Guptkashi	USP and uniqueness of the village
1	Kaviltha	1,502	17	• Birthplace of Great poet Kalidas • Poet convention organised every year where poets from different regions take part • Kalimath a famous temple of Godess Kali
2	Makku	1,687	22	• Largest forest cover (van panchayat) area in Uttarakhand • Winter abode of Tungnath(Third Kedar) • Valued as wilderness and rich in avifauna • Unique rural landscape having cultivation of traditional crops
3	Gaundar	1,700	25	• High altitude meadows, a long range of Alpine trees, rivulets, waterfalls • First village on the way to Madhyamaheswar (Second Kedar)
4	Tyuri	1,772	07	• Covered with lush green meadows that attract multitude of wildlife and home to various medicinal and aromatic plants • Only temple of Lord Balram in Kedar Valley is situated here
5	Dewar	1,805	06	• Cultural events like PandavNirtya, Chakravyuh etc. • Panoramic views of snow-capped mountains with beauty of Garhwal hill region can be seen from here • Cultivation of traditional cash crops
6	Jamu	1,843	14	• Jameshwar temple built by Jamadagni rishi (one of the saptarishis and father of Lord Parshuram) • Naagtaal water pond covered with natural beauty, forest and wildlife
7	Triyuginarayan	2,100	36	• Lord Vishnu temple which was the venue of celestial marriage of God Shiva and Goddess Parvati • Wedding destination • Enclosed with snow clad mountains and lush green forests, perfect destination among nature lovers
8	Chaumasi	2,211	28	• Ideal destination for tourists and hikers • Trekking path to Kedarnath • High altitude based 'ringal' (a local bamboo) cottage industry by local people

5. Different approaches were used to improve the skill and capacity of local communities to manage their own resources and assets. These include conservation and cultivation of medicinal and aromatic plants, bio-prospecting of bio-resources, serving traditional local foods items and cuisines at rural areas and use of alternative fuels, safety, hygiene and sanitation, organization of cultural programmes to promote cultural awareness among tourists.
6. Impact assessment of helicopter services particularly on local economy, livelihood, and environment, wildlife/livestock behaviors has been carried out. Besides, increased frequency of helicopter services from various locations and high intensity of noise pollution affected the class room teaching of many primary and secondary educational institutions inhabited surrounding the helipads in the valley.
7. Prepared handouts with guidelines to the locals, visitors, tour operators and tour guides for managing pilgrimage and other form of tourism in the valley.

8. Drafted plan of action and suggested priority interventions for promoting responsible rural tourism so as to meet socio-economic development and conservation goals together in the valley.

Enhancement of Livelihood Options based on Locally Available Resources in Disaster Affected Villages in Kedar valley of Uttarakhand (SEED-DST, 2016-2019)

Uttarakhand is known for its rich spiritual and religious tourism, ecological richness and diversity, and cultural ethos rooted in tradition, but it also known for growing frequency and intensity of natural disasters due to the fragility of ecological and geological system. 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, tourists and damaging huge property in Kedar valley and down streams. Overflowing rivers destroyed many lodges/hotels, human settlements and thousands of hectares of agricultural and forest land. The disaster also has claimed the lives of many locals (950) working in Kedarnath and nearby areas. In the post-disaster scenario, local inhabitants in the Kedar valley are facing challenges due to shortage of food, livelihood insecurity and poverty. The economy of the region was totally tourism dependent. Lack of livelihood options for the landless and those with small land holdings is forcing them to extract and exploit natural resources found in and around the area and in that situation there is an urgent need to identify and suggest location specific appropriate options and strategies for livelihood enhancement & income generation. 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-based and other livelihood options in order to develop the socio-economic condition of the disaster affected areas. It will help the disaster affected people to change their socio-economic status by harnessing the locally available potential bio and land based resources for their income generation and livelihood enhancement.

Objectives

- Demonstration of cost-effective protected cultivation of promising high value off-seasonal and seasonal vegetables under protected condition (polyhouse/shade net house/polytunnels) through participatory approach.
- Demonstration through cultivation of selected high value and 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. Forty five (45) polysheet (20 X 20 feet) and 32 shade net of 75 % mesh size (20 X 20 feet) were distributed to progressive farmers on the basis of willingness to grow vegetables and medicinal plants.
2. 92 farmers (HH) adopted vegetable cultivation under protected condition and earned about Rs 22,800/yr as an additional income from this venture
3. Raised 2.20 lakhs MAPs seedlings (*Picrorhiza kurroo, Saussurea costus, Valeriana wallichii* and *Inula racemosa*) with horticultural system (apple, apricot, pears, walnut) and distributed 0.90 lakhs seedlings to three village institutions namely Triyuginarayan, Tarsali and Jammu villages.
4. Three village institutions (Triyuginarayan, Tarsali & Jammu) started cultivation of MAPs under Rural development scheme of MGNREGA and (0.90 lakhs) seedlings distributed to farmers for large scale cultivation.
5. Raised small nursery of six (06) multipurpose tree species (MPTs) (i.e. *Alnus neplenisis, Salix wallichiana, Betula alnoides, Litsea* spp., *Pyrus pashia, Quercus semicarpifolia*) at RTC for restoration/rehabilitation of flooded rural landscape following agro-forestry & restoration ecology approaches.
6. 65 HH and 5 youth started microenterprises based on value addition of local products & individual HH earned about Rs 22,000/yr and individual entrepreneur earned Rs. 3.75 lakhs/yr as an additional income.
7. Developed (13) value added product of five (5) MAPs (*Allium stracheyi, Angelica glauca, Carum carvi*) and eight (8) wild edible plant spp for more employment generation.
8. Advanced cultivation and flowering of Tagets yield (arround 500 kg) at RTC, (2000 m asl) from month of May through

simple science & technology intervention for Promoting large scale cultivation of Gainda between May to November in the villages located along the routes of Kedar Dham so as to meet its growing demand.

9. Organized one training on fish farming with the help of fishery Department, Govt. of Uttarakhand and encouraged 14 HH in Badasu and Triyuginarayan villages to adopt for income generation.
10. Organised Five (5) skill development/training programmes (each of two days) under DST-SEED project and four (4) under in-house & ICSSR sponsored projects between November 2016 to Oct, 2018 and trained about 466 participants (186 women's and 280 men's) of 12 villages on protected cultivation, bio-composting, bio-prospecting & MAPs cultivation/conservation. Details of various activities are dipicted (Fig. 29).

Fig 29. Details of various activities undertaken in RTC at Trijuginarayan

Identification of Land and Bio-resources based Potential Options for Livelihood Enhancement and Diversification Through Simple Technological Interventions for Sustainable Development of the Disaster Affected Rural Landscape of Kedar Valley, Uttarakhand (ICSSR, 2016-2020)

The traditional societies 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, a generalized and uniform action plan cannot be much useful for this region because of vast diversity in respect of topography, natural and bio-cultural landscape, diverse climate, water and bio-resources availability, etc., and in that situation only location specific livelihood management plans can be useful. At a juncture when development is hampered by natural disasters (resource depletion and environmental degradation), the role of sustainable utilization of bio-resources and land based activities through simple, cost-effective and appropriate technological interventions which promote and ensure ecologically

sound development of the rural areas/village cluster becomes crucial. Lack of livelihood options for the landless and those with small land holdings compel them to extract and exploit natural resources found in and around the area. 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-based and other livelihood options in order to develop the disaster affected areas. There is also an urgent need for linking developmental organizations with village institutions like the village panchayat for rebuilding infrastructure and to provide opportunities in the disaster- affected regions of the state. Capacity building and skill development through on-site training programmes, live demonstrations and interactions between stakeholders and scientists is urgently required and need to be facilitated. It is anticipated that if people of disaster affected villages implement and replicate bio-resources based income generation activities it will improve their own socio-economic conditions in short and long term basis and will make themselves self reliant.

Objectives

- To explore and prepare an inventory of the locally available agro- and wild bioresource based potential options for livelihood diversification and enhancement of disaster-affected people.
- To identify, develop and strengthen alternative and sustainable sources of income and value chain.
- To probe ways and means of empowering and developing skills of women and local people through training/live demonstrations/field exercise in simple technologies and value addition of local bio-resources.
- To promote linkages between local people including women group/women panchayat representatives, line departments, NGOs, researchers, and extension workers in developing sustainable livelihood options and capacity development in disaster-affected areas.
- To develop appropriate strategies and action research framework for empowering local people for securing sustainable livelihood in the short- and long-term basis
- To evaluate the policy interventions for the use of bio resources, promotion of organic farming and diversification of crops
- To assess the impact of these interventions on empowerment of the local people and improving livelihood and conservation of natural resources

Achievements

1. A two-day training and capacity building programme on “harnessing bioresources potential for livelihood enhancement through simple technological intervention in disaster affected villages of Kedar valley”was organized at Rural Technology Centre established at village Triyuginarayan district Rudraprayag, Uttarakhand between 4-5 October 2018 in which about 80 participants belonging to different sections of the society participated in the programme.
2. A total of ten villages were surveyed in which there were total of 213 males and 37 females respondents and only two villages are getting training from Government institution and NGOs for making Ringal based product.
3. While documenting the cost benefits analysis of Ringal-based product it was observed that the product made after providing training through skill development program by different NGOs and Government institution were more profitable and consumed less raw material, manpower and time as compared to un-trained workers who make these product only for their own use.
4. Villages/farmers have been trained to increase the livelihood option by which they can add value to bioresources available locally.

Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basins using Spring Sanctuary Concept (NMHS, MoEF&CC, 2016-2019)

The Indian Himalayan Region (IHR) is one of the most diverse and versatile mountain systems of the world considering the physical, biological and socio-cultural attributes. The sensitivity of these attributes towards changes (anthropogenic and climatic) is recognized world over. Among others, the water resources in the Himalayan Mountains have been recognized as most sensitive systems, which are subject to changes. One such conspicuous change is the drying-up of the springs/ streams due to due to global climate change as well as anthropogenic onslaught on mountain woodlands. Water being a fundamental constituent of environment and vital for the living beings, sensitivity of water resources have long-term consequences for mountain ecosystem properties and human societies. Water stress and sustainability are functions of

the available water resources and their withdrawal and consumption. In view of the expanding footprints of water scarcity zones throughout the Indian Himalayan region, this action oriented project is attempting to develop field level demonstration models to rejuvenate the life-supporting springs and spring-fed streams for selected watershed of the IHR in collaboration with state implementing agencies using spring sanctuary concept as well as initiating the long-term-ecological monitoring networks in four watersheds across Indian Himalayan Region.

Objectives

- To quantify hydrological processes and establish functional relationship of land use changes and hydrological responses in social and climate change scenario.
- Model development for ground water augmentation through participatory approach in Kumaon and Garhwal region.
- Development and demonstration of functional land use model using optimized hydrological response (water allocations) at sub-watershed level.
- Disseminations of an adaptive land use policy and integrated decision support system for water resource management at watershed level.
- To recommend policies and practices of land use (forest and non-forest land), land transformation (one land use category to other) and related water use

Achievements

1. Baseline database in terms of spring-flow and peizometric head measurement for pre and post implementation years was generated for 2017 and 2018 for Domat Khal intervention site (Fig. 30).
2. Staggered trenches, storage-tank, recharge cum monitoring well (80m deep) and plantation (mainly oak) was carried out for groundwater augmentation in 1.2 hectare land of catchment area of Mandir Dhara spring.
3. Domat Khal Intervention site in Ir-gad watershed do not show increase in spring flow due to trenching in catchment area of the spring. This could be due to deficient rainfall during the monsoon period of 2018 compared to the 2017 monsoon rainfall.

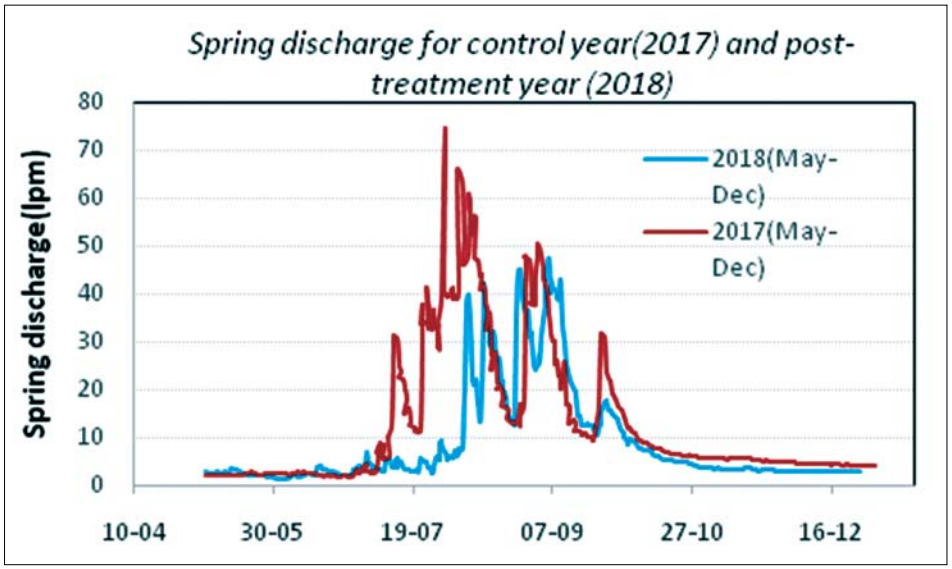


Fig 30. Spring-flow of mandirdhara spring during 2017 and post implementation period of 2018 do not indicate an increase in the baseflow during the post-monsoon period

4. Deep recharge well in Domatkhal indicate 4 to 19% recharge during the monsoon period of 2018.
5. 139 samples of rainfall was collected from four different elevation ranging between 1400m to 1850m to generate the local meteoric water line as well as to decipher the recharge elevation of Ayal village spring located within the study area (Fig. 31).
6. Village wise spring inventory, and creation of Geodatabase in GIS Domain for Ir-gad watershed.

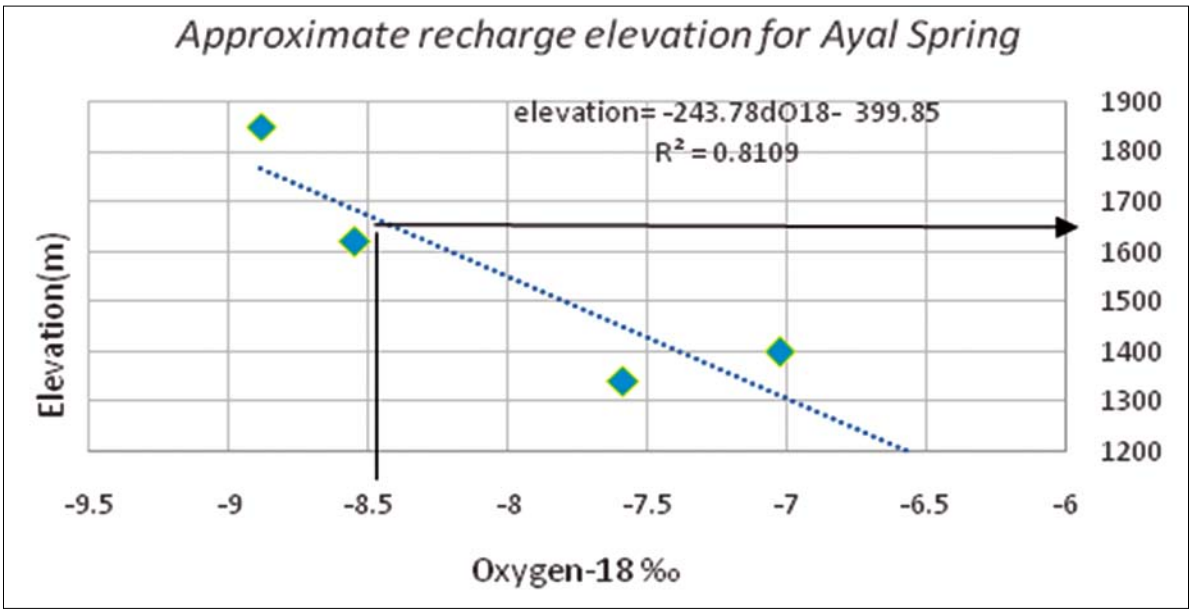


Fig 31. Altitude effect indicating an approximate recharge elevation of 1700m for Ayal village spring

Biological Nitrogen Fixation and Soil Nutrient Dynamics with Reference to *Hippophae salicifolia* and *Myrica esculenta* in Uttrakhand (Uttarakhand Council of Biotechnology, 2018-2020)

Indian Himalayan region (IHR) is a global biodiversity hotspot comprising unique biodiversity of angiosperms, gymnosperms, petridophytes, and bryophytes. However, due to urbanization, anthropogenic pressure and climate change events there is severe reduction in diversity and density of these species which ultimately affects the livelihood of the local inhabitants. Therefore there is a need to restore and manage these species or forests to conserve biodiversity along with sustaining the livelihood options of the local inhabitants in this region. In view of this the present study is attempted to evaluate vegetation and regeneration potential of *M.esculenta* and *H.salicifolia*.

Objectives

- To understand and quantify patterns of the nitrogen fixation and soil nutrient dynamics by *H. salicifolia* and *M. esculenta* plants in the selected forest types of Uttrakhand.
- To conduct in depth study of population dynamics, vegetation analysis and regeneration status of *H. salicifolia* and *M. esculenta* in prominent valleys of the Uttrakhand.
- To document traditional ecological knowledge (TEK) and socio-cultural/religious values/practices and understand local people perception/response on these species due to impact of climate change.
- Field plantation and establishment of demonstration plots at different Himalayan locations.

Achievements

1. Soil analysis of *Myrcia esculenta* and Hippophae salicifolia growing sites revealed variation in the soil nutrient dynamics (Fig. 32). Among 10 studied sites of *M.esculenta* maximum value of Nitrogen content (10.31±0.06 g/kg) in Khirshu followed by phosphorus (0.03±0.007g/kg) in Ghat, potassium (0.808±0.19g/kg) in Paun were found. Likewise, maximum pH (7.6) in Pauri, water holding capacity (74.9±5.8%) and moisture content (1.210±0.141%) in Kirshu and organic carbon (118.22±0.170g /kg) in Ranichauri was recorded.
2. Seed germination studies in both the species using different treatments showed poor germination in *M.esculenta*, however, good germination was recorded in *H.salicifolia* in natural conditions. Over 70.4% seedlings survived incase of *H. salicifolia*.
3. Studies related to nitrogen fixers show the following results: Root colonization of *M.esculenta* using microscopy visualization showed varying percentage of association of bacteria (55%), fungal mycelium (63%), vesicles (15%), hype (40%), dark septate (43%), arbscules (32%), and spores (65%), however, no nodules were recorded during winter season. Similarly, in *H.salcifolia*, percentage association of bacteria (41%), fungal mycelium (51%), vesicles

(69%), hype (79%), dark septate (28%), arbscules (36%), and spores (79%) was recorded. Nodules of *H.salcifolia* showed total percentage of bacteria (22%), fungal mycelium (80%), vesicles (54), hype (78%), dark septate (23%), arbscules (52%), and spores (69%). Further confirmation of bacterial strains, or frankia isolates is under progress.

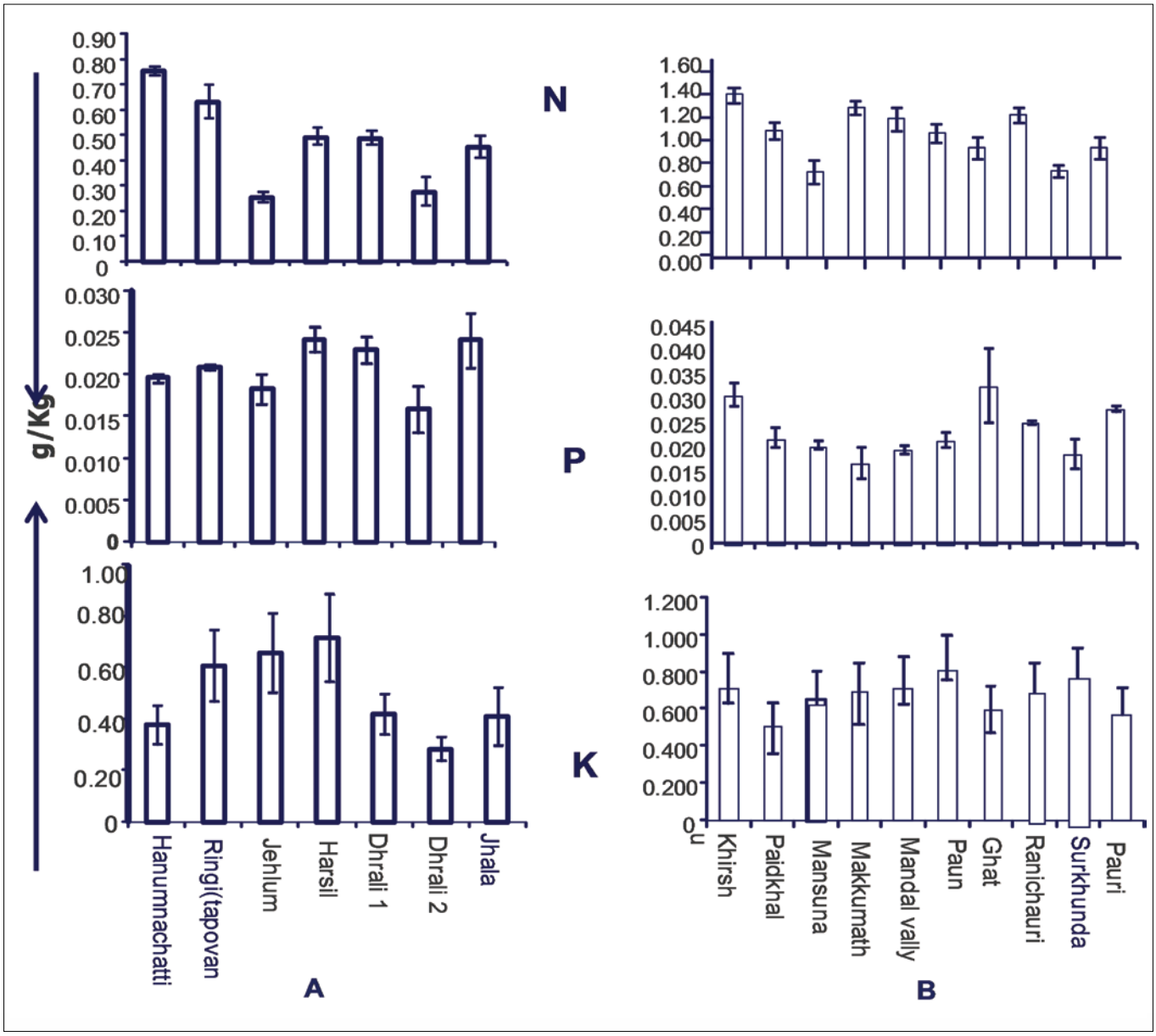


Fig 32. Soil nutrients Composition (N, P, K) across the studied sites of (A). *H. salcifolia* and (B). *M. esculenta*

Himachal Regional Centre (HRC)

The focus of the center is entire Himachal Pradesh state covering parts of north western Himalayan Bio-geographic province. The region is recognized for its ecological and economic values manifested by ecosystem integrity, adaptability and ecosystem services. Its protective and productive functions for both upland and lowland dwellers are well known. The major thrust areas of activities include (i) vulnerability assessment of biodiversity of the ecosystems in Trans and North Western Himalaya under biological, anthropogenic and climate scenarios and developing strategies for conservation management, (ii) assessment, monitoring and management of agricultural crops/farming systems for sustainability under chemical contamination and climate change scenarios along an altitudinal gradient in North Western Himalaya, (iii) assessment, characterization and valuation of ecosystem services for sustainable development of the native communities under changing climate scenario, (iv) development of strategies for monitoring and management of water resources under climate change scenario, (v) assessment and sustainable management of eco-tourism in the changing climate scenario through entrepreneurship development, (vi) assessment, monitoring and analysis of the anthropogenic and natural environmental impacts for developing management strategies under climate change scenario, (vii) development and strengthening of institutional mechanism for information sharing and capacity building of the stakeholders for environmental management

Community Driven Solid Waste Management in Himachal Pradesh: A Step Towards Swachh Bharat Mission (In house, 2017-2020)

Among the anthropogenic activities in the Himalayan ecosystems, solid waste management has become one of the major problems across the globe. Increasing human population, urbanization and unplanned disposal of solid waste particularly in the urban areas has created a lot of problems worldwide. In India and entire Himalayan region the migration of human population from rural areas to urban areas and semi urban areas has created imbalance in the carrying capacity of urban areas. The quantity of solid waste has increased many folds. The unplanned disposal of solid waste by the inhabitants has increased the air, water and soil pollution and affecting biological components directly or indirectly. The highly populated areas within the Himalayan ecosystem are more vulnerable to this problem rather than less populated areas. In the past studies carried out on solid waste management had addressed mostly estimation of waste generation and pollution separately. Such isolated studies are unable to convince the stakeholders about the harmful effects of solid waste and also to draw concrete conclusion. Therefore, integrated study for the management of solid waste using standard methods is urgently required.

Objectives

- To study the status of solid waste in selected sites of Himachal Pradesh and identify related issues
- To reclaim dumping sites through plantation of suitable species
- To assess the impact of solid waste on soil health
- To develop community driven models for solid waste management

Achievements

1. Secondary data on solid waste management (SWM) from different agencies/Departments such as Municipal Council, Department of Tourism and Civil Aviation, State Pollution Control Board, and Town and Country Planning from Chamba and Kangra districts was collected. Total 717 households were surveyed from Chamba town (total population 3940; 51.24 % male and 48.76% female) through random sampling method. The structured questionnaire was divided into 4 main sections which dealt with general household information, solid waste scenario, awareness regarding solid waste management and willingness to pay for improved SWM services.
2. Soil samples of dumping and control sites of the selected towns were collected and analyzed for various parameters like Electric Conductivity (114.30-685.50 µS), pH (6.27-6.88), soil moisture (4.58-17.17%), Phosphorous (32.25-181.50ppm), Potassium (14.40-81.03ppm) and Organic Carbon (0.32-1.82%), and shown in Fig. 33 and 34.

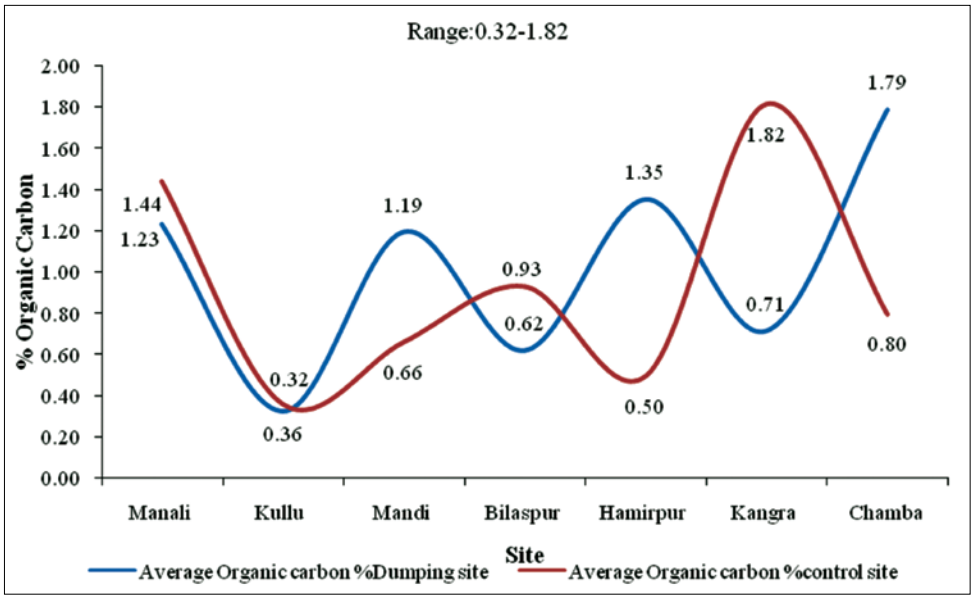


Fig 33. Average organic carbon % at dumping sites and control sites

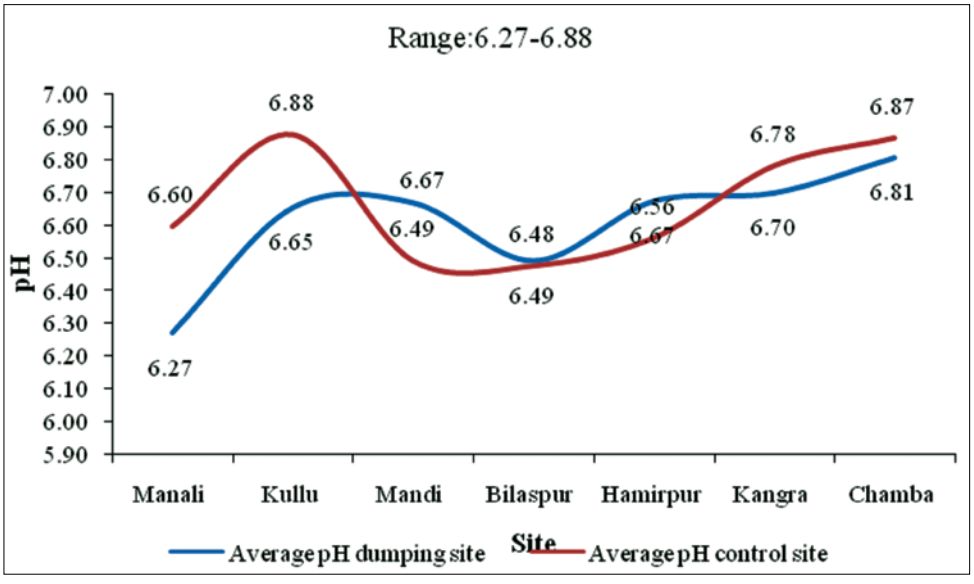


Fig 34. Average pH at dumping sites and control sites

3. Total 150 species of trees, shrubs and herbs were identified through extensive and intensive field surveys from the Kullu and Chamba towns. Suitable species for the reclamation of dumping sites were identified and propagules were collected for propagation in the nursery.
4. Training-cum-Capacity Building Workshops (07) were organized in Mandi (1-02-2019) , Hamirpur (13-02-2019), Bilaspur (14-02-2019), HRC Mohal - Kullu (02-03-2019 & 19-03-2019), Kangra (22-03.2019), and Manali (26-03-2019) for the Municipal Councils, Ward Members, Panchayat Pradhans, Garbage pickers, sanitary contractors, Mahila Mandals, Yuvak Mandals, Hotelliers, etc. Total 680 participants participated. Cleanliness drive was organized at Mohal Khad during plastic free campaign (18.05.2018). Total 200 participants from different Mahila Mandals, Gram Panchayat representatives, Yuvak Mandals and residents of slum near Mohal Khad participated.
5. Automatic Bio-composter (for making compost from the biodegradable waste especially kitchen waste and providing training) and Paper Recycling Machine (for value-added products and training) were installed and training to the hoteliers, Panchayats, Municipal Council members, Mahila Mandals, participants of GSDP, etc. was given. For awareness creation, information boards regarding SWM were prepared and installed at 11 locations from Sharabai to Kais in Kullu, 4 locations in Mandi, 7 locations in Manali and 10 locations in Kangra.
6. Using trash items such as used glasses, plastic bottles, used vehicle tyres, waste paper, cardboards, used household items, etc. 13 products i.e., Decorative Paper Roll Frame, Paper bowl, Dahlia flower, Paper trophy, Plastic bottle lantern, Artistic glasswares and plastic wares, Decorative wrapped bottle, Flower bouquet, Bicycle, Guitar, Tyre sofa, Cartoon Minion using tyres were made and displayed in RTC for the training and awareness of stakeholders.

Population Assessment, Standardization of Propagation Protocol and Establishment (*ex situ* & *in situ*) of Selected Species as a Part of Biodiversity Conservation Plan under Sainj Hydro-Electric Project in Himachal Pradesh (HPPCL, Sarabhai, 2014-2019)

Biodiversity is most valuable for the human beings directly, indirectly, aesthetically and ethically. The state Himachal Pradesh is also known for the representative, natural, unique and socio-economically important biodiversity. The Sainj Hydro-Electric Project (100 MW), a run of the river development on river Sainj, a tributary of river Beas in Kullu district. Due to over exploitation and habitat degradation, the population of many economically important plants is depleting at an unprecedented rate. Tissue culture also enables rapid clonal propagation of plants; this is also called micropropagation. The principle of tissue culture was all around us-in nature, in the field, and in the greenhouse. The technique has developed around the concept that a cell is totipotent that has the capacity and ability to develop into whole organism. Present study is part of this biodiversity conservation and management plan proposed for Sainj hydroelectric project in Sainj valley.

Objectives

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

Achievements

1. Total 19 sites between 1,420 – 2,300 m were sampled for the population assessment of selected species. Of the total sites, 13 sites were represented by the populations of *Polygonatum verticillatum* and 3 sites by the *Delphinium denudatum*; 3 sites were common for both species. *D. denudatum* was found in rocky and shady moist habitats and in east and south east aspects between 2,200-2,276 m, whereas *P. verticillatum* mostly preferred shady moist habitat and North East aspect between 1,420 – 2,300m amsl.
2. Amongst 6 sampled populations the relative density (%) of *D. denudatum* was ranged from 1.25-2.87 %, whereas among 16 sampled populations of *P. verticillatum* the relative density was ranged from 0.52-4.89%.
3. Seeds of *P. verticillatum* and *D. denudatum* were also collected and subjected to improve germination and mass multiplication through tissue culture. Similarly, seeds and tubers of *P. verticillatum* were sown in the nurseries and herbal gardens for plant production. Plantlets produced through seed and cutting methods were transferred to nursery for further monitoring growth and survival percentage.

Community based Conservation and Long Term Monitoring of Pollination Projects in Kullu, Himachal Pradesh (Earthwatch Institute India, 2017-2018)

Virtually all of the world's seed plants need to be pollinated. Pollination is an essential ecological survival function. Without pollinators, the human race and earth's entire terrestrial ecosystem would not survive. Of the 1,400 crop plants grown around the world, i.e. those that produce all of our food and plant based industrial products; almost 80% require pollination by animals. Visits from bees and other pollinators also result in larger, more flavorful fruits and higher crop yields. Over the past few decades, there has been a significant loss of pollinators, including honey bees, native bees, birds, bats, and butterflies, from the environment. One of the biggest obstacles that pollinators are facing today is the excessive use of certain pesticides. The problem is serious and requires immediate attention to ensure the sustainability of our food production system, avoid additional economic impact on the agricultural sector, and protect the health of the environment.

Objectives

- To plant and monitor bee foraging plants
- To organize capacity development workshops
- To assess the pollination and other ecosystem services
- To promote apiculture and provide bee hives with bee colonies
- To monitor apiculture practices

Achievements

1. Total 5165 seedlings of 09 species were developed in the nursery. Of these, 2195 seedlings of bee flora i.e. *Pyrus pashia, Berberis lycium, Callistemon citrinus, Pittosporum eriocarpum, Rosa moschata, Aesculus indica, Prunus cerasoides, Sapindus mukososii* and *Bauhinia variegata* were planted in 22 villages.
2. Seeds of *Brassica camprestris* (Mustard) and *Corriandum sativum* (Coriander) distributed to farmers in Kais, Karadsu, Archandi, Hirni, Banogi, Bari, Nashala, Katrain, Maheliseri and Dobi villages for promoting insect pollinators in different seasons.
3. 87 Bee hives with bee colonies were distributed to 77 farmers in 6 villages i.e., Kais, Karadsu, Archandi, Seobag, Nashala and Naggar of Upper Beas Valley.
4. Evaluation of Insect pollinator density and diversity on Mustard and Coriander crops was done in which maximum insect diversity was recorded for syphid flies, followed by Indian honeybee.

Standardization of Post Harvest Technology for Wild Rose Hips and Promotion as Sustainable Livelihood Pption among Poor Self help Women Groups in Kullu Valley, Himachal Pradesh (DST, 2015-2018)

Wild Rosehips (*Rosa moschata*) belongs to family Rosaceae and found abundantly in Indian North-western Himalayan district of Kullu in Himachal Pradesh. It has turned out to be popular worldwide as a result of its evident health-giving properties. Therefore, project proposes to develop locally available wild rose based products through introduction of post-harvest technology backed by scientifically proven benefits. There are two products which had been developed from Rosehip pods i.e. Rosehip tea and Rosehip seed oil. The Rosehip tea and oil has high antioxidant activity. Rose pods are available in plenty in the region but due to lack of awareness and scientific value addition, the produce is left unattended. Involvement of the local women self-help groups in this entrepreneurial activity is increasing their economic status at the same time ensuring its sustainability. Capacity building of these women was also done on post-harvest technology like harvesting, drying and storage which is the integral part of the project.

Objectives

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

Achievements

1. Antioxidant activity of water and methanol extract of Rosehip flesh showed IC50 values for DPPH assay (2.72 AAE μgml^{-1}) and 1.48 AAE μgml^{-1}), ABTS assay as 14.10 GAE μgml^{-1} (water extract) and 22.68 GAE μgml^{-1} (methanol extract), FRAP assay as 1.22 Fe (II) g^{-1} DW. The testing of products showed encouraging results hence recommended for use as tea and oil.
2. GC-MS analysis of Rosehip seed oil showed total of 25 chemical compounds at different retention time and area percentage. Major terpenoids present were Farnesene (15.23%), gamma-eudesmol (16.53 %), Alpha-bisabolol (14.24 %), 2-Naphthalenone (9.20 %) and Terpineol (1.24 %). Fatty acid composition of rosehip seed oil analysed by GC-MS.

Development of Sustainable Rural Livelihood Options Utilizing Locally Available Bio-resources through Transformative Rural Technologies in the Indian Himalayan Regions of Himachal Pradesh and Sikkim (NMHS, MoEF&CC, 2018-2021)

The Seabuckthorn berry, also called the "Wonder berry", "Leh berry" and "Ladakh gold", is among the most nutritious of fruits. Concentration of pro-vitamins A, B_2 and C, flavonoids and Omega oils in the berries is much higher than other fruits and vegetables. Seabuckthorn berries (locally known as 'Drilbu'and 'Chharma' in Himachal) also have the unique characteristic of remaining intact on the shrub throughout the winter months despite of the subzero temperature. As such, many bird species feed on the berries at times other sources of food are limited in the region. The leaves, on the other hand, serve as protein rich fodder for cold desert animals. Seabuckthorn can act as a prominent afforestation species of cold desert due to its property of having physiological mechanisms to grow under environmental stress. In Lahaul, Seabuckthorn is found in abundant quantity in Tod Valley which can be one of the major incomes generating aspect if proper technological interventions are being provided to the local community.

Objectives

- To develop scientific and sustainable strategies for cultivation and harvesting of natural bio-resources such as aromatic and herbal plants, crops and scrubs, agro produce, and timber and non-timber forest products in the Indian Himalayan regions.
- To develop appropriate scientific and technological interventions for processing and value addition of these local bio-resources into high value products.
- To establish replicable community models through rural transformative technologies and participatory rural action research for sustainable utilization of the bioresources in collaboration with local grassroots organizations

Achievements

1. Tod Valley in Lahaul and Spiti district was selected based on the availability of seabuckthorn. Technology Incubation Center was established at Shansha village, Lahaul and Spiti district for the procurement and further processing, and MoU signed.
2. Stakeholders were identified for the further project implementation. Seeds of Seabuckthorn were collected from the region for its further testing.
3. Sample of leaves were also collected on monthly basis to check its chemical constituents and its acceptability as tea.
4. Interactive meeting with the stakeholders is streamlined, and procurement of the machinery process initiated.

Vulnerability Assessment of Mountain Ecosystems due to Climate Change: Ecosystem Structure and Functioning – Himachal Site (IIRS, Dehradun, 2014-2019)

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. The unique topography, diverse habitats and large altitudinal range 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 the 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 suggest suitable management options for conserving the Himalayan ecosystems.

Objectives

- To assess the floristic diversity of the sub-alpine and alpine ecosystems
- To assess the conservation and socio-economic values of the floristic diversity of sub alpine and alpine ecosystems
- To assess the carbon sequestration of the sub-alpine ecosystems
- To monitor floristic diversity in relation to climate change
- To assess the floristic diversity of sub-alpine and alpine ecosystem for vulnerability
- To prioritize and map the habitats and communities for conservation and suggest management options

Achievements

1. Total 44 sites were surveyed in Great Himalayan National Park (GHNP) between 2803-4480 m. Six (06) tree communities, sixteen (16) shrub communities and eight (8) herb communities were identified. Amongst the identified communities, the total trees density was ranged from 10.00- 930.00 Ind ha^{-1}; total basal area 0.015-17.84 m2 ha^{-1}; total shrubs density 100-2430 Ind ha^{-1}; total herb density 31.40-281.22 Ind m^{-2}; total saplings density 30-552 Ind ha^{-1} and total seedlings density 50-562 Ind ha^{-1}. Total basal area was recorded maximum in *Betula utilis* (17.84 m2 ha-1) community, followed by *Quercus semecarpifolia* community (6.91 m^2 ha^{-1}). Total shrub density was highest in *Salix lindleyana* community (2430.00 Ind ha^{-1}), followed by *Betula utilis* community (17.15 Ind ha^{-1}). *Salix lindleyana-Salix denticulata* mixed community showed the highest herb density (281.22 Ind m^{-2}). *Quercus semecarpifolia - Betula utilis* mixed and *Quercus semecarpifolia-Taxus wallichiana* mixed communities showed maximum regeneration while *Betula utilis - Abies spectabilis* and *Abies pindrow* mixed community showed lowest regeneration.
2. Species richness was maximum in *Betula utilis* (129 spp.) community; followed by *Quercus semecarpifolia* (127 spp.) community. It was lowest in *Oxyria digyna -Poa pratens* (09 spp) mixed community. Species Diversity (H') of trees species ranged from 0.06–0.68. In the identified communities. Diversity of shrubs ranged from 0.08-2.97, and for herb it ranged from 1.93-3.99. *Picea smithiana-Pinus wallichiana* mixed (0.68) community showed highest diversity for tees, followed by *Quercus semecarpifolia-Taxus wallichiana* mixed (0.62) community.
3. Of the total 583 species, 14 species were identified as critically endangered, 08 species endangered, 21 species vulnerable and 87 species near threatened, categories and remaining species under least concern category.
4. Ecological Niche modeling of *Betula utilis, Quercus semecarpifolia* and *Abies pindrow* has been done and the model calibration test showed significant results. *Betula utilis* showed AUC_{Train}=0.93±0.004 and AUC_{Test}=0.91±0.004), *Quercus semecarpifolia* AUC_{Train}=0.94±0.004 and AUC_{Test}=0.91±0.01 and *Abies pindrow* AUC_{Train}=0.91±0.004 and AUC_{Test}=0.91±0.01. In *Betula utilis*, the climatic factor was Bio_15 i.e., Precipitation seasonality (Coefficient of variation), *Quercus semecarpifolia* environment variable, Bio_19 i.e., Precipitation of coldest quarter was the most influential and contributed 52 % to the habitat model and *Abies pindrow* Bio_19 i.e., Precipitation of Coldest Quarter was the most influential factor the growth of *Abies pindrow* and contributed 61% to the habitat model (Fig. 35 a-c).

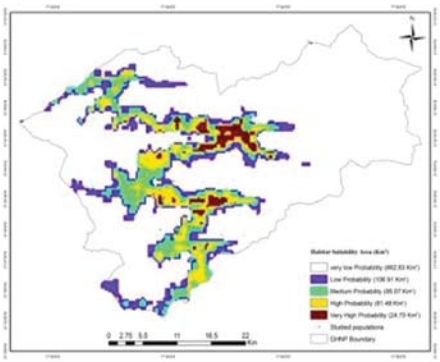


Fig 35a. Probability distribution map of Betula utilis

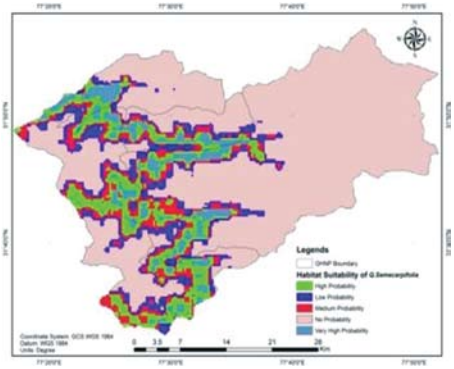


Fig 35b. Probability distribution map of Quercus semecarpifolia

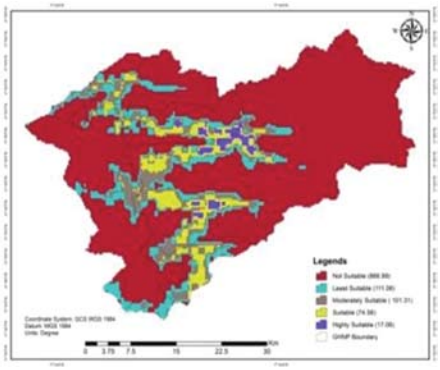


Fig 35c. Probability distribution map of Abies pindrow

Microbial Endophytes and Soil Enzymes as Indicators of Climate Resilience with Respect to Himalayan Birch: A Critically Endangered Timber Line Species (NMHS, MoEF&CC, 2018-2021)

Betula utilis D. Don is a broadleaved angiosperm and native tree species of high altitude Himalaya. This species is distributed in sub-alpine region of the Himalayan range between 3,300 - 4,500m amsl and forms tree line all across the Himalaya. Rhizosphere research is being recognized due to the world wide emerging concern on climate change and food security. Microorganisms are always a crucial part of any ecosystem as they carry out various activities to maintain the sustainability of that ecosystem. The biological services provided by soils are referred as life support functions. Climatic variation at micro-scale, for example variation due to altitudinal difference, also affects the microbial communities. This is due to change in climatic factors such as temperature, net precipitation, O_2 availability, etc. These changes enable colonization of higher population of microbes which are adapted to particular type of environments causing reduction in the diversity. There is a great need for identifying the microbial indicators to assess climate variability especially in the mountains which are being affected by climate change. Extracellular enzymes in soil are released mainly due to the microbial activities leading to various ecological functions. It includes nutrient recycling in the soil by degradation of soil organic matter to maintain the soil health. Microbial components, including mycorrhizae present in the roots, are the key producers of soil enzymes. Due to natural calamities, changing environmental conditions and over exploitation, the species (*B. utilis*) has become vulnerable and habitat alterations have started taking place. Such conditions are making the species more vulnerable. Microbial associations will also change with habitat alterations and climate change. Such changes may affect the mutual benefits of these species. Most of the studies on this species have been carried out in isolation and studies integrating different components of *B. utilis* forests have not been carried out so far.

Objectives

- To assess the representative *Betula utilis* populations in Himachal Pradesh, North-West Himalaya
- To assess the soil enzymes and microbial endophytes as indicators of climate resilience
- To assess the contribution of root associated microbes in propagation and conservation of *B. utilis*
- To create awareness among the local inhabitants, officials of the forest department, NGOs and other stakeholders
- To use the generated knowledge in suggesting management options and policy briefs for the conservation *B. utilis* populations
- To suggest management plan

Achievements

1. In Hampta Pass area, 16 sites were sampled between 3,047– 3,760 m. 14 sites represented Shady moist and 2 sites bouldary habitats, and 8 sites represented NW, 5 W and 3 SW aspects. The slope varied from 20°-60°. Total 129 species representing trees, shrubs and herbs recorded. Six tree communities (i.e., *Betula utilis, Acer acuminatum - Betula utilis* mixed, *Abies pindrow - Betula utilis* mixed, *Abies pindrow - Acer acuminatum* mixed, *Betula utilis - Corylus jacquemontii* mixed and *Quercus semecarpifolia*) representing *Betula utilis* populations were identified. Species richness ranged from 17 – 129; tree density 160-297 Ind ha^{-1}; TBA - 6.9-56.2 m^2 ha^{-1}; total herbs density 9.90 – 34.60 Ind/m^2; and species diversity for trees 0.4 – 3.7.
2. In Fozal area, four sites were sampled between 2850– 3209 m. Two sites were represented by shady moist habitat and 01 site each by rocky and dry habitats. Two sites were represented in NW aspect, 1 site each by NE and N aspects. The slope varied from 40°-65°. Four tree communities (i.e., *Abies pindrow - Quercus semecarpifolia* mixed, *Acer caesium - Abies pindrow* mixed, *Abies pindrow - Acer caesium* mixed, *Abies pindrow - Quercus semecarpifolia* mixed) were identified. Trees density was ranged from 106-279 Ind ha^{-1} and TBA 133-1784 m^2 ha^{-1}; species diversity (H') of trees from 0.99- 1.56 and concentration of dominance of trees 0.22-0.41.
3. In Hamta Pass, the pH was ranged between 5.17 – 6.16 whereas, the electrical conductivity was ranged between 72.50 – 207.00 µS. The moisture content (%), organic carbon (%) and organic matter (%) ranged from 22.52 - 50.17, 1.00 - 2.51 and 1.72 - 4.33, respectively. Available N, P and K ranged between 1.4 - 95.90 mg/kg, 0.61 - 3.43 mg/kg and 131.69 – 3320 mg/kg, respectively. In Fozal, the pH was ranged between 6.21-6.47, moisture content (%), organic carbon (%) and organic matter (%) ranged from 32.3 – 37.0, 5.23-7.68 and 9.1 – 13.05, respectively. Available N, P and K ranged between 275 – 526 Kg/ha, 0.26-0.34 mg/kg and 226-461kg/ha, respectively. Soil NPK showed variations in all populations.

4. Various root endophytic structures, namely, fungal endophytes, dark septate endophytes and bacterial endophytes were observed. The root colonization for fungal mycelium and dark septate endophytes varied. The recorded fungal root colonization was 64 % whereas, the dark septate colonization was 74 %. Total 12 endophytes (7 bacterial and 5 fungal endophytes) were isolated from the root sample of B. utilis. The microbial endophytes take three weeks to two months to grow.

Development of People's Biodiversity Register in Selected Gram Panchayat of Kullu district, Himachal Pradesh (HPSBB, Shimla, 2017-2018)

The term Biodiversity is globally recognized as a corner stone of a healthy ecosystem. India, a mega bio-diverse country of the world is a land of Biological and Cultural diversity. National Biodiversity Authority (NBA) is working on the development of Peoples' Biodiversity Register (PBR) throughout the India for the mainstreaming and maintaining of bio resources and sustainable use of it. The state Himachal Pradesh is also known for the representative, natural, unique and socio-economically important biodiversity. The people of Himachal Pradesh is continue to depend on natural bio resources at varying scales and aspect. The diverse and large traditional and ethnic knowledge of the inhabitants of Kullu is passed from one generation to another. Hence, the notion behind the documentation of this undocumented indigenous and associated wealth of the communities is necessary for sustainable utilization and conservation of biodiversity towards a healthy future.

Objectives

- To document the biodiversity components such as plants, animals, microbes, insects and their possible use by the local communities in the selected BMC
- To document topographic and socio economic features of the selected BMCs with special emphasis on human population, climate, topography, natural ecosystems, livestock resources, livelihood patterns etc.
- To documentation the traditional knowledge and accurate information about the BMC, ecosystem and its natural resources
- To facilitate and engage the trained youth in developing BMC
- To develop the reports on the program using the suitable self-monitoring and evaluation tools

Achievements

1. A total 24 Panchayats namely, Archandi, Bahlan-II, Burua, Basturi, Chheinure, Diyar, Dwara, Halan-I, Halan-II, Jagatsukh, Jindaur, Jaugran, Kadarsu, Katrain, Mohal, Mangarh, Naggar, Nathan, Niyul, Prini, Raila, Shanag, Shilirajgiri and Soyal were selected for the preparation PBRs. Map and demographic profile of each Panchayat were prepared. Wild biodiversity i.e., forest types, habitats, plants, animals, medicinal, wild edible, fodder, fuel, timber, fiber and religious plants diversity were documented.
2. Domesticated biodiversity i.e., plant diversity (Agricultural, Horticultural, ornamental and religious), animal diversity (Mammals and Birds) and cultivated medicinal plant diversity were documented (Fig. 36).
3. Unique plant diversity was recorded in some of selected Panchayats. Citrus limon and *Prunus amygdalus* from Burua and *Mangifera indica* from Diyar Panchyats were recorded.
4. Some of the important medicinal plants i.e., *Angelica glauca, Aster thomsonii, Bergenia ligulata, Dactylorhiza hatagirea, Delphinium denudatum, Geranium wallichiana, Taxus wallichiana, Trillium govanianum, Thymus linearis* and *Viola canescens* were recorded.

Identification of Elite Planting Material of Selected Temperate Medicinal Plants, Mass Multiplication, Field Demonstration and Post- Harvest Processing (DBT, Govt. of India, 2018-2022)

For centuries the local communities were considered custodians of natural biological resources and were freely accessing those resources for their day-to-day needs and livelihoods. However, the imposition of legal restrictions on the collection of medicinal plants raw material from natural habitats have caused not only economic constraints on the local communities but also resulted in shortage of raw material for pharmaceutical and herbal drug industries. This shortage has lead to illegal procurement, substitution and adulteration of raw material of medicinal plants, which has not only affected the livelihood of local farmers but also resulted in adulteration of herbal products. Therefore, production of quality herbal raw material by maintaining chemical/genetic purity would go a long way in providing a sustainable solution to the problem.

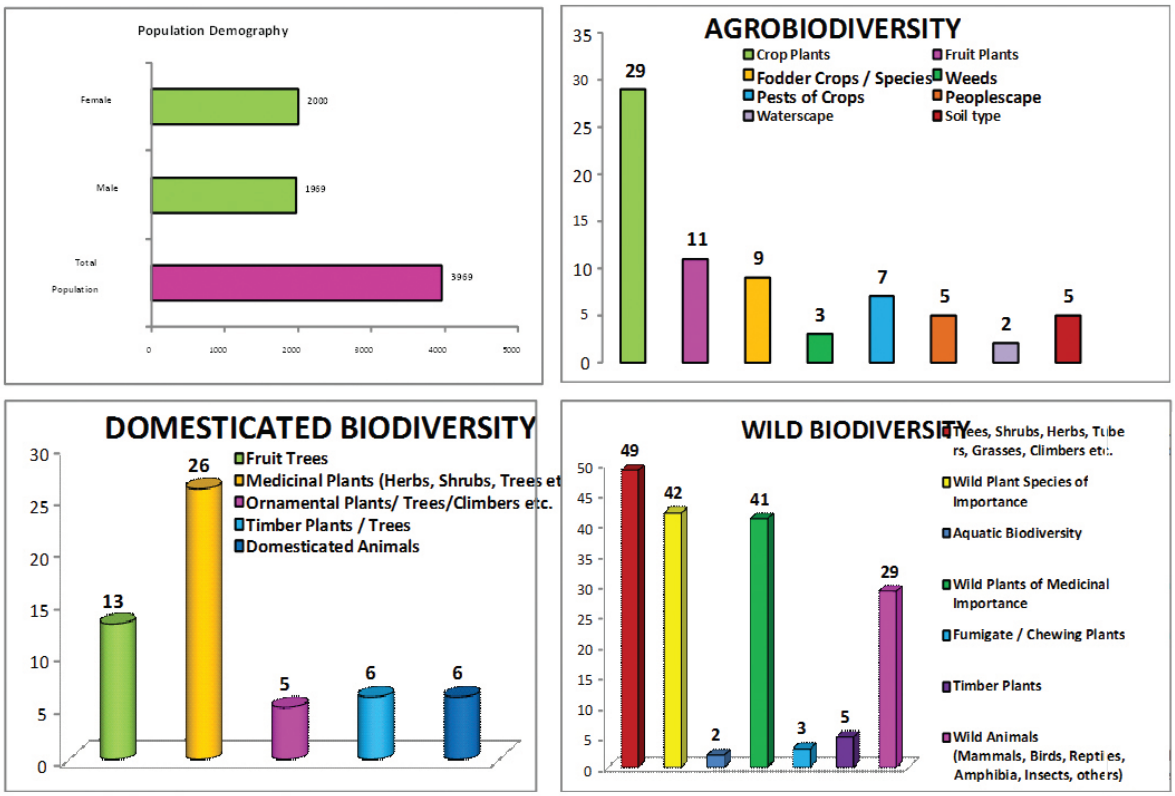


Fig 36. Population demography, agrobiodiversity, domesticated and wild biodiversity of Nathan Panchayat

The systematic cultivation of elite material as per industry API standards will, therefore, provide a sustainable system for large-scale cultivation of elite material of target medicinal herbs. In the present study, high value medicinal plants such as *Picrorhiza kurrooa, Nardostachys grandiflora, Rubia cordifolia* and *Swertia chirayita* have been selected for cultivation and conservation.

Objectives

- To identify elite planting material of *Rubia cordifolia* and *Nardostachys grandiflora* as per API standards of Ayurvedic industries and contents of desired chemical constituents in herbal extracts from different locations of Himachal Pradesh
- To establish Genetic Resource Center of elite material for target species, *Swertia chirayita, Rubia cordifolia, Picrorhiza kurrooa* and *Nardostachys grandiflora* at research stations of GBPIHED, HRC, Mohal - Kullu.
- To promote mass multiplication of elite planting material of *Swertia chirayita* and *Picrorhiza kurrooa*
- To optimize post-harvest primary processing of herbal raw material of *Swertia chirayita* and *Picrorhiza kurrooa*
- To organize training programmes for proper harvesting, drying, storage, and packaging of herbal plant material as per industry requirements
- To arrange buy-back mechanism and capacity building of primary growers to set up Marketing Federation
- To organize exposure visits of selected farmers to user industries and major markets

Achievements

1. Launch Meeting of DBT Project entitled “Identification of elite planting material of selected temperate medicinal herbs, mass multiplication, field demonstration and post-harvest processing” was organized by GBPIHED, Mohal - Kullu, Himachal Pradesh in collaboration with Bennet University, Noida and Emami Limited, Kolkata/ ZFHC on December 01, 2018 at Himachal Pradesh. The Launch Meeting was organized to finalize action plan along with listening concerns of high altitude farmers and medicinal plants traders. Total 20 participants including Advisor, DBT participated.
2. Procurement of seeds of *Swertia chirayita* and *Rubia cordifolia* was done. 10,000 seeds of *Rubia cordifolia* were shown at Mohal and Dohranala nurseries. Out of 10,000 seeds only 855 seeds germinated and survived. Collection of seeds of *Rubia cordifolia* (> 2000) from Shagad Nala, Dohranala and Tichi Nala was done.
3. Interaction with the farmers (20) of Solang village, Solang valley, Tosh village (03), Upper Parbati valley, Deori village, Sainj valley (14) and Bragran, Upper Beas valley for the sowing of seed of *Swertia chirayita* was done.

Environment Assessment and Management Framework of Sutlej Basin in Himachal Pradesh (HPFD, 2018)

In Himachal Pradesh, Himachal Pradesh Forest Department (HPFD) owns and manages the forest related issues. It is a unitary body and undertakes all functions of forest management, spanning from policy formulation and planning, to provision of forest goods and services, to monitoring and evaluation, to enforcement of rules and regulations. The Environmental Management Framework (EMF) is developed to incorporate environmental and social concerns into the main project planning, execution and operation. It will be applied to all the sub-projects in different stages of the project cycle. The framework has been developed considering three broad stages of project cycle viz., project preparation, project implementation and project operation. For each stage, potential adverse environmental and social issues have been identified and mitigation measures proposed that have been integrated with the EMF implementation process. al livelihoods. As per the provisions of the 14th Finance Commission, the HPFD secure financial resources for state development programs, while maintaining forest cover of the state. Timber, firewood, fodder, and other non-timber forest products (NTFP) produced by HPFD on public forests enhance local livelihoods. Similarly, HPFD ensure sediment retention and water regulation services to the benefit of the hydropower sector though catchment area management plans. The Department has also zoned 22.65% of the legally classified forest area as protected areas (5 national parks, 26 wildlife sanctuaries and 3 conservation reserves) to protect biodiversity and promote ecotourism in these areas. It also manages all the activities falling place in these areas.

Objectives

- To provide a systematic approach for identifying the various possible environmental impacts at the different stages of the project cycle
- To identify appropriate mitigation measures for addressing the identified environmental impacts
- To devise an institutional arrangement for mainstreaming environmental management in project implementation processes

Achievements

1. The main purpose of the Environment Management Framework (EMF) was to provide a transparent framework with clear liability for managing environment effects and risks associated with the operation phase of the project.
2. Surveys of 255 households in 13 Panchayats were conducted following structured questionnaire to generate baseline data and identify various environmental issues.
3. The major impacts of associated unscientific developmental interventions are road constructions, tunneling and associated blasting, mining on land, changes in landscape, land stability and soil loss.
4. Constructing large dams have enormous consequences for people's lives and livelihoods, which include controversial issues such as human displacement and resettlement.
5. To minimize and manage environmental and social impacts, the World Bank's Operational Policies (OPs) and Bank Procedures (BPs) are to be complied with as part of due diligence.
6. During the implementation of the project, strengthening of nurseries and selection of suitable species with community consultation in the project area will be undertaken. Approximately 2,00,000 additional seedlings in each of 19 nurseries (one per range) for subsequent planting in forest plantations will be done.
7. Strengthening and inclusive value chains for NTFPs and other commodities are to be done by community participation in sustainable land and water management by removing barriers to private investment in NTFP value chains and increasing local incomes from sustainable production and increased value addition.
8. For developing the environment management framework, different consultation (06) and disclosure meetings (02) with different stakeholders namely forest officers, NTFP collecters and sellers, Gram Pradhans and members from different panchayats, members of JFMCs, farmers and villagers, consultants, NGOs, research scholars and scientists were conducted in different locations of the study area.

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 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

1. At Mohal, $PM_{2.5}$ concentration was the highest 92.6 µg m^{-3} during November while lowest was 1.12 µg m^{-3} in December 2018. The average concentration of $PM_{2.5}$ from January 2018 to December 2018 was 36.2 ± 3.56 µg m^{-3}. The particles below 10 µ (PM_{10}) at Mohal were found to be with maximum concentration in December, while its minimum concentration was in August. Its mean concentration from January 2018 to December 2018 was 51.06 ± 3.47 µg m^{-3} at Mohal. PM_{10} at Mohal with maximum concentration was observed 95.2 µg m^{-3} in December 2018 while its lowest concentration was 1.3 µg m^{-3} in November 2018 (Fig. 37).

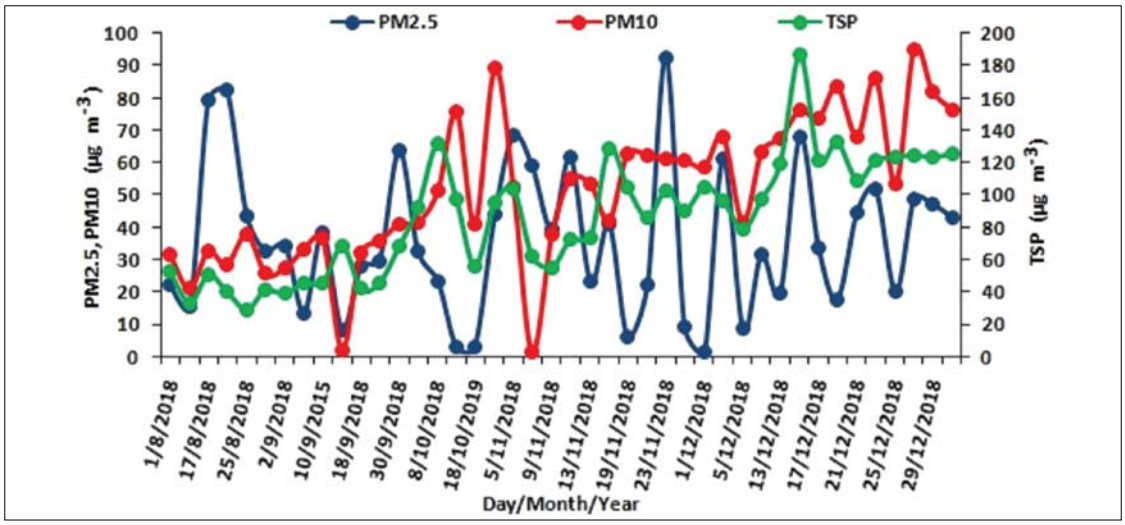


Fig 37. Diurnal concentration of PM_{10}, $PM_{2.5}$ and TSP from 1st August 2018 to 31st December 2018 at Mohal- Kullu

2. At Mohal, the daily maximum concentration of TSP from April 2018 to December 2018 was 186 µg m^{-3} on November 15, 2018, while the minimum concentration was 29.2 µg m^{-3} on September 25, 2018. The monthly mean concentration of TSP was 86.2 ± 5.54 µg m^{-3} during observation days. Gaseous pollutants like NO_2, SO_2 and NH_3 were observed to be 3.8 µg m^{-3} , 0.4 µg m^{-3} and 1.1 µg m^{-3}, respectively in 2018 (Fig.38).
3. To see the relationship between pollutants and meteorological parameters Karl Pearson's correlation analysis between pollutants and meteorological parameters (temperature, rainfall, RH and wind) showed that temperature had negative correlation with $PM_{2.5}$, PM_{10}, ammonia but positive correlation with TSP and SO_2. Rainfall is negatively correlated with $PM_{2.5}$, SO_2 and NO_2 but positively correlated with PM_{10}, TSP and NO_2. Humidity is negatively related with PM_{10}, TSP and SO_2 and positively related with $PM_{2.5}$ and NO_2.Wind has shown negative correlation with all the pollutants except SO_2.

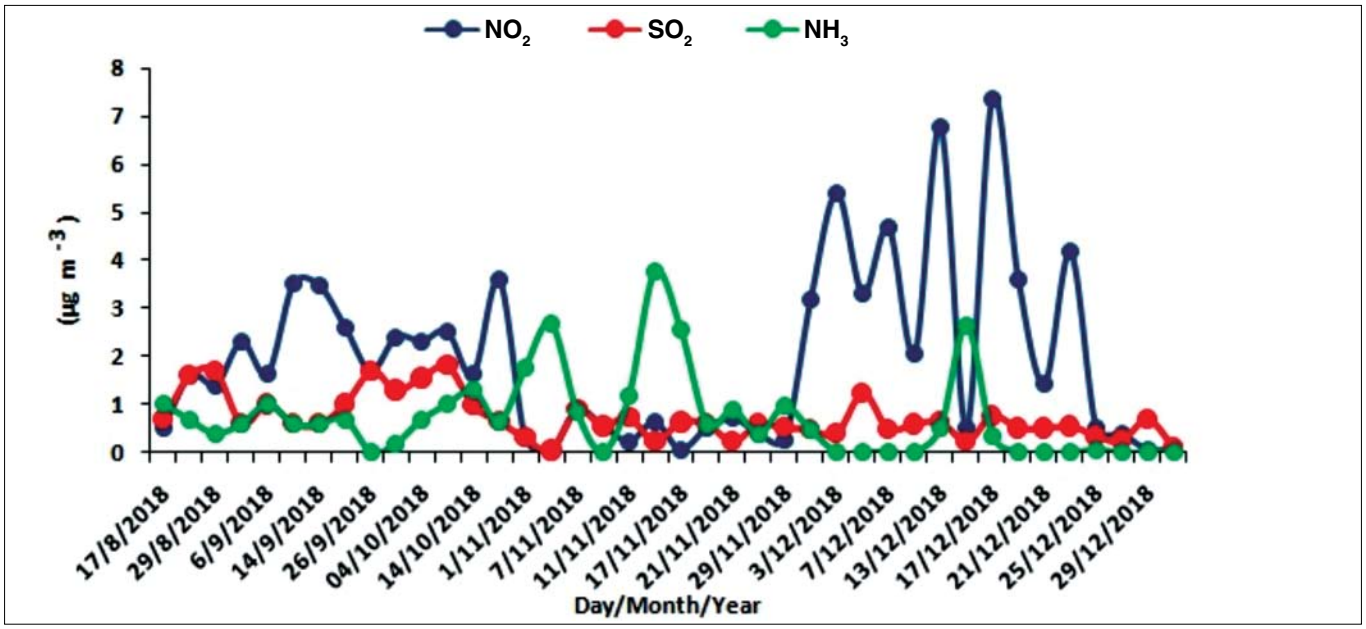


Fig 38. Diurnal concentration of PM_{10}, $PM_{2.5}$ and TSP from 1st August 2018 to 31st December 2018 at Mohal- Kullu

4. In 2016, apple production in Kullu was 1, 43,475 tons and in 2017, it was 89,570 tons. While, the mean annual temperature in Mohal and Kothi was 17.9 C° and 10.5 C° in 2016 and 16.8 and 10.3C° in 2017, respectively. The total rainfall during 2016 at Mohal and Kothi was 1050mm and 760mm, respectively. Whereas, in 2017 total rainfall was 890mm and 1050.4mm at Mohal and Kothi, respectively. To see the effect of temperature on apple production further long-term study is required.

Hydrological Monitoring and Modeling, Household Survey, Modeling and Statistical Applications and Implementation of Interventions to Strengthen the Institutional In-house project (NMHS Fellow Project, 2016-2019)

Indian Himalayan Region (IHR), being most diverse mountainous range in the world, rich in biodiversity water resources and providing distinctive ecosystem services to millions of people is also considered as one of the hot-spot in global warming phenomenon. Water demand and supply available is one of the most important topic of discussion at present. Increasing population, change in land use, industrialization, and climate change has drawn heavily on water resource system in the Indian Himalayan Region. At present, there is inadequacy in developing framework for sustainable mapping and management of mountain water resources using scientific solutions that supports the climate adaptations strategies and development of policies in IHR. This needs the new versatile assessment tools which will evaluate the water resource system and help managers to make a comprehensive water management plan. An effort in this direction is vital considering the importance of IHR regions, its vulnerability and massive dependent population/communities. This study presents the application of Water Evaluation and Planning (WEAP) model in Mohal khad watershed (area 54 km^2), in Kullu district of Himachal Pradesh. WEAP model is customized for Mohal Khad watershed using primary and secondary available/ generated datasets. The model is applied to evaluate and analyze the existing and future water balance and probable effects on the water demands and supply in the watershed. We generated the trends of water demand and supply as well as the scenarios for water resources management till year 2030. This numerical analysis demonstrate the ability of the simulation modeling of water resources when anthropogenic activities are superimposed over natural system and can able to develop relationship between climatic factors, land resources and water availability.

Objectives

- To explore immediate to medium to long term societal implications of changing hydrological and land resources of a central Himalayan watershed

Achievements

1. Input datasets for WEAP modeling were updated from primary and secondary sources and customized WEAP model was fine tuned for accuracy in simulation modeling of water demand & supply in Mohal Khad watershed. GCM output of GFDL ESM2M model with IPPC's scenario RCP 4.5 was used. WEAP model outputs were analyzed for temperature

variations and rainfall distribution over the land classes. Average maximum temperature of the Mohal khad watershed for 15 years (2015-2030) will be 18.71^{0}C with maximum temperature predicted to be 39 ^{0}C; whereas, predicted average minimum temperature will of about 8.11^{0}C with minimum temperature predicted to be -11^{0}C. Number of hot days will increase. The predicted average humidity will remain about 70% till year 2030 (Fig. 39). Predicted temperature variation will help in planning the agricultural activities for proper moisture management in the land which is the key for crop development.

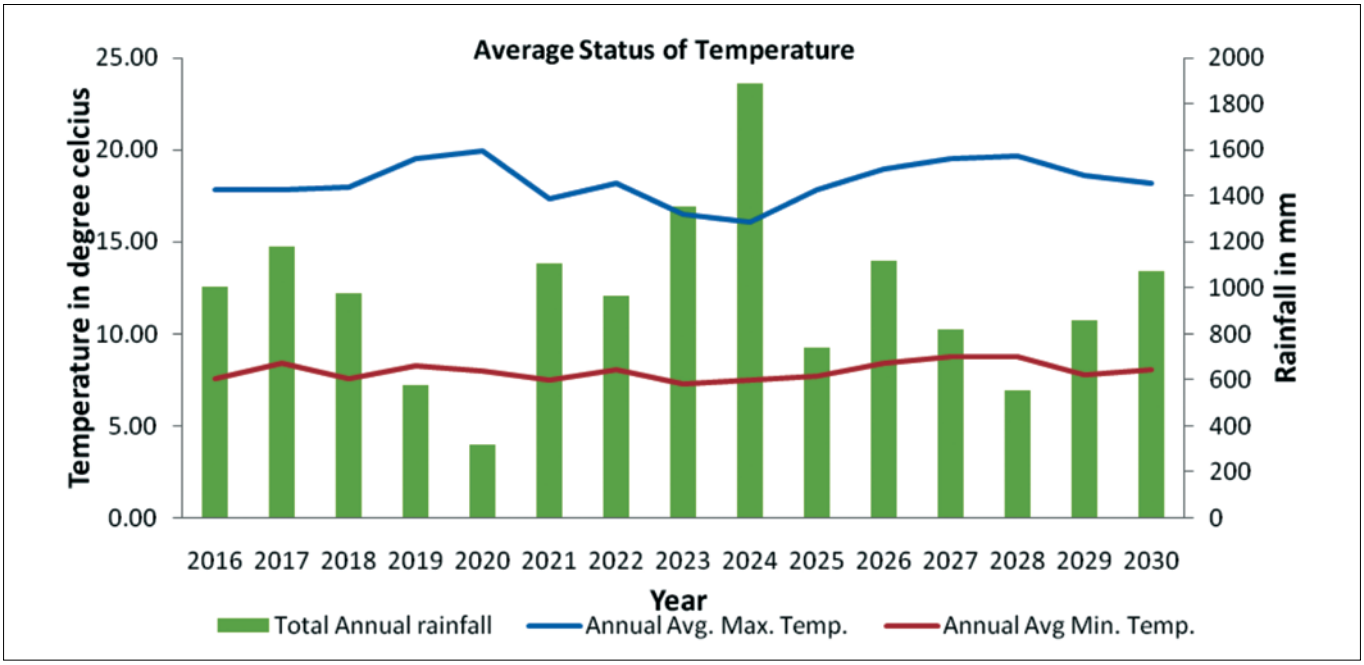
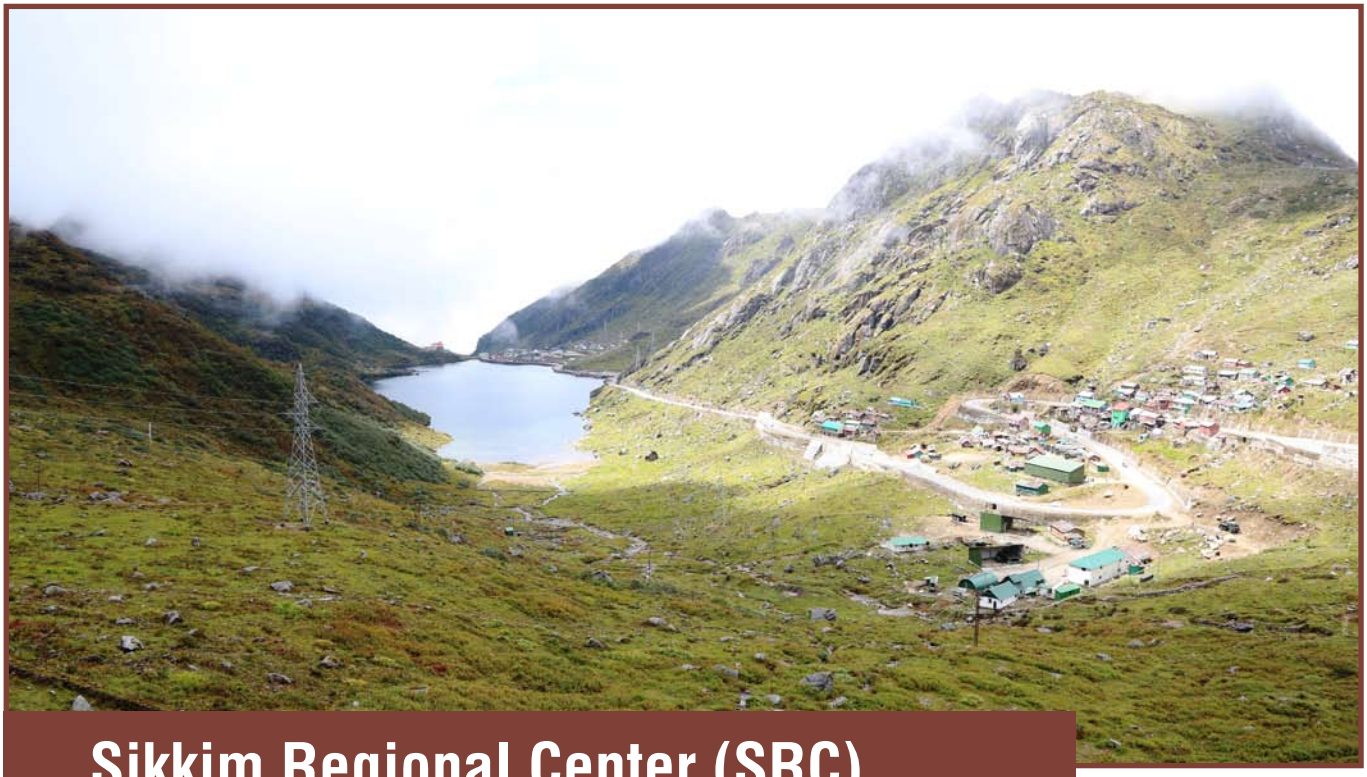


Fig 39. Predicted variation in average maximum and minimum temperature (2015 to 2030)

2. WEAP simulation in Mohal Khad watershed showed the possible predicted trade-off of rainfall distribution on different land use/land cover classes. Significant amount of rainfall falls in forest type of land use as compared to other land uses in monsoon and non-monsoon months was found. Dry and wet years - 2020 and 2024, respectively, showed lowest and highest share of rainfall distribution on corresponding land cover classes; and with-in-the year forest land is the greater shareholder of rainfall. Surface runoff shows lowest value in year 2020 being driest year among others and highest in year 2024 being wet year.
3. Water demands of population and livestock were calculated using standard of Bureau of Indian Standard. For Mohal Khad watershed, the unmet water demands are higher in non-monsoon months than in monsoon month as expected. However, our simulation couldn't able to establish the relationship in annual case with respective to projected rainfall, where annual unmet water demand of population and livestock shows constant values till 2030.
4. While in establishing relationship between future climatic factors and agriculture demands in Mohal khad watershed, we used standard crop coefficient (Kc) criteria for evapo-transpiration component of the different selected crops. Our analysis found that the unmet agriculture water demand is low in Kharif season than in Rabi season. This is because of the fact that in Kharif season, agriculture demands are mostly fulfilled by the rain water, whereas, in Rabi season, agriculture demands are mostly dependent on irrigation or groundwater or winter rainfall. The within-the-year relationship shows that the average unmet demand of agriculture is highest in May due to fact of predicted high temperature summer month and less or no rainfall and absence of any other water source to satisfy the demand.
5. The crop yield in Mohal khad watershed responded to the dry, wet and normal year conditions of the rainfall and shows the change in the yield in respective years accordingly. The analysis shows the scope of watershed management work in forested area. Through evidence of WEAP modeling outputs, it is suggested that water conservation work such as structural (construction of percolation pond, storage tanks, trenches, check dams, etc.) and non-structural (maintaining water quality, wise use of water, afforestation, etc.) interventions could be carried out in the watershed to capture the excess water in wet year in order to cater the water demands in dry year at all levels.



Sikkim Regional Center (SRC)

Sikkim state supports rich floral and faunal diversity varying in different eco-climatic ranges (300m to 8685m). There are high endemic and threatened species covering diverse ecosystems and habitats that represent the uniqueness of biodiversity. Local people are largely dependent on natural resources for their livelihood. However over-extraction and utilization of the natural resources demands immediate action to reverse the trend of degradation. Besides, there is need for strengthening participatory management, enhancement of livelihood and self sufficiency and policy review/analysis and capacity building. Major thrust area of Sikkim Regional Center is (i) biodiversity safeguarding at ecosystems, species and genetic level, including ecosystem services, (ii) natural resource use and sustainability, (iii) enhance implementation of strategies through participatory planning and policy analyses, and (iv) socio-economic improvement/extension and knowledge management through capacity building

Gridded biodiversity database for conservation and development in Sikkim Himalaya (focus: woody taxa) (Inhouse, 2017-2020)

Biological resources are viewed as 'resource capital' of a nation. Cataloging, mapping and geographical distribution of these natural resources are perhaps the most important information needed for any country in the post-CBD era. Documenting biological resources and construction of bio-resource maps reflecting the spatial distribution at an eco-regional level would serve several purposes, but such maps are rarely available. Thus, there is an urgent need for cataloging and mapping of natural plant resources datasets especially in globally hotspot area, for converting our bio-resources into economic wealth. Sikkim Himalaya represents the uniqueness of the bio-socio-climatic integrity symbolized along the elevational gradients, which offers a very high diversity of ethnobiological plants interlinked with traditional practices of the local community. Several mixed diversity enforcing to representative cultural paradigms are recognized, which are historically interlinked with the significance of the landscape. Nevertheless, such entity of the region is rapidly degrading and shrinking with the traditional practices and knowledge base losing ground under changing climatic regime. This invariably indicates an alarming signal for sustainability of biotic and abiotic assimilates vis-a-vis linkages being disturbed between natural and cultural entity. In addition, the region is a home of diverse and endemic assemblages of plants, reptiles, mammals, insects and amphibians. Broad representative vegetation types of this region were classified into tropical moist deciduous, subtropical broad-leaved forests, broad-leafed and conifer mixed forests, wet temperate forests, sub-alpine forests, and alpine meadows (moist and dry alpine scrubs). Despite the ecological, economical and cultural importance of this region, the ecosystems have been

subjected to a variety of assaults causing a high degree of threat to many plant and animal species. As our biological heritage fritters away, we find ourselves without a comprehensive conservation and management plan, and without an adequate institutional and policy framework to implement the plans. Lack of complete and consolidated information on plant resource is a major stumbling block in the whole process of conservation and utilization. Documenting the plant resource base is also imperative in the age of the intellectual property rights. Further, intensive data on Endemic, Rare, Endangered and Threatened plant species are specially required for drawing suitable management plans to conserve these species under the climate change phenomena. Earlier surveys have not specifically focused on uniform cataloging and spatial distribution of these species. With a view to accelerating the conservation and utilization of the natural plant resources, the aim of this study to assess and quantifying the geographic distribution, conservation status and phytogeographic aspects of plant resources of Sikkim Himalaya. The grid-based spatial inter-operable datasets will be the main outcome of this proposal. This will have important implications for the conservation, sustainable utilization and management of our plant resources.

Objectives

- Quantify the geographical distribution and status of natural plant resources (trees and shrubs)
- Identify the threats to plant diversity and its consequences on socio-ecological dimensions in Sikkim Himalaya
- Developing gird based spatial datasets of natural plant resources in Sikkim Himalaya

Achievements

1. The geographical area of Sikkim Himalaya was divided into small sampling grid. The sampling grids were generated using Survey of India (SOI) toposheet of 1: 50,000 scale. Each toposheet was divided into sixteen sampling grids wherein a sampling grid represents 6.25 km × 6.25 km geographical area (Fig. 40).

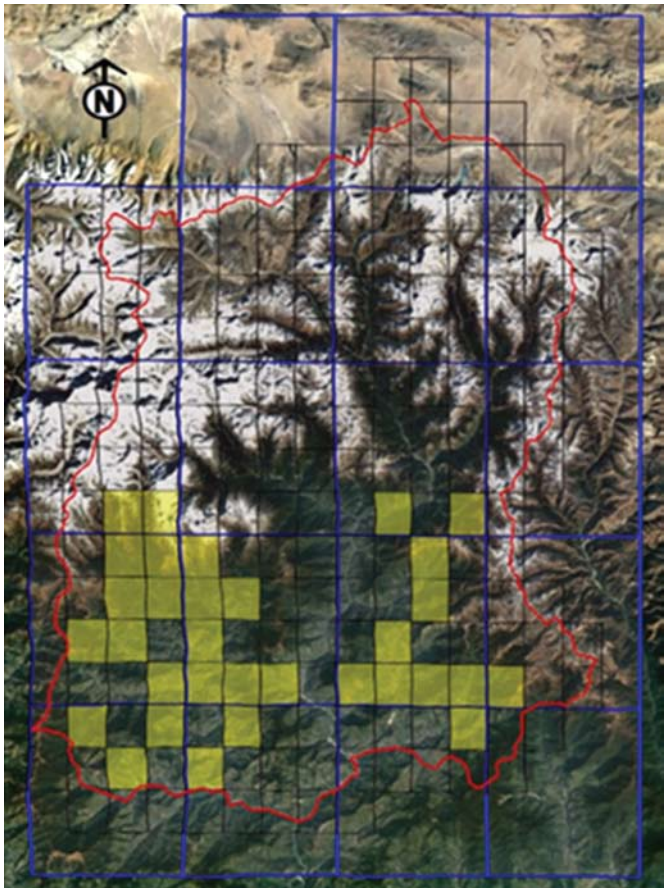


Fig 40. Map of study area showing grid-based design with completed sampling girds (yellow in color) of Sikkim Himalaya.

2. Thirty two sampling grids have been sampled covering moist-deciduous forests, oak-mixed forests, sub-tropical evergreen forests, *Abies* dominated forests, *Rhododendron* mixed forests, sal dominated, and sal mixed forests of Sikkim Himalayan region ranging elevation 800 m to 3800m asl. The specimens of all species were identified by consulting herbaria. The sampled transects contained 23,256 individuals of about 198 woody species, where 124 species identified using regional flora and e-flora.

3. A cover page of database information of each sampled grid has been designed for generation of spatial interoperable database. All information of each transects such as number of species, fauna, disturbance, etc., is hyperlink with the cover page. For generating distribution map using ecological niche modeling, various information and datasets downloaded from free web resources viz., Worldclim, MODIS, NDVI etc. Further, compilation of secondary information from published literature and herbarium records for each sampling grids is under process. Till date approximately 450 number of distribution records of different woody taxa were compiled for different spatial grids.
4. A 10 days (80 hrs) Green Skill Building Programme (GSBP) on "Vegetation Assessment and Livelihood Improvement for Biodiversity Conservation" was organized from 7 to 18 March 2019 which includes hands on training from and field orientation training in Lingdem, Dzongu, North Sikkim. The objectives of this workshop were; i) to generate awareness and build capacity of diverse stakeholders on biodiversity conservation, vegetation assessment, long term database management using modern tool and techniques, ii) to provide hands-on training on Herbarium techniques and Ecological Niche Modeling using RS & GIS techniques, and iii) to build capacity of unprivileged youths/ local peoples for biodiversity monitoring and livelihood improvement. A total of 18 participants (research scholars, project staffs, M.Sc. students and unprivileged youths) from different organizations attended the training.
5. Events of SBM were organized in the five villages; Pangthang Naya Basti, Samdung, Dhanbari, Asam-Lingzey and Ranka of east district of Sikkim. A total of 608 participants comprising of students and teachers of various schools and Panchayat members, Non Government Organization staff and villagers participated in the events. Participants were imparted training on segregation of waste into biodegradable and non- biodegradable category, proper disposal of the waste, cleanliness of the surrounding environment. Dustbins were also distributed to the schools, community representatives, and NGOs for promotion of cleanliness drive.

Khangchendzonga Landscape Conservation and Development Initiative KLCDI-India: Implementation phase (ICIMOD, 2017-2021)

Khangchendzonga Landscape (KL) emerged as one of the potential areas for addressing biodiversity conservation and development and advocating benefits of the transboundary approach. Here, three countries, viz. Bhutan, India and Nepal signatories of Convention on Biological Diversity (CBD), came up to share the transboundary problems and looking jointly for a unique cooperation initiative. Earlier, over the past many decades, several efforts on the conservation of KL, was successfully resulted in the establishment of many protected areas (PAs). The KL located at the southern stretch of Mount Khangchendzonga, the third highest mountain in the world, is a part of a global biodiversity hotspot, representing unique biodiversity, bio-cultural and geo-climatic assemblage. It is one of the six transboundary landscapes identified by International Centre for Integrated Mountain Development (ICIMOD) in the Hindu Kush Himalayas. The KL covers a total area of 25,085.8 km^2, shared by India (56%), Bhutan (23%), and Nepal (21%), offering life support systems to over 7.25 million people (87% in India, 11% in Nepal and 2% in Bhutan). KL-India covers a total area of 14,061.7 km2 along the altitudinal gradient (40 m to 8586 m asl), comprising the state of Sikkim, and the northern part of West Bengal (four districts, viz. Alipurduar, Darjeeling, Jalpaiguri, and Kalimpong). KL India is located along 26°29'13.56" to 28°7'51.6" latitudes and 87°59'1.32" to 89°53'42.96" longitudes and provides varied ecosystem and ecosystem services for sustenance and well-being of people. Applying multi-phases process, a preparatory phase was initiated by developing Regional Cooperation Framework (RCF) and to prepare the supporting documents like Feasibility Assessment Report (FAR), Conservation and Development Strategy (CDS), and Implementation Plan (for 20 years) of the KL-India. In continuation, an intermediary phase was successfully completed with: i) Baseline information for the socio-economic and ecosystem status, and ii) Participatory Bioresource Management Plans for the three identified pilot sites of KL-India. Now, an execution of implementation phase of KLCDI programme in India has been initiated in time bound manner.

Objectives

- To enhance well-being of women, men and children in the landscape
- To improve ecosystem management and conservation through inclusive and equitable benefit sharing of natural resources, community-based approaches, and economic valuation and incentive mechanisms
- To strengthen local and national level mechanisms for evidence-based decision-making through long-term environmental and socio-ecological monitoring, and
- To strengthen regional cooperation for transboundary landscape management in the Khangchendzonga Landscape

Achievements

1. KLCDI-India provided opportunity to benefit the households (165 HHs) as beneficiaries and train local people (471 Nos.) through skill development and training programme under the promotion of livelihood diversification and economic development in different components in KL-India (Fig 41).
2. Songing Nature and Culture Fest-2019 was organized in Lingdem (Lingthem-Lingdem GPU), Dzongu site for promoting ecotourism and traditional practices in KL–India.
3. In Dzongu, documentation of various bioresources used by the Lepcha Priest (Mun/Bungthing) was carried out where, information on ethnic Lepcha food habits, wild edible fruits and their knowledge on bamboo crafts were compiled.
4. One Long-Term Environment and socio-ecological monitoring (LTESM) site (1ha) has been established near the Laven village forest area and analysed baseline information.
5. Community based mushroom cultivation chamber was developed as an adoptive measure towards human elephant interface and an alternative livelihood for local communities in Bandapani site.
6. Solid waste management programme was synergized with the national level cleanliness drive programme i.e., Swachh Bharat Abhiyan, promoting and monitoring the Gorkhey village as cleanest village.
7. Organized an interaction with highland community on Yak conservation and livelihood at Lachen and Lachung region of KL-India.

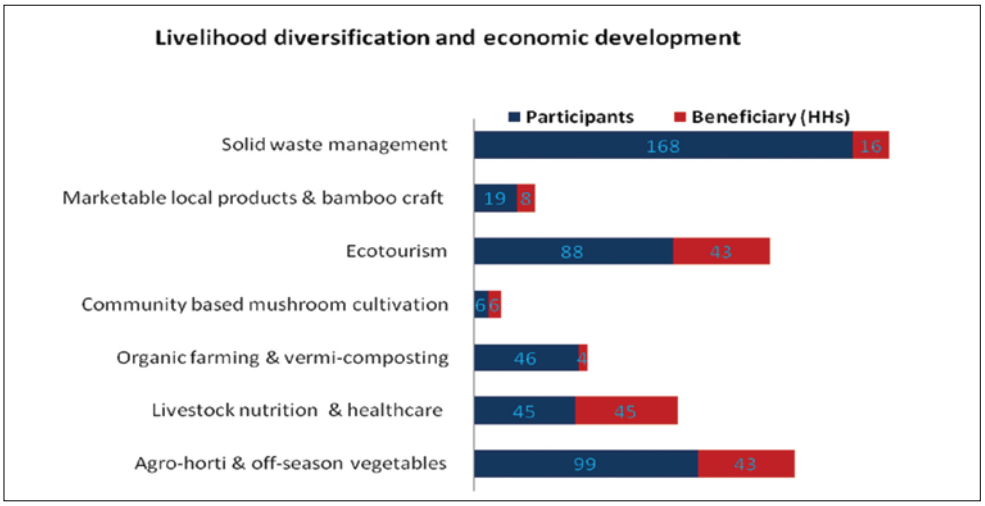


Fig 41. Livelihood diversification and economic development activities in KL India

Promotion of Sustainable Community Based Tourism in the Khangchendzonga Landscape: Linking Livelihoods with Nature Conservation (NMHS, MoEF&CC, 2018-2021)

Tourism development in the Indian Himalayan Region (IHR) has experienced continuous growth. The current trend of tourism development in the IHR forecasts that 25 million tourists are expected to visit by 2025. It underlines significant information such as; (i) IHR has plethora of rich natural and cultural heritages to attract global tourist at large (ii) tourism promotion and development in IHR can diversify local economy through employment opportunities and by engaging locals in income generated activities (iii) large scale tourism promotion and development in IHR has potential threat to the natural and cultural heritages. Therefore, to bring tourism into the main stream development agenda must focuses and go in parallel with the destination and region specific opportunities and challenges. Further, to introduce sustainability into the discourse of tourism development in IHR invites different forms of tourism those can intervene in areas such as; equity, efficiency, innovations and carrying capacity. In this context sustainable community based tourism promotion and development is one of the appropriate forms of tourism much on global debate in recent years. To bring the discourse into the Khangchendzonga Landscape (KL) of IHR which covers 14,061.7 Km^2 area stretching along the elevation gradients from 40 m representing foot hills to 8,586 m asl of Mt Khangchendzonga in Sikkim. The Indian part of KL harbours 17 protected areas, including recently inscribed, in July 2016, UNESCO World Heritage Site, the Khangchendzonga National Park in Sikkim. As a major attraction, the KL India has a wide range of rangelands and alpine-pastures and trans-Himalayan region. Besides, low lands and temperate zones offer one of the richest biodiversity elements of the world and tremendous ethnic diversity and culture. In a whole, it sets a suitable platform to introduce community based tourism in the landscape as an apt fit to generate employment, income and conserve local cultural and natural heritages. This project, therefore, focuses on promotion of sustainable community based tourism in the KL through linking livelihoods with nature conservation.

Objectives

- Assessment and promotion of community-based ecotourism with equitable benefit sharing;
- Strengthening community based tourism by integrating traditional knowledge;
- Promotion of sustainable tourism through integration of (i) Livestock and horticulture, (ii) handicraft products and iii) knowledge management of water resources;
- Build critical mass of informed and skilled youth for harnessing tourism potential and working for conservation of nature through sensitization and capacity building.

Achievements

1. Surveys were conducted to collect the baseline data on geophysical setups of pilot sites, socioeconomic background, cultural background, tourism support infrastructure and destination based indicators through preliminary survey in pilot sites of Barsey-Singalila (i.e. Okhrey, Ribdhi, Hillay (Sikkim), Gorkehey and Samanden (West Bengal), Dzongu (Lingthem, Lindem and Tingvong) and Bandapani (West Bengal) (Fig. 42).
2. Entry level community consultations in all the three pilot sites were organized. A total of 121 community members participated in the initial 6 consultations and discussions held on level of understanding, interest and the challenges towards CBT.
3. Three local indigenous product based stall were opened to showcase traditional products of all the three pilot sites. A total of nine craftsmen were presented on the occasion and showcased their products at M.G., Marg, Gangtok. These products include nettle bags, handmade scarf, traditional Lepcha bags, dresses, bamboo crafts etc.
4. Two best practice based campaigns were organized at Bandapani pilot site and Dzongu pilot site. At Bandapani pilot site a cleanliness drive was organized with the active participation of the students of Garochira Primary and Betty's English School, where 55 students participated in the campaign. At the Dzongu pilot site responsible tourism practices through photographs were demonstrated during the Songbing Tourism festival
5. A five-days Green Skill Development Programme (GSDP) was organized on Eco-Guide in the Khangchendzonga Landscape from 27th-31st January, 2019. The programme primarily targeted underprivileged youths from the Khangchendzonga Landscape pilot sites (Dzongu, Barsey-Singalila and Bandapani).

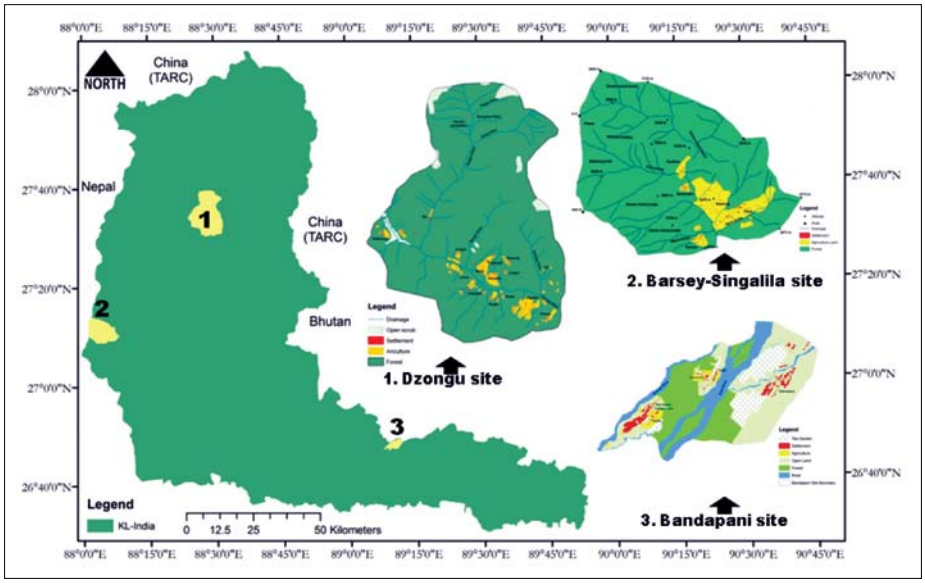


Fig 42. Map of the three pilot sites in KL India.

Developing Disaster Resilience Action Plan through GIS and prioritizing actions for Natural Disaster Risk Reduction in Urban Agglomerations of Shillong and Gangtok (NMHS, MoEF&CC, 2017-2019)

India has experienced exponential urban growth in the last few decades. Urbanization exerts environmental stress (including air and water pollution, deforestation, construction activities) which also increases the risk of frequency of natural disasters like food, landslides, water scarcity, etc. Further, urbanization enhances the risk of hazards as well as vulnerability of the urban population. Therefore, there is need for systematic review to collect evidence relating to impact of urbanization on

disaster risk and vulnerability to natural disasters in the Indian Himalayan Region. North-East India is more vulnerable to natural and man-made disasters because of its location in the eastern Himalayan periphery, fragile geo-environmental setting and economic underdevelopment. A high degree of vulnerability to these disasters will increasingly make the region environmentally insecure in the future unless pragmatic interventions are made. In Sikkim Himalayas, landslides, mass movement and cloud burst are common phenomenon due to its high relief and high monsoon. Sikkim falls under the Zone IV of the seismic zonation map of India. Gangtok, the capitol of Sikkim, is presently undergo disproportionate urbanization because of the fast-growing population and tourist influx. This project focuses on study of two cities (Shillong and Gangtok) with a view to develop their disaster resilience plans by high lightening exposure to potential risk and hazards using Geographical Information System (GIS). Under this project, GBPIHED, SRC has entrusted the task to conduct socio-economic survey in both the cities to identify the factors and collect base line information for developing disaster resilience plans.

Objectives

- To develop cadastral maps for scale of 1:4000 and map the hazard/disaster wise vulnerable zones of the Shillong and Gangtok urban agglomerations.
- To identify and map critical infrastructure at risk through ground surveys – telecommunication, emergency operation centres, shelter, slums, hospitals, schools etc. on cadastral maps of 1:4000.
- To develop a disaster resilience action plan for the identified cities and prioritise actions for disaster risk reduction through multi-stakeholder consultations involving citizens, government, public and private sector.
- To spread awareness and capacity building of citizens, city, district and state authorities on disaster resilience of the North East region cities.

Achievements

1. Survey for collection of socio-economic data has been completed in the Gangtok municipal area through a structured questionnaire which covered information related to climate change over the past 2 decades, frequency of occurrence of hazards, variation in the temperature during summer and winter, variation in rainfall during monsoon and winter rain, status of water resources and its quality, air quality, solid waste management, public involvement in the natural resource conservation practices, awareness among the locals before, during and after the disaster and early warning system for disasters. The coordinates and representative photographs of every site visited are taken during the field survey (Fig.43).
2. Analysis of survey revealed that 80% of people have experienced climate change, the main reason behind the climate change are deforestation followed by urbanization, climate change and industrialization.
3. There are more variations in the summer and winter temperature than 20 years ago. Among the participants, 60% of people have observed increase in summer temperature while ~48% of people experienced increase winter temperature.
4. Analysis of people perception results showed that not much of change has been observed in monsoon rainfall, (55% response) and the winter rainfall (81% of response).
5. Survey results showed that parts of ward 3 (Lower Sichey I) & ward 4 (Lower Sichey II) erosion and landslide are active mainly due to urbanization. Earthquake, landslide, erosion and hailstorm were found as main reason for natural hazards in Gangtok Municipal Corporation area.
6. In the ward 6 (Chandmari) Sinking Zone has observed whereas in wards No. 10 (Lower MG Marg) and 17 (Tathangchen) some areas are vulnerable to landslide from a longer period and is still active in the recent past due to the impact of rapid Urbanization and heavy rainfall.

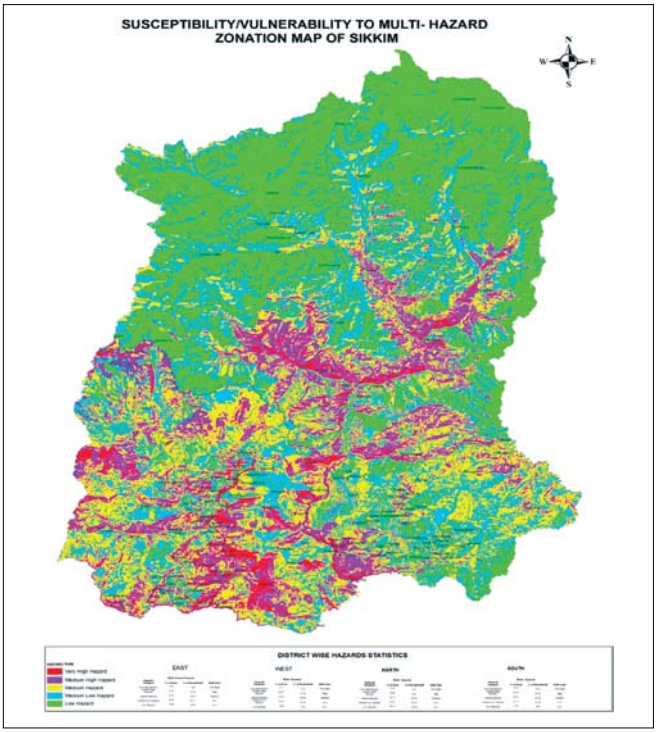


Fig 43. Multihazard zonation map of the Sikkim

Quantifying Population and Distribution of Selected High Value Medicinal Plants of Sikkim Himalaya (NMHS Fellowship MoEF&CC, Govt. of India, 2016-2019)

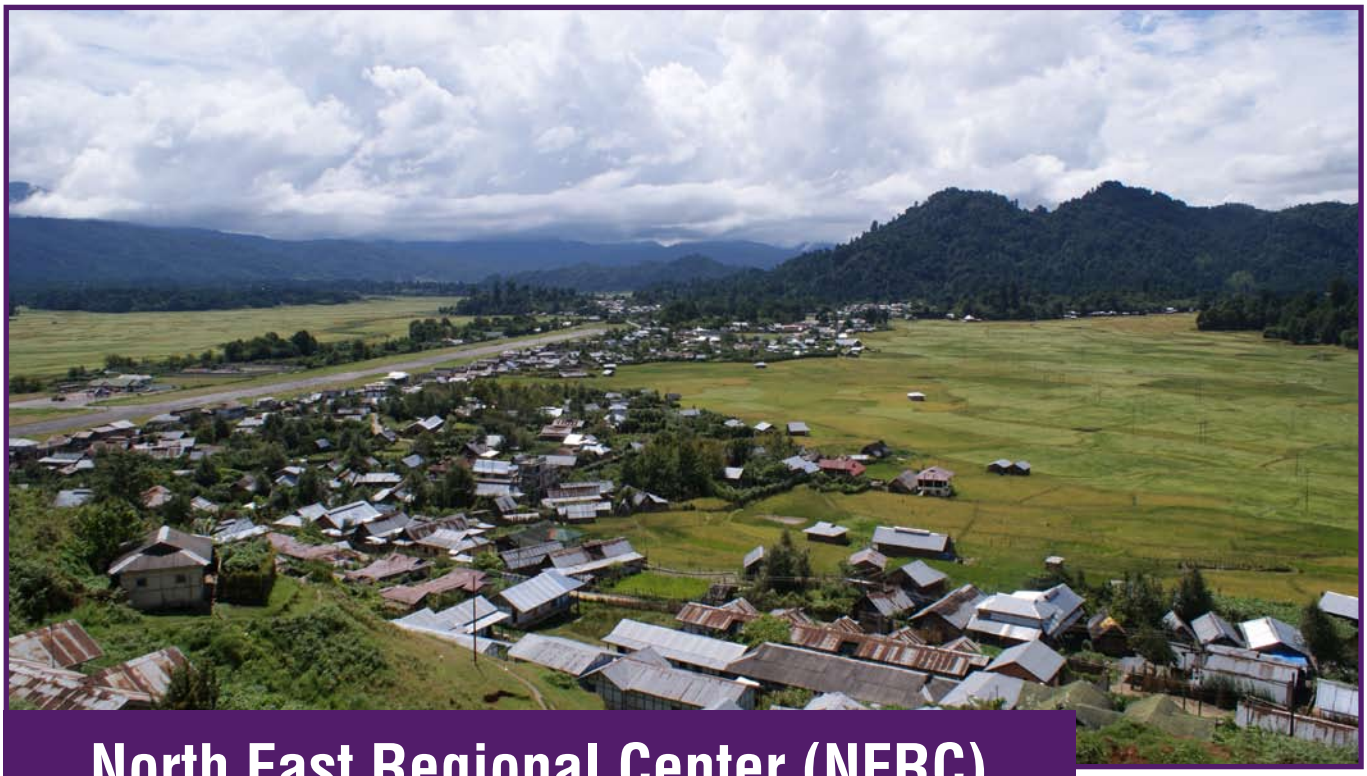
Indian Himalayan Region (IHR) , a home of ~50% of the total medicinal plants (MPs) available in the country, bounds between 26°20'-35°50'N and 74°50'- 95°40'E. Among the different geographical zones of IHR, Sikkim falls in the Eastern Himalayan region and consists parts of Siwalik, lesser and great Himalayan ranges and covering only 0.2% geographical area of the country. It is most biologically diverse Himalayan state in India, harbors of more than 4500 flowering plants, 550 Orchids, 36 Rhododendrons, 16 Conifers, 28 Bamboos, 362 Ferns and its allies, 9 Tree ferns, 30 Primulas and 11 Oaks. This rich biodiversity is well connected with rich cultural integrity of indigenous community like Lepcha, Bhutia, Limboo and Nepali for their traditional medicinal practices. Consequently, they are highly dependent on natural forests. Due to unscientific over exploitation, invasion of alien plant species, and global climate change; a number of plant species are under stress. However, the information on MPs of Sikkim is fragmented and not yet documented properly especially endemic, threatened and high value MPs. Therefore, it is essential to have proper documentation/information of MPs and its bio-cultural linkages. Keeping these facts is in mind, the National Mission on Himalayan Studies (NMHS) programme was launched by MoEF&CC, with focus on IHR and its mountain communities. Among the several components of NMHS, fellowship programme for Sikkim Himalaya is targeted to document endemic, threatened and high-value MPs of Sikkim and evaluate the status with respect to climate change scenario.

Objectives

- To survey and document endemic, threatened and medicinal plants of Sikkim Himalaya
- To analyze and map their distribution pattern.
- To evaluate the status of endemism, threatened categories and conservation status.
- To analyze the impact on climate change in relation to endemic, threatened and high value medicinal plants.
- To build awareness and provide training to local people and relevant stakeholders on identification/ importance of these plant species.
- To evaluate the potential marketing linkages, sources and valuation of high value medicinal plants.

Achievements

1. Total 559 MPs were documented in 148 families along with different parameters like, family, altitude, habit, habitats, part used, uses and conservation status through secondary data and Asteraceae family represented highest number of MPs (44 Nos.).
2. Out of 559 MPs, 64 MPs were represented the threatened categories as per IUCN Red list in which 76% MPs recorded under least concern, likewise 8% endangered, Vulnerable, 2% Critically endangered, and 1 % Extinct in the wild. Among these, 16 endemic and 31 high value MPs are found in Sikkim Himalaya. Under the documented MPs, herbs are 51% followed by trees 22%, shrubs 19% climbers 7% and fern 1%.
3. Household study was undertaken in East Sikkim to collect information about the ethno-medicinal practices and validation of MPs by Bhutia tribes. The survey shows that the younger generation of the communities is losing interest on indigenous medicinal practices due to modern system of treatment. Therefore, it is necessary to take major steps to preserve the traditional knowledge of primary treatment in community.



North East Regional Center (NERC)

Strengthening of alternative and innovative livelihood options, conserving indigenous knowledge system, capacity building and human resource development are key areas where North East Regional Centre is focussing. The regional center is working on (i) sustainable socio-economic development and livelihood security (focus on shifting cultivation), (ii) conservation of biological diversity and ecological security, (iii) adaptation/mitigation of climate change (CC) impacts, (iv) ecotourism, and (v) sustainable technologies and capacity building. Shortening of fallow cycle & changed practices of Jhum is resulting in changes in land use pattern, land tenure and ownership pattern, and customary laws. Lack of appropriate policy packages and technological intervention for soil conservation, soil nutrient management and yield enhancement; loss of agro-diversity & promotion of mono-cropping, improper policies, lack of marketing, depletion of traditional knowledge base and policy deficiency in promotion of alternative & innovative livelihoods are the biggest constraints for the North East region. Similarly inventorization of biodiversity, sacred groves, community conserved areas, village forests, hotspots and keystone species needs ti be addressed for biodiversity conservation. Alternative employment opportunities based on biodiversity based tourism needs to be explored.

Enhancing Eco-cultural Livelihoods in Biodiversity Rich Areas of Arunachal Himalaya (In-house 2017-2020)

The State of Arunachal Pradesh, which forms a major portion of the eastern Himalayas in north-eastern India, is well-known for its rich biological as well as cultural diversity. The indigenous communities living in the biodiversity rich areas of the state are primarily dependent on subsistence agriculture and forest resources for their sustenance with limited livelihood options. The total dependency of local communities on forest resources has been one of the causes of biodiversity loss. Therefore, management of resources and ecosystem services is desired to address the conservation and sustainable utilization of natural resources. This project aims to explore alternative livelihood options for the local communities in order to reduce natural resource dependency and conserve biodiversity. Development of eco-cultural tourism sector, agro-diversity products, strengthening access and benefit sharing through Biodiversity Management Committees (BMCs) and PBRs at village level as well as policy interventions will be the main focus of the project.

Objectives

- To augment multidisciplinary research and knowledge base on ecosystems, cultural diversity and socioeconomic status of the region including understanding on drivers of change.

- To promote biodiversity conservation, natural resource management and community development through direct efforts and capacity building.
- To address poverty and climate change threat through alternative livelihood options, capacity development and good practices.
- To strengthen policy environment through national and state policy analysis and develop village level cooperation framework and mainstreaming in the national conservation and development agenda.

Achievements

1. Baseline data on the livelihood of different households of Ziro valley were collected. Results revealed that among 70 households survey of 7 villages in Ziro valley, 43 of kuccha, 25 sp-type and 2 pukka house types were observed and a total of 123 farms (both dry and wet farms) were recorded. Records were also made on the uses of LPG and firewood for cooking purposes. It has also been recorded that most of the inhabitants of Ziro, used to trade crops for their livelihood. Trading crops includes Rice, Maize, Millets and vegetables. Forest resources like timber, bamboo and canes were also used by some inhabitants in trading for their livelihood purposes.
2. While considering ecotourism as a source of livelihood, it was found that Arunachal Pradesh has showed rapid growth of tourist since 1999. In 1999 total tourist arrival in the State was only 2178 which increased to 1,86,168 in 2014, showing a compound annual growth rate (CAGR) of 34.52%. Domestic tourists account for more than 97% share in total tourist arrivals in the state. The relatively low share of foreign tourist in the state can be attributed to its remote location, lack of infrastructure and entry restrictions (as foreign tourists need protected area permit to visit the state). In the study sites, the growth rate of tourist inflow was found to show a increasing trend (Fig. 44).

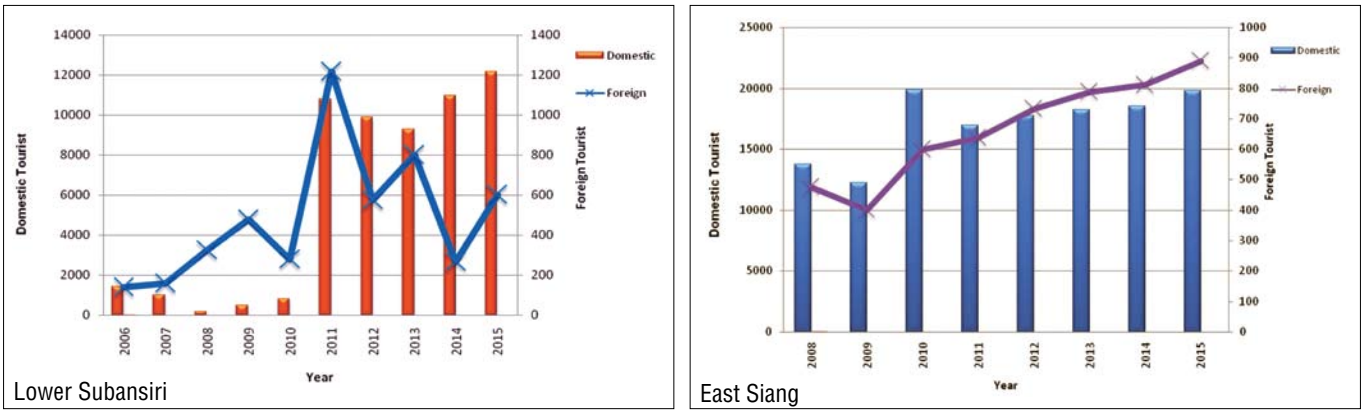


Fig 44. Trend in total tourist arrivals in study sites

3. Strengths, Weakness, Opportunities and Threats (SWOT) analysis has been done for ecotourism in Arunachal Pradesh, which sowed ample opportunities of rural and eco-tourism like Homestays facilities (24 registered homestay), Bird Watching spots (>300 species), Butterfly habitats (>200 species), Ziro Festival of Music, Panyor River Festival, etc. Potential toursit destination at Lower Subansiri district could be Shiva Lingam at Kardo Forest, Tarin Fish Farm, Talle Valley Wild Life Sanctuary, Orchids Farm, Ziro Putu, Kile Pakho, Tahi Lampw, Ranganadi Hydel Project and in East Siang district Daying Ering could be Memorial WLS, Sirki Waterfall, Dangoria Baba, Mandir, Donyi Polo Gangging, Ellam textile industry, Bodak angling centre, Raneghat, Komlighat and Pongging hanging bridge
4. In East Siang District socio-economic status and livelihood information were recorded from 4 villages of Mebo circle namely, Silluk, Ngopok, Kiyit and Borguli, which showed that 61.6% houses are good, 36.9% are livable and 1.4% are dilaidated.
5. Agricultural practices and Agro diversity of Ziro valley and East Siang district was docuented. Forest conservation and settled agriculture practice are inherent in the culture of Apatani Community, while shifting cultivation, locally known as Jhum, was the main agricultural practice but now shifted towards settled cultivation and farmers are converting their Jhum lands to horticultural and cash crop plantations like orange, banana, pineapple and large cardamom. A small section of farmers still practice Jhum cultivation only for cultivating vegetable mainly for household consumption while paddy is only cultivated in terrace fields.

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 (DST-SERB, 2016-2019)

The high altitude wetlands (HAWs) are an important category of natural wetlands found mainly in the higher elevations (above 3000 m asl) in the Himalayan region. They are extreme ecosystems, characterized by adverse climate and presence of a seasonal or diurnal permafrost layer. 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 the remoteness, harsh climatic condition and inaccessibility of the terrain of the region. Therefore, comprehensive information is urgently required for developing and implementing plans for conservation and sustainable management of these unique ecosystems. 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 unavailable for the Eastern Himalayan region so far. Therefore, an urgent need has been felt 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 & land cover of high altitude wetland region of Eastern Himalaya.

Objectives

- To assess the baseline status, both qualitative and quantitative, of floristic diversity in the selected high altitude wetlands (HAWs) area. To study the status of rare, endangered, threatened & 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. 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. Mapping the potential distribution of Rhododendron anthopogon using ecological niche modelling approach was done. The maxent modelling predicted potential distribution of Rhododendron anthopogon in southern, northern and western parts of the Tawang district and revealed that 11.77% area is medium suitable, 5.69% is high and 0.96% is very high suitable for the R. anthopogon plantation. However, 68.57% area did not find suitable for the species (Fig. 45). Potential distribution map shows various possibilities for conservation and management of this valuable plant species.
2. A total 281 flowering plant species belonging to 136 genera and 69 families recorded from high altitude wetlands areas of Tawang district. Of these, 9 spp. were trees, 41 shrubs and 231 were herbs and climber. Family Asteraceae (40 spp.) showed the maximum species followed by Ericaceae (23 spp.), Gentianaceae (20 spp.), Rosaceae (19 spp.), Polygonaceae (17 spp.), Primulaceae (15 spp.). The genus Rhododendron (17 spp.) represented with maximum species followed by *Primula* (14 spp.), *Gentiana* (9 spp.) and *Potentilla* (8 spp.), *Swertia*, *Saussurea* (6 spp. each).
3. Ethnobotanical uses of Rhododendron species that the species is mainly used as fuelwood (55%) followed by juice (11%), medicinal (10%), religious purpose (8%), wood handicraft (8%), packaging (2%) and insect repellents (2%) by Monpa community living in the high altitude ares of Tawang . Dried Leaves of Rhododendron anthopogon are crushed and mixed with ghee for making incense that are used in the Buddhist monasteries (Gompa), local houses and ritual functions. Concentrated liquid extracts obtained from distillation of leaves of *R. edgeworthii* is applied on skin diseases by Monpa tribe. *R. arboreum* is used for making juice at Sakpret village, Tawang district. Leaves of R. dalhousiae are used for insect repellent. The dense tomentum on the undersides of leaves of *R. fulgens* is scrapped and used as wick for lighting fires by Monpas.
4. Assessment of various anthropogenic threats and pressure on floral diversity of study area showed that the collection of fire wood by herders, pilgrim, unregulated grazing, tourism, infrastructure development and NTFP collection were

the major threats in Nagula wetland complex. Whereas collection of wood of Rhododendron for firewood by pilgrims and collection of NTFP product were observed very high at Bhagajang wetland complex.

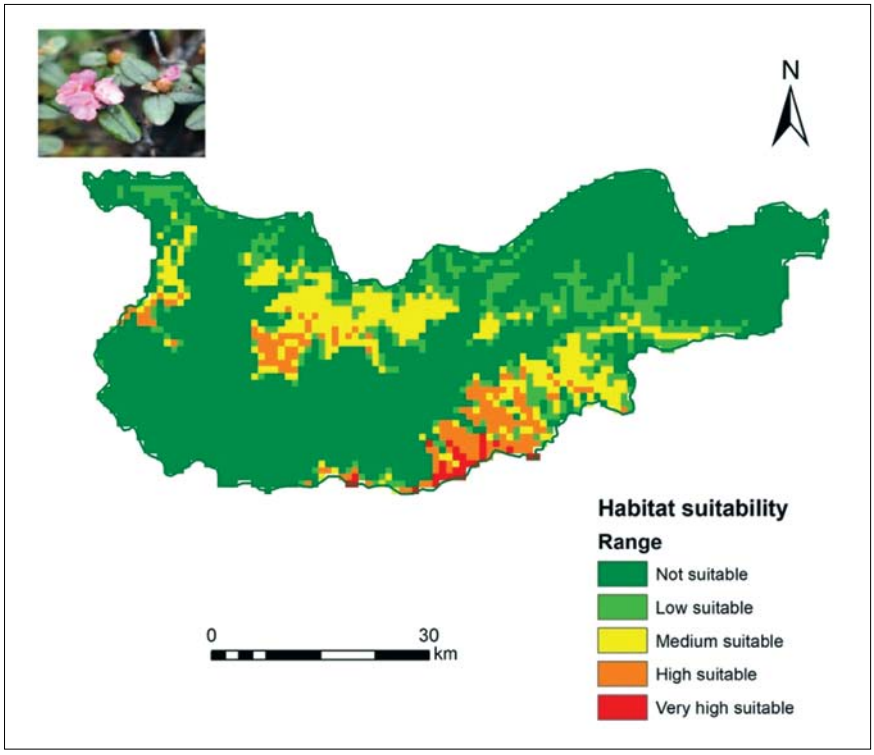


Fig 45. MaxEnt ecological niche modelling of Rhododendron anthopogon D.Don

Assessment of Biochemical and Phytochemical Content of Selected Threatened and High Value Plants with Diverse Environmental Conditions (NMHS fellowship, 2016-2019)

The North East region (NER) is the richest reservoir of plant diversity in India and is one of the 'biodiversity hotspots' of the world. Plants are important sources of therapeutic drugs and a natural resource of survival for ethnic communities. Natural product structure continued to play a highly significant role in the drug discovery and development process. There are a large number of unique, narrowly distributed, and endemic species which fulfill the medicinal plant need of the industries. These plants have high market value and possess a number of phytochemical compounds for development of valuable drugs for treatment of various major diseases and disorders. While the increased demand and over exploitation have pushed several high value plants into threatened category, the present study attempts to understand the changes in secondary metabolite profile of plants in different environmental conditions towards their conservation and sustainable utilization. Fruit sample of Illicium griffithii and rhizome of Curcuma caesia were collected from Dirangand Shergaon area of West Kameng district of Arunachal Pradesh for biochemical and phytochemical analysis.

Objectives

- To study the survival and growth of different plant species among diverse environmental conditions
- To investigate phytochemical and biochemical contents across altitudinal gradients

Achievements

1. The extraction of fruit sample of *Illicium griffithii* with various solvents i.e. Methanol, Ethanol, Ethyl Acetate, and Acetone at different concentration (20%, 40%, 60%, 80% and 100%) showed variation in the extract color. The colour of the extract changes from light to dark when solvent concentration increases and an indication of higher compounds yield.
2. Phytochemical analysis of *Illicium griffithii* from Shergaon area of West Kameng district with different solvents at different concentrations showed that total phenolic content (TPC) was highest (40.062 mg GAE/g dw) at 80 % methanol followed by (36.865 mg GAE/g c/n) at 60% Ethanol and others. While total flavonoid content (TFC) was highest (6.582 mg QE/ g dw)) at 100% ethyl acetate followed by other solvents (methanol, ethanol, acetone). Phytochemical analysis of the *Curcuma caesia* shows that TPC was highest at 80% methanol (119.95 µg GAE/g dw) while TFC was higher in methanol at 60 % methanol and 80% methanol (776 79 µg GAE/g dw and 760.68 µg GAE/g dw, respectively).

3. The characterization of the plant samples using TGA and FTIR have confirmed the existence of various compounds and functional groups. The TGA analysis confirmed the presence of moisture content, cellulose, hemicellulose, lignin, aliphatic chains and ash content. The FTIR analysis spectra shows existence of alkane, alkene, aromatic rings, and carbonyl functional groups (Fig. 46).

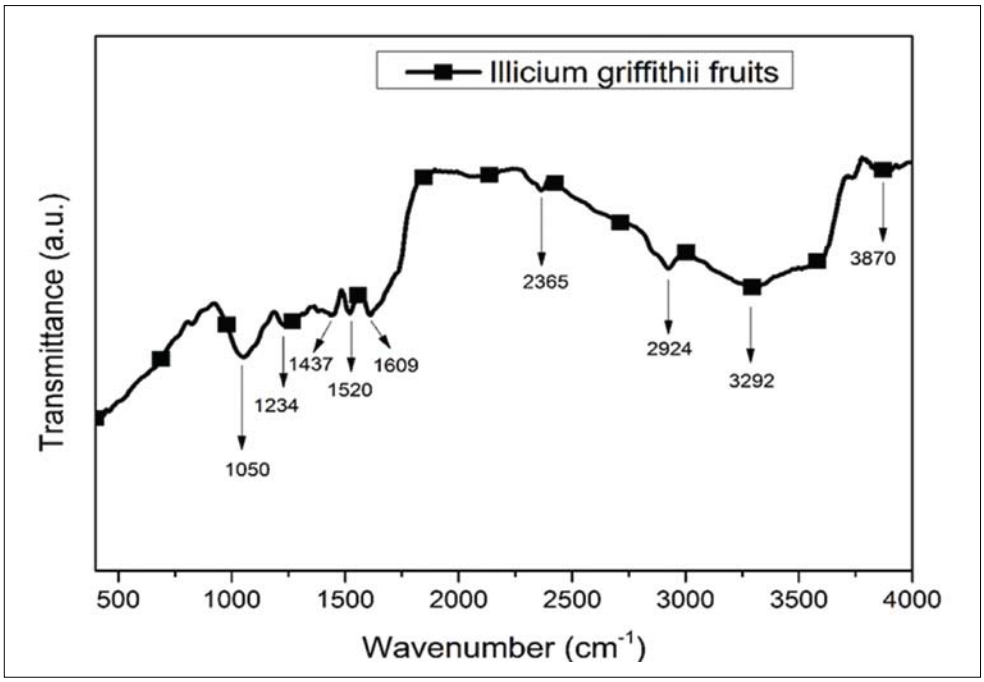


Fig 46. FTIR spectra of Illicium griffithii fruit

Anthropogenic Impacts and their Management Options in Different Ecosystems of the Indian Himalayan Region (NMHS 2017-2020)

The Himalayan ecosystem as a whole is facing a variety of changes in terms of its current environmental scenario. These changes from top to mountain base are faster melting of glacier / snow, erratic seasonal surface run-off, and its effect in down slope regions on existing developmental interventions in the form of mass tourism, hydropower projects, land use components, biodiversity, riverine aquatic life and above all livelihood options and well being of human life inhabiting the region. As a result, the two different ecosystems such as snow and/or headwater environment on top of mountains and riverine basins in down slope regions are going to be most adversely affected from the northwestern to the northeastern Himalayan Region. Knowing the primary status of these issues in a current scenario is a difficult task without any data. As a result, monitoring of the major impacts due to anthropogenic impacts within these ecosystems of the IHR for long duration is must from mitigation, management and sustainable development point of views. The faster melting of the glaciers and snow causes erratic distribution pattern of surface run-off over the seasons in the river basins where lot of developmental and economic activities are in full swing. Most of the activities are entirely dependent on water for drinking, irrigation, power generation, etc. If the water demands for a range of economic activities and land use practices could not be adequate and uniform, its situation become erratic affecting adversely a variety of economic activities of the local communities in the downstream regions. So understanding alike interlinkages from top glacier/snow and head water environment to down slope riverine basin, changes in either of the ecosystem due to anthropogenic impacts including climate change on the inhabiting human populations and its mitigation and managements options for sustainable development in these sensitive parts of the IHR would be a pioneering effort to address in the present context.

Objectives

- To monitor snow melt and/or headwater contribution in total river water flow, their seasonal behavior and quality due to climate change.
- To assess the impacts due to erratic seasonal behavior of river/stream water flow on overall land use pattern, the developmental projects such as HEPs and riverine aquatic biodiversity.
- To enhance capacity building of the stakeholders including women in terms of increasing their resilience and adaptive capacity due to climate change for their sustainable livelihood options.

- To suggest mitigating measures and management options due to anthropogenic impacts.
- To provide policy guidelines for strengthening existing policies on snow fed rivers.

Achievements

1. A questionnaire-based survey in different villages of upper catchment of Ranganadi basin (Peni, Old pitapool Billo, Chullunyu, Pussa, Mengio) revealed that climate change is taking place in the region and the same is evident by change in rainfall pattern (95% respondants). The major reason of climate change is deforestation particularly for Jhum cultivation and commercial timber logging (Fig. 47).
2. The major anthropogenic impact in the basin is jhum cultivation practice followed by road development. Jhum cultivation continues to be the mainstay of sustenance for a vast majority of the tribal communities due to non-availability of alternative livelihood opportunities.
3. Maximum respondents in the villages said that the quality of water is good for drinking. Drinking water is mainly obtained from rain fed small streams or springs in the village.
4. Water quality monitoring results showed the maximum TDS (31ppm) and temperature (17.3 °C) at lower catchment or lower altitude site (74m) named Pohumara. Minimum TDS (14ppm) and temperature (11 °C) was measured at upper catchment or higher altitude site (1050m) named Mengio. Also, maximum velocity of water and depth of tributary stream Panyor was measured 9.1 ft/s and 3.6m, respectively at Mengio.
5. Soil analysis for agricultural and forest soil reveals that moisture content varies from 13.26 to 23.04%, texture showed 52% sand 38% silt and 10% clay. Other parameters such as pH (4.75 to 5.42), nitrogen (0.14 to 0.24%), potassium (1.34 to 1.99%), sodium (0.30 to 0.40%%, calcium (1.18 to 1.50%) and carbon (1.06 to 1.67%).
6. Livelihood options and health conditions need to be strenthened by promoting agri-horticulture practices, local tourism and embroidery and proper waste managment in the project site.

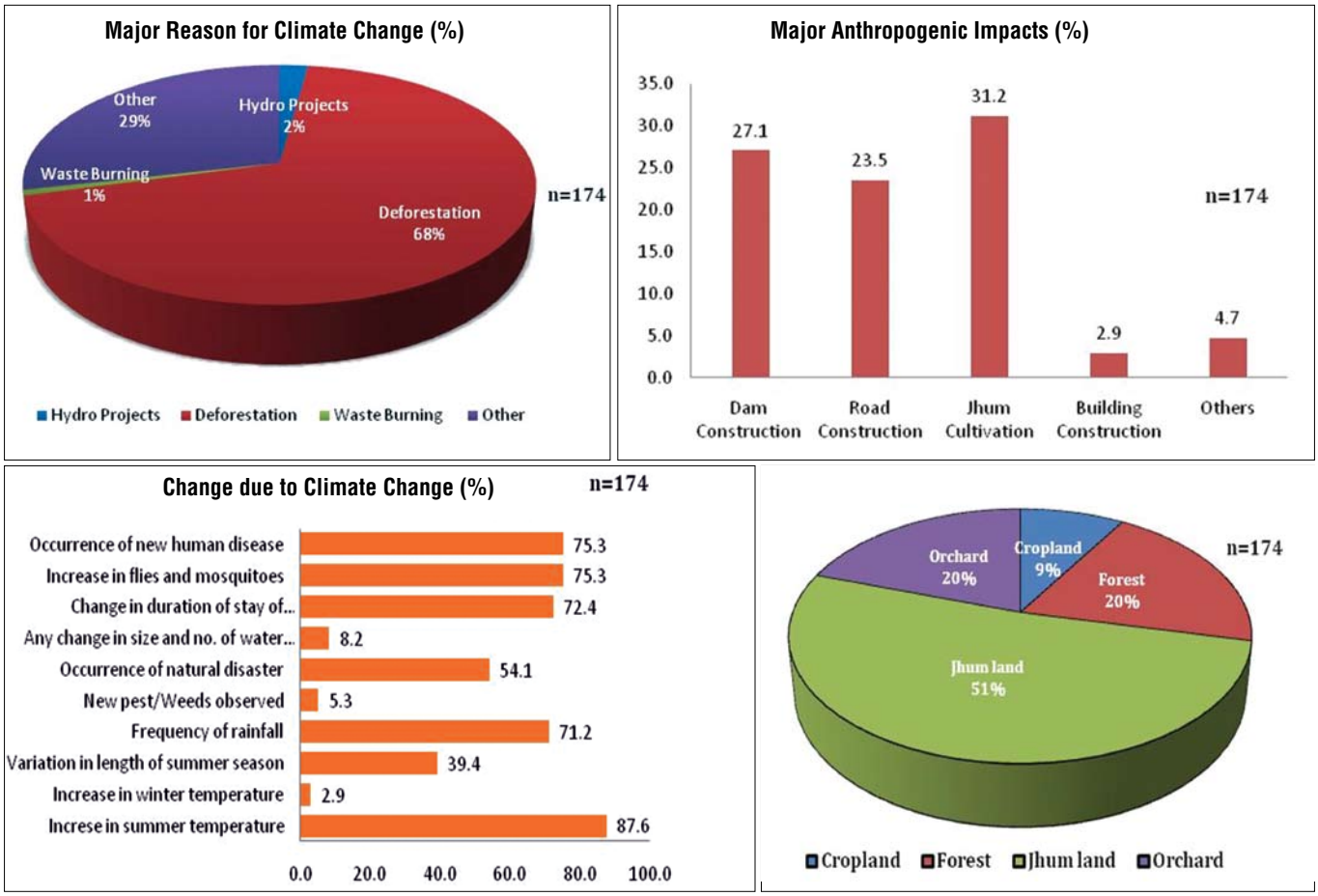


Fig 47. People perception on major reason for climate change, anthropogenic impacts, change due to CC & land use of Ranganadi basin of Arunachal Pradesh

Landscape Initiative for Far-Eastern Himalaya (HI-LIFE), (ICIMOD, 2017-2021)

A Letter of Agreement (LoA) was signed between GBPIHED, NERC and ICIMOD on 31st August 2018 with a vision of efficient implementation of management strategies along with conservation of ecosystem goods and services in Far-Eastern Himalayan Landscape that would further help in improving the livelihood status of the local inhabitants and thereby improve ecological integrity, economic growth and socio-cultural flexibility towards ecological changes. The primary target of Landscape Initiative for Far Eastern Himalaya (HI-LIFE) is to promote regional collaboration among the three countries i.e. China, Myanmar and India on trans-boundary issues and challenges on conservation and development of the landscape. In next five years, HI-LIFE is planning to work towards promoting sustainable tourism development, sustainable use and equitable access to natural resources for reduction of poverty, trans-boundary cooperation in managing National parks and science, policies and their implementation, ecosystem services, livelihoods and climate change impacts, encouragement of regional data sharing and strengthen partnership for trans-boundary collaboration. In India, for the Programme Implementation (2018-2019) under the HI-LIFE, a meeting of the Arunachal Pradesh 'State Level Coordination Committee (SLCC)' was organized on 18th April 2018 at the office of PCCF & PS, Itanagar (A.P.). During the SLCC, the participants developed and endorsed the priority activities that have already begun in Indian part.

Objectives

- Facilitate stakeholder meeting and leverage contributions in jointly developing plan for ecosystem management in pilot areas.
- Update information on biodiversity of Namdapha National Park.
- Follow-up and review of Eco Tourism Policy of Arunachal Pradesh.
- Establish Homestay Tourism Management Committee & Identify Capacity/Training Need (facilitated by SEACoW).
- Build the capacity of the local communities in tourism development.

Achievements

1. Vraious consultation meeting with SEACoW (local NGO partner), stakeholder's consultation cum awareness workshop and interactive meets with local communities were organized for sharing the project concept, ecotourism development and economic upliftment with the establishment of home stays as an alternative source of livelihood development of the villagers such as development of tea trails and home stays with support from Pvt. Sectors.
2. Extensive socio-economic survey carried out in 23 villages located in fringe areas of NNP. Information on the livelihood status along with the prospects of eco-tourism development gathered during the survey.
3. The Institute appraised the state government on 'Home-stay guidelines' developed by the Institute and the workshop was organized by Dept. of Forest, Govt. of AP.
4. Training on Low cost effective agriculture technique known as "Trellis system" at Bodhisatta and development of 'Bio-composting Unit' at New Yumchum village was conducted. A total of 16 villagers were trained on weed-composting and a low cost weed-composting unit was constructed for the community.

Mountain Division Regional Center (MDRC)

Realizing the importance of the Himalayan region as a unique treasure of environmental goods and services and a rich repository of biodiversity, including cultural and ethnic diversity, and considering its sensitivity to natural disasters, climatic and anthropogenic perturbations, the Government of India accords Himalaya the highest priority. Considering this, MoEF&CC has established a dedicated unit as "Mountain Division" as 5th Unit of GBPIHED within the MoEF&CC to address specific issues of the mountain ecosystem in an integrated manner within divisions of the MoEF&CC, across the relevant key Ministries, and with NGOs and Academia to ensure conservation of mountain ecosystem and sustainable development of the mountain regions. The envisaged broad objectives of the Mountain Division are i) To contribute to sustainable development of mountain ecosystems in integrated manner within divisions of the ministry and across the key ministries; ii) To sharpen focus on mountain issues by bringing in "Mountain Perspective" across policies, programmes, missions and schemes; iii) To foster linkages between upstream and downstream regions by influencing policy & planning based on mutual dependence; iv) Develop a suitable framework of incentives for providers of ecosystem services. To achieve the objectives of the division the following project based studies are launched through Himalayan Research Fellows and Associates.

GIS based Land use Modeling for Deriving the Trends of Urban Sprawl in the Cities of Indian Himalayan Region (Mountain Division Center, 2017-2020)

Himalaya is known for its unique, diverse, sensitive and fragile ecosystems. Its sensitivity towards climatic changes and pressure of anthropogenic on Himalayan environment is adversely affecting its ecological security and sustenance of human settlements. Expansion of urban area due to increase in population and migration from rural areas is bound to create the impact on urban areas in terms of infrastructure, environment, water supply and other vital resources. The expansion of cities entails the abandonment of forest and agricultural lands, and conversion of these lands into urban areas results in substantial impacts on ecosystem. There has been tremendous increase in size, area, number and complexity of urban settlement in the region resulting in expansion of urban cluster and urban sprawl. The uncontrolled and unplanned growth is further acting as the trigger to severe problems including the increased population density over a small area, rapid consumption and consequent depletion of natural resources, manmade disasters such as landslides, etc. It therefore becomes crucial to have a thorough understanding of past, present land use changes to predict potential future land use changes in order to better manage and plan against expected potential impacts. The task can be effectively achieved using remote sensing and GIS technique to monitor these changes using multi-temporal remote sensed datasets, spatial metrics

and modeling, etc. GIS based land use modeling can be used to support planning, policy formulation and decision making. Two sites have been selected for this study; namely,Almora city, in Uttarakhand located at 1600 m asl and Gangtok city, the capital of Sikkim located at an elevation of 1650 m asl.

Objectives

- Analysis of land use dynamics in the context of irregular urban sprawl in IHR.
- Land use modeling for future prediction of two growing cities using Remote Sensing, GIS and stochastic (statistics) models.
- Assessment of impact of increasing urban sprawl using multi-criteria analysis.
- Suggestion and guidelines for sustainable urban development.

Achievements

1. Procurement of remotely sensed very high resolution 4 band (Red, Green, Blue, Infra Red) Pleiades satellite imagery at 0.5 m for Almora and Gangtok city was processed. Classified LISS IV datasets for 2005 & 2013 for land use land cover has been utilized to calculate the Shannon's entropy to understand the type of urban sprawl for Almora city by dividing the city in concentric ten zone taking the city centre as the centre of all zones (Fig 48).

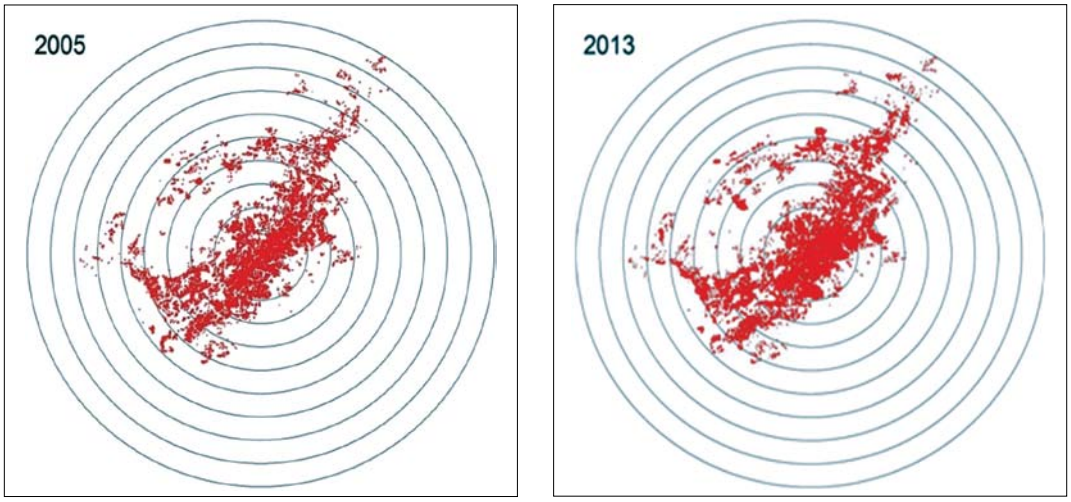


Fig 48. (A) Zone-wise distribution of Builtup area for 2005 for Shannon's entropy
(B) Zone-wise distribution of Builtup area for 2013 for Shannon's entropy

2. Utilizing the classification over LISS IV MX 5.8 m data of Almora city for 2005 and 2013 land metrics including the Largest Patch Index, Class Area, Edge Density, Number of Patches, Fractal Dimensions of Area, Weighted Mean Patch, Diversity Index, Dominance, Evenness,& Contagion was calculated for both the time periods and their relative change estimated (Table 9).
3. Settlement distribution pattern was mapped using the ALOS Palsar DEM at 12.5 m using the elevation profile of the Almora city. For Gangtok city the free available datasets of planetscopewere downloaded for 2018. Also the archival datasets of quid bird imagery at 0.6 m resolution for year 2003. The LULC map at 1:10K scale for year 2013 was collected from SCoST.

Table 9: Land Metrics calculation and its relative change for year 2005 and 2013

Landscape Metrics	2005	2013	Change in %
LPI (Largest Patch Index)	3.45	6.88	99.42
CA (CLASS AREA)	227.00	315.50	38.99
ED (EDGE DENSITY)	148.36	147.10	-0.85
NP (NO. OF PATCHES)	1081	986	-8.79
FRAC-AM (Area weighted mean patch Fractal dimension)	1.52	1.49	-1.97
DIVERSITY INDEX	0.38	0.44	13.87
DOMINANCE	3.19	3.24	1.66
EVENNESS	13.61	15.50	13.87

Eco-physiological Assessment of Selected Medicinal Plants with Changing Environment for Understanding Adaptation Mechanism (Mountain Division-RA scheme, 2016-2019)

Global climate change has emerged as a major concern today that imposed major threat on plant biodiversity. The climate change has induced various impacts on Himalayan region such as reduced water availability, erratic monsoon, recurrent drought events, invasion of weed species and increased insect-pest attacks. Shift in distribution pattern (upward march), change in phenology pattern (early flowering), decreased species diversity, loss of potential habitat of endemic plants, habitat fragmentation, expansion of scrublands, spread of alien invasive species, increased frequency of insect-pest attack are some of the major impacts of climate change in Himalayan ecosystem. This situation is more exacerbated due to over-collection and unscientific exploitation of medicinal plants and has reduced its availability in natural habitat. All these factors have increased the threat for the survival of Himalayan plants and its biodiversity. Thus, there is an urgent need to protect the Himalayan plants from extinction to conserve biodiversity, to increase their resistance against various biotic and abiotic stress conditions, to identify the stress adaptation mechanisms and to determine the optimum environmental conditions for plant growth and metabolite production.

Objectives

- To investigate physiological and biochemical attributes of selected Himalayan medicinal plants in different environmental conditions
- To improve stress tolerance of plants through microbial colonization and its effect on growth dynamics and bioactive metabolites
- To identify suitable conditions for better survival and growth of plants
- To understand the mechanism of adaptation under different biotic and abiotic stresses

Achievements

1. The SImdy conducted in *Valeriana jatamansi* and *hedychium spictrum* under drought, temperature and combined stress conditions, chlorophyll content, photosynthesis rate and carboxylation efficiency of plants decreased. However, other physiological parameters like transpiration rate and stomatal conductance decreased under drought stress, while increased under high temperature to cope the stress condition. In contrast water use efficiency (WUE) increased under drought stress, while reduced under temperature stress.
2. Among various biochemical parameters, protein and proline content initially increased under drought, high temperature as well as combined stress conditions, while started reducing after 20-25 days after stress, in both the plant species.
3. Among various antioxidant enzymes, superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD) activity increased under stress condition in order to prevent the reactive oxygen species (ROS) mediated damage.
4. Hydrogen peroxide (a reactive oxygen species) and malondialdehyde (product of lipid peroxidation) content increased under all stress conditions, when compared to control plants, suggesting membrane damage of plant cells.
5. Some adaptation mechanisms common for all kind of stresses were identified and they includes synthesis of stress responsive proteins, increased activity of antioxidant enzymes, increased carotenoid content and proline accumulation. For promoting cultivation, selection of plants based on these physiological and biochemical traits should be performed to select superior and resilient individuals.

Tradeoffs between Conservation and Livelihood Outcomes in Protected area Management: an Assessment based on Stakeholders Analysis (Mountain Division-RA scheme, 2017-2020)

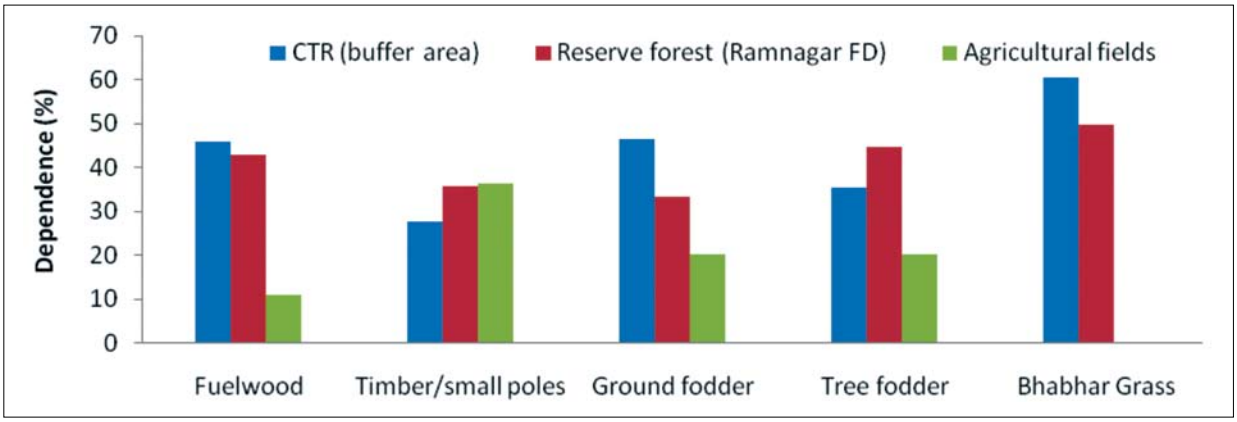
The Himalayan region is a biodiversity hotspot and harbors rare assemblages of flora and fauna with a high degree of endemism. About 2100 bird species and 5800 plant species (26% of which are endemic) are found here, and of India's 372 mammalian species, as many as 241 (65%) have been recorded in the Himalayas. To conserve such a rich biological diversity, 9.2% of its geographical area has been protected in a network of 3 biosphere reserves, 18 national parks, and 71 wildlife sanctuaries. Undoubtedly, this protected area (PA) network has helped conserve significant portions of Himalayan biodiversity, but it has also engendered severe conflicts/concerns between local communities and PA management in the IHR, because most of these PAs in the IHR contain human settlements or are located adjacent to them. In view of increasing concern being paid by social as well as conservation scientists about the livelihood impacts of conservation policies, a project proposal "Tradeoffs between conservation and social outcomes in Protected Area management: an assessment based on stakeholder analysis" has been envisaged to come up with strategic pathways that could lead to a synergy between conservation and livelihood outcomes in PA management in the western Himalayan region. The project primarily intended to assess the scale and magnitude of impacts (whether positive or negative) of PA management on the livelihoods of local people living in and around PAs in the Indian Himalayan region.

Objectives

- To assess conservation and social outcomes of PA management in the western Himalayan Region
- To assess, review and prioritize social and livelihood conflicts that prevails around PA management in the western Himalayan Region
- To develop policy pathways that could lead to win-win outcomes (i.e. better conservation as well as livelihood outcomes) in PA management

Achievements

1. Corbett Tiger reserve (CTR) is known to have maximum density of tigers in the world (18 tigers per 100 km^2). The reserve is being visited by >2 lakh tourists each year that generates an average annual revenue of about Rs. 2 crore.
2. The park brings substantial income to local community residing nearby places. Around 21% population across the surveyed villages was found engaged in economic activities that linked directly to CTR. However, with an average monthly income of rupees approximately 8850, maximum population was found engaged in menial jobs such as care takers, cook and helpers in the private hotels and resorts. As compared to other activities, villagers driving their self-owned gypsies in the ecotourism zones were found getting maximum income (approximately 21750 rupees/month) from the reserve.
3. Although there were resource use restrictions, the CTR forest was accessed frequently by villagers mainly due to its proximity to the villages. An analysis of fuel wood consumption in 3 villages (Dhela, Mohan and Chukam) located at the fringes of CTR revealed that an average of 6.95±1.85 ton firewood is being consumed annually by a household in these villages, of which around 46% is harvested form CTR forest. Similarly, of the total average household annual consumption of ground fodder (2.5±0.75 ton) and tree fodder (2.8±1.05 ton), 46% and 35 %, respectively, was collected from the reserve. Furthermore, Bhabhar (Eulaliopsis binata), a seasonal grass, was also extracted by villagers from forests in summer to make rope that is sold in market. Per household average annual harvest of Bhabhar grass in the study villages was recorded 0.44±0.23 ton, of which around 60% was found harvested from CTR forest.
4. As far as indirect benefits are considered, all the surveyed households (n=90) acknowledged that they getting indirect benefits of air purification followed by temperature control (93% HHs), soil fertility improvement (87% HHs), water availability (77% HHs), good health (70% HHs) and pollination (38% HHs) from the CTR forest.
5. Beside these economic and subsistence benefits, loss is also borne by local peoples in the form of human casualty, livestock depredation and crop raiding (Fig. 49). About half of agricultural crop was found damaged by wild animals in the surveyed villages. A maximum damage (45%) was reported for sugarcane followed by wheat (40%) and pluses (35%). The number of livestock being killed by wild animals each year range from 11 to 13 across the study villages. Similarly, at least one case of human death and >1 cases of human casualty are being recorded each year in the study villages.



Crop raiding by wildlife

Fig 49. Villagers dependence (%) on CTR forest, Reserve forest and crop fileds

Water Quality Assessment of Existing Water Sources in the Lower Parbati Basin (Mountain Division, 2018-2021)

The water quality from the rivers has a considerable importance for the reason that these water resources are generally used for multiple matters such as: drinking and residential water supplies, agriculture (irrigation), hydroelectric power plants, transportation and infrastructure, tourism, recreation, and other human or economic ways to use water. The Indian Himalayan Region is rich in water resources; however, this is going to be threatened due to anthropogenic stress, over-exploitation, and lack of management techniques. On account of anthropogenic stress in many forms, freshwater resource is

continuously depleting. Studies of different climatic variables in terms of long-term information on temperature, precipitation, environmental flow, water quality, quantity and others, both dissolved and suspended, have therefore been important to know a trend of particular variable from management viewpoints. The high degree of anthropogenic activities like quadrupling demand of the growing population, tourism and the accelerating pace of Industrialization is highly responsible for natural destruction, deterioration and ultimately climate change leading to changes in the water composition. The Parbati basin is one of the major sources of water in Himachal Pradesh so there is a need to analyze first water quality, quantity, overall environmental flow, water use pattern, drainage pattern and management possibilities to preserve and prefect the natural ecosystem.

Objectives

- To assess the status of water sources like river, streams, springs, hand pumps, etc. and assessment of topographic, anthropogenic and climatic impacts on water resources
- To delineate the palaeochannels of Parbati sub-basin and existing drainage system of the study area with the help of remotely sensed data and establishment of their relationship with the water sources
- To assess the changing water quantity and quality (physico-chemical, biological) of existing water resources
- To suggest strategy for sustainable development of the water sources

Achievements

1. Water samples were collected from 13 locations of the Parbati basin. Parameters like Temperature, pH, EC and TDS were analyzed on the spot using potable water and soil analysis kit. For the analysis of other parameters, the bottles were taken to the laboratory and stored at 4^{O}C. The physico- chemical properties were analyzed by using standard method given by APHA, 2005.
2. The minimum values for pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were 6.87, 150 µs cm^{-1}, 80 mg $^{l-1}$ respectively. Whereas, the minimum concentration for Total Hardness (TH) calcium and alkalinity were 48 mg^{l-1}, 125 mg $^{l-1}$, and 11.747 mg $^{l-1}$, respectively . The detail of physico-chemical parameters of soil is given in table 10.
3. The maximum values for the pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were 8.05, 929 µs cm^{-1} and 234 mg^{-1}, respectively. However, the maximum concentration for Total Hardness (TH), calcium and alkalinity were 80 mg^{-1}, 23.54 mg^{-1} and 250 mg^{-1}. All the analyzed parameters were found under the permissible limits prescribed by BIS 2012 and WHO 2011.

Table 10: Physico- chemical analysis of the water samples collected from different sites

Sample site	DO mg $^{l-1}$	pH	EC µs cm^{-1}	TDS mg $^{l-1}$	TH mg $^{l-1}$	Calcium mg $^{l-1}$	Alkanity mg $^{l-1}$
Rudranag	7.5	7.42	241	121	48	15.1389	225
Parvati River Guwacha	7.8	6.87	210	98	62	11.7747	250
Tosh Nalla	6.3	7.49	150	80	56	12.6157	175
Barshaini	7.5	7.57	246	123	60	11.7747	150
Manikaran market	6.8	7.46	250	127	68	16.821	125
NHPC Manikaran	7.2	7.8	248	124	76	13.4568	175
Grahan nalla	9.1	7.67	216	108	74	14.297	175
Kasol(confluence)	7.2	7.69	231	114	66	20.1852	150
Jari	7.3	7.34	226	112	72	12.6157	175
Shat confluence	7.5	7.43	299	150	74	16.281	125
Jiah	5.8	7.22	311	156	80	23.5494	250
Hathithan	8.3	7.5	362	234	72	16.821	241
Bhunter (confluence)	8.1	8.05	473	181	68	18.5031	200
Permissible limit	6.5 to 8.5	2000	2000	600	200	600	

Assessment and Valuation of Alpine and Sub-alpine Ecosystems of Himachal Pradesh in relation to Climate Change (Mountain Division, 2018-2021)

The Indian Himalayan Region (IHR) is recognized among the 34 global biodiversity hotspots. The Indian Himalayan Region with its unique topography, climatic conditions, diverse habitats and a large altitudinal range constitutes an important part of this hotspot. The Indian Himalayan Region which constitutes a significant part of the Himalayan hotspot represents tropical, sub-tropical, temperate, sub-alpine, alpine and tundra biomes. While biodiversity of this region is depleting fast due

to habitat degradation caused by various anthropogenic activities coupled with the changing environmental conditions, the diverse ecosystems prevailing in the region are increasingly been recognized for their provisioning, cultural, regulating, and supporting services to both upland and lowland inhabitants. The climate change has been recognized as one amongst the most confounding factor in shaping the future of mountain ecosystems, and also the rural communities. The biodiversity components of the sub-alpine and alpine ecosystems are severely affected by anthropogenic activities particularly by heavy grazing, over exploitation of woody species for fuel by the herdsmen and non-timber forest products (NTFPs) including medicinal plants. The floristic diversity varies along altitudinal gradients, and across the habitats, aspects and vegetation types. The sub-alpine and alpine ecosystems are very sensitive to global climate change. Change in vegetation patterns are expected in the changing climate scenario. Therefore, assessment and valuation of floristic diversity becomes utmost important. A very few studies have been carried out on qualitative and quantitative assessment of sub-alpine and alpine ecosystems. Further, an integrated study to assess floristic diversity, community structure, distribution pattern of the native and endemic species in relation to climate change, identification of economically important species, impact of climate change on floristic diversity, and suggest appropriate management options and policy briefs for conservation.

Objectives

- To assess the floristic diversity of the sub-alpine and alpine ecosystems
- To assess the physico-chemical properties of soil of the sub- alpine and alpine ecosystems
- To assess the conservation and socio-economic values of the floristic diversity of sub- alpine and alpine ecosystems
- To assess the floristic diversity in relation to climate change
- To assess the floristic diversity of sub-alpine and alpine ecosystems for vulnerability
- To suggest suitable management options

Achievements

1. Total 10 sites in Fozal valley were surveyed between 2500m– 3209 m amsl. Habitat conditions varied and represented by moist (5), Dry (4), and Rocky (1) habitats. 3 sites were represented in North aspect, 2 sites each in North West, North East & West aspects and 1 in East aspect. The slope varied from 35°-65°.
2. Five (5) plant communities were identified. Sites were represented by *Abies pindrow* community (05 sites), followed by *Quercus semecarpifolia* community (02 sites) and *Abies pindrow- Quercus semecarpifolia* mixed (01 site), *Acer caesium-Abies pindrow* mixed (01 site) & *Prunus cornuta-Acer acuminatum* mixed (01 site) communities.
3. Site wise analysis of data revealed that Species richness ranged from 2-15. Total basal area (TBA) for Trees 159.34-9758.37 (m^2ha^{-1}), density for trees 110-710 (Ind/ha^{-1}), Species diversity (H') 0.59-1.35 and Concentration of Dominance (Cd) 0.26-1.04 (Table 1). Site wise Density for shrubs ranged from 60-920 (Ind/ha^{-1}), Species diversity (H') 0-13.36 and Concentration of dominance (Cd) 0.13-1 (Table 11).

Table 11: Community wise TBA, SR, Density, Species diversity and Concentration of Dominance for trees and shrubs

Site	Community Type	TBA (m^2ha^{-1})	SR	Trees			Shrubs		
				Density (Ind/ha^{-1})	H'	Cd	Density (Ind/ha^{-1})	H'	Cd
1	AP	3332.45	6	110	0.99	0.40	160	0	1
2	AP-QS mixed	1787.19	10	160	1.35	0.26	920	1.29	0.32
3	AP	9758.37	11	160	1.25	0.32	910	1.27	0.33
4	AC-AP mixed	274.49	7	320	1.25	0.31	60	1.01	0.38
5	AP	1047.43	11	710	1.06	0.44	160	1.84	0.17
6	QS	159.34	7	270	0.99	0.41	70	1.27	0.30
7	AP	8088.88	2	190	0.62	0.57	-	-	-
8	AP	5795.25	15	260	0.59	0.68	950	13.36	0.13
9	QS	3356.51	9	140	1.29	0.32	830	1.00	0.44
10	PC-AA mixed	1038.68	11	110	0.74	1.04	880	1.56	0.27

Abbreviations used: TBA = Total basal area; SR = Species Richness; H' = Species diversity; Cd = Concentration of dominance; AP= *Abies pindrow* community; AP – QS = *Abies pindrow* - *Quercus semecarpifolia* mixed community; AC-AP = *Acer caesium* - *Abies pindrow* mixed community; QS = *Quercus semecarpifolia* community; and PC – AA mixed = *Prunus cornuta* - *Acer acuminatum* mixed community

Application of R&D Outputs in Demonstration and Dissemination

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

Ministry of Environment, Forest & Climate Change (MoEFCC), 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. Through this scheme the Institute extends R&D support under two broad thrust areas (i.e., Technology Development and Research for Integrated Eco-development, and Technology Demonstration Extension) covering 6 thematic areas (viz; Watershed Processes and Management, Biodiversity Conservation and Management, Environmental Assessment and Management, Socio Economic Development, Biotechnological Applications, and Knowledge Products and Capacity Building) of the Institute.

Objectives

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

Achievements

1. A total of 357 R&D projects have been supported by IERP, to the University, Institutions, NGOs and Other Government Organizations, of which 315 projects have been successfullycompleted.
2. Organized 21st meet of Project Evaluation Committee during 1-2 March 2019 at Mizoram University, Mizoram and a total of 51 project were evaluated, of which 16 were recommended for financial support.
3. At present there are 42 R&D projects at various stages of implementation covering11 States (namely; Assam, Arunachal Pradesh, Himachal Pradesh, J&K, Manipur,Meghalaya, Mizoram, Nagaland, Sikkim,Tripura and Uttarakhand) of the Indian Himalayan region.
4. Regular monitoring of project activities and feedback is being received from project implementing agencies.

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

1. The Centre collected, collated and synthesized the quantitative and qualitative databases on various aspects of Himalayan Ecology from authentic data sources. These databases covers the temporal trends across important segments, e.g., demography, literacy, land, water, agriculture, horticulture, forest cover, protected areas, weather profiles, etc. In addition, the center compiled data on subject experts and important web links related to Himalayan Ecology and published four thematic ENVIS Newsletters Vol. 15(1-4), 2018.
2. The centre conducted two certificate courses Green Skill Building Programme (GSBP) on Nature Conservation & Livelihood: Nature Interpretation (1-21 August 2018) for 14 trainees selected form 9 district of Uttarakhand in which 34 expert lectures and various field-exercises were conducted on ecotourism, nature guides on flora and fauna, plant-animal interaction, mountain farming, nature and wildlife photography, biodiversity conservation and climate change mitigation, remote sensing, environmental friendly rural technologies, etc. (Fig. 50).
3. Under the GSBP programme two training courses of 15 days each on Preparation of People's Biodiversity Register (PBR) were organized from 7-21 January 2019 and 12-26 February 2019. Involving experts of State Biodiversity Board, Govt. of Uttarakhand a Biodiversity Management Committees (BMCs) was formed in Papoli Gram Panchayat in Hawalbagh Block of Distt. Almora. The trainees prepared 7 People's Biodiversity Registers (PBRs) both in Hawalbagh Block (Dhari, Dhaili, Kaneli, Papoli and Salla Rautela) and Ramgarh Block of Distt. Nainital (Moura and Simayal Raikwal). During this programme five master trainers were produced and tie up with State Biodiversity Board, Uttarakhand was executed.
4. National Regional Workshop of North Region ENVIS Centres (15-16 Nov, 2018) was organized in which officials of ENVIS Secretariat, MoEF&CC and Coordinators of 10 ENVIS Centres of Himalayan region participated.

Fig 50. Participants of the green skill building programme organized by ENVIS centre

Central Laboratory Services

Institute has centralized facilities for physicochemical, biological, heavy metal analysis of fresh and waste water, quantification of organic compounds (mainly volatiles) of water, soil and plant samples, elemental analysis (carbon, hydrogen, nitrogen and sulfur) of solid samples. The heavy metals in the liquid samples (such as water, digested samples of soil and plant) 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 800plus). For elemental analysis, CHNS (make- Elementar, Vario EL-III) is available in the facility. Along with this, central facility is equipped with various other minor instruments such as UV-Vis spectrophotometer, flame photometer, digestion systems, extraction units etc. The Institute has extended these services to other organizations (NGOs and Government Organization) on payment basis. Individuals (researchers, villagers) are also using the facility for sample analysis. During the financial year 2018-19, Institute received Rs. 2,36,118/- as a Central laboratory service charges from different organizations including Govt. (eg. Uttarakhand jal sansthan, MES, Ranikhet, DCFR, Bheemtal, Navodaya Vidyalayas etc.), private /NGOs (Himmothan society, Grasrrot India, etc.) and individual. In addition, 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 51) depicts month-wise samples analyzed for Institute as well as other organizations.

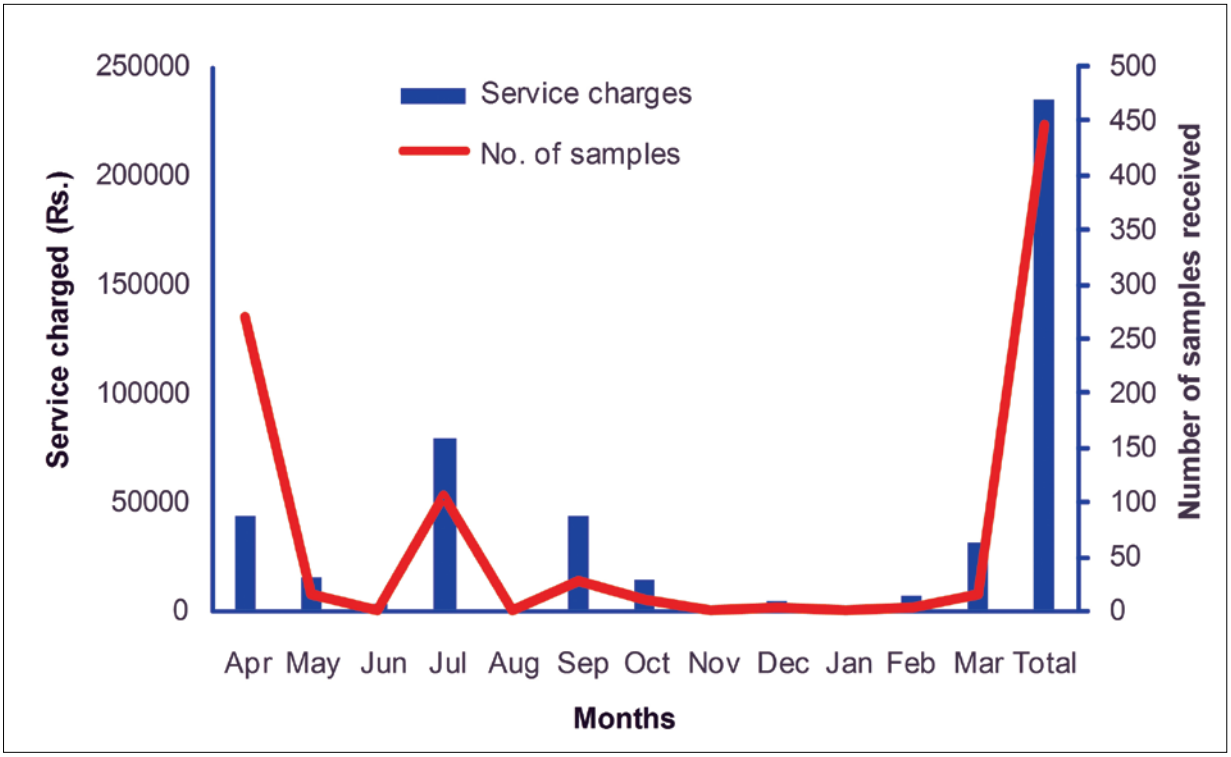


Fig 51. Graphic representation showing total samples analysed under Central Laboratory Services in financial year 2018-19.

Strengthening and Maintenance of the Central Library at HQs

The Central Library of the Institute at its headquarters, at the end of financial year 2018-2019, had 17387 books. The library is subscribing a total of 89 periodicals (61 Foreign and 28 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 web site (https://librarygbpihed.weebly.com). During the reporting year, 372 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

Scientific Publications

(I) SCIENTIFIC JOURNALS

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(III) Authored/Edited Book/Flyers

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Tiwari A, Mukherjee S, Rai S, Kumar K (2018). Unplanned urban sprawl: a threat to agricultural land in Himalaya. KrishiJagaran.

(V) Policy papers

Maikhuri RK, Rawat LS, Maletha A, Bahuguna YB, Bisht T, Jugran A (2019). Organic farming for synergizing environmental and socio- economic development in Uttarakhand, G.B. Pant Institute of Himalayan Environment and Development, Srinagar Garhwal. pp 38.

Maikhuri RK, Rawat LS, Maletha A, Jugran A, Bisht T, Tarafdar S, Sahani AK (2019). Promoting rural tourism in Kedar Valley of Uttarakhand, G.B. Pant Institute of Himalayan Environment and Development, Srinagar Garhwal. pp. 34

Awards and Honours

1. Rajbhasha Shield and Certificate for excellent performance in official Hindi language for the year 2017-2018 on 02 June, 2018 by Town Official Language Implementation Committee, Kullu - Manali, Himachal Pradesh (S. S. Samant, J. C. Kuniyal, S. Shashni, R. Lata, V. E. Gosavi & K. Kumar).
2. Green Maple Foundation (GMF) Award 2018 for Research Excellence on 24 June, 2018 by the Green Maple Foundation, Chandralok, Lucknow, Uttar Pradesh (S. S. Samant, J. C. Kuniyal, S. Shashni, R. Lata, V. E. Gosavi & K. Kumar).
3. Awarded by "Honorary Fellow of Indian Academy of Environmental Sciences, Haridwar, Uttarkhand", during 2 Days National Seminar on Research in Environment and Biosciences Current Scenario and Future Perspective (22-23 June, 2018) organized by Indian Academy of Environmental Sciences, Haridwar & DAV (PG) College, Dehradun, Uttarakhand (Kishor Kumar).
4. Young Scientist Award during 13th Uttarakhand State Science and Technology Congress (UCOST 2018-2019) for poster presentation under the discipline Biotechnology on the topic "Vegetation analysis and regeneration potential of Myrica esculenta in Uttarakhand" (Mr. Anmol Rawat).
5. Young Scientist Award during 13th Uttarakhand State Science and Technology Congress (UCOST 2018-2019) for oral presentation under the discipline Geology on the topic of "Analysis of recent changes in land use land cover, rainfall and temperature trends in mid-Himalayan watershed" (Mr. Pratik Deb)
6. Young Scientist Award during 13th Uttarakhand State Science and Technology Congress (UCOST 2018-2019) for poster presentation under the discipline Environmental Science and Forestry on the topic entitled "Assessment of forest vulnerability using an index based approach of community forests in Kumaun Himalaya" (Ms. Shinny Thakur).
7. Young Scientist Award during 13th Uttarakhand State Science and Technology Congress (UCOST 2018-2019) for oral presentation under the discipline Botany on the topic entitled "Temporal changes in forest structure, species composition and diversity in sub-tropical and temperate forests stands in the Western Himalaya" (Mr. Vinod Chandra Joshi).
8. 1st prize for Poster presentation in 9th International conference on Medicinal aromatic and nutraceuitical plants from Mountainous areas organized by Graphi Era University on the topic entitled "Bioactive content and antioxidant activity in Mahonia jaunsarensis: an endemic species of Himalaya" at Dehradun (Ms. Arti Bisht; February 14-16, 2019)

Participation in Different Events

Events	HQ	Units				Total
		NE	Sikkim	Garhwal	HP	
National						
• Symposia/Conference/Workshop	40	8	16	08	20	92
• Training Courses	23	4	03	06	8	44
• Meetings	52	8	18	20	35	133
• Participation as a Resources Person	65	12	13	10	40	140
• Any Other	55	-	08		-	63
International	10	2	5	-	1	18

RTI Cell, GBPIHED

Details of applications received under RTI Act, 2005 (Year : 2018- 2019)

S.N.	Date of receipt of application	Name of the applicant	Received directly from the applicant	Transferred from other authority	Fee received	Appeal disposed off	Rejected
1	19.04.2018	Mr. R.K. Singh, Type IV-7, G.B. Pant Institute Campus, Kosi-Katarmal, Almora-263 643, Uttarakhand	Yes	No	No	Appeal disposed off on 01.05.2018	---
2	19.04.2018	Mrs. Ranjana Singh, Type IV-7, G.B. Pant Institute Campus, Kosi-Katarmal, Almora-263 643, Uttarakhand	Yes	No	No	Appeal disposed off on 01.05.2018	---
3	03.04.2018	Mr. R.K. Singh, GBPIHED, Kosi-Katarmal, Almora, Uttarakhand	Yes	No	Rs. 10/- Cash	Information sent by Speed Post on 27.04.2018/ by e-mail on 01.05.2018	---
4	04.04.2018	Mr. Narendra Lokwani, 226 B Block, Pratap Nagar UIT Colony, Near Kendriya Vidyalaya, Udaipur, Rajasthan-313 001	Yes	No	Recd. Online	Information sent on 04.04.2018 by E-mail/Speed Post.	---
5	07.04.2018	Mr. Abhinaya Gupta, H 702 A, Palam Vihar, Gurgaon, Haryana.	Yes	No	Recd. Online	Information sent by Speed Post on 25.04.2018.	---
6	13.04.2018	Mr. Prithvi Raj, A-29, New Friends Colony, New Delhi-110 025	Yes	No	Rs. 10/- IPO	Information sent on 25.04.2018 by Post.	---
7	17.04.2018	Mr. K.K. Pande, Ex Finance Officer of GBPIHED, C/o Shri R.C. Tripathi, H. No. 2, Lane-2, Vasant Vihar Enclave, Vasant Kunj, Dehradun-248 006, Uttarakhand	No	Yes, transferred from MoEF&CC, New Delhi.	No	Information sent on 11.05.2018 by Speed Post	---
8	18.04.2018	Mr. Narendra Lokwani, 226 B Block, Pratap Nagar UIT Colony, Near Kendriya Vidyalaya, Udaipur, Rajasthan-313 001	Yes	No	Recd. Online	Information sent by Speed Post on 11.05.2018.	---
9	18.04.2018	Mr. Narendra Lokwani, 226 B Block, Pratap Nagar UIT Colony, Near Kendriya Vidyalaya, Udaipur, Rajasthan-313 001	Yes	No	Recd. Online	Information sent by Speed Post on 11.05.2018.	---
10	18.04.2018	Mr. Narendra Lokwani, 226 B Block, Pratap Nagar UIT Colony, Near Kendriya Vidyalaya, Udaipur, Rajasthan-313 001	Yes	No	Recd. Online	Information sent by Speed Post on 11.05.2018.	---
11	23.04.2018	Dr. Subrat Sharma, Scientist-D, GBPIHED, Kosi-Katarmal, Almora	No	Yes, transferred from MoEF&CC, New Delhi.	No	Information sent on 21.05.2018 by E-mail/Speed Post.	---

12	03.05.2018	Dr. Paromita Ghosh, Scientist-D, GBPIHED, Kosi-Katarmal, Almora	No	Yes, transferred from MoEF&CC, New Delhi.	No	Information sent on 28.05.2018 by e-mail/Speed Post.	---
13	03.05.2018	Mrs Raj Shree Karan Pur, Mansingh wala, Near Cross Road Mall, H.No. 111/93 Dehradun	Yes	No	Rs. 30/- IPO	Information sent on 21.05.2018 by Speed Post.	---
14	14.05.2018	Shri Subrat Sharma, E-56 A, Judge Farm, Haldwani-263139, Uttarakhand.	No	Yes, transferred from MoEF&CC, New Delhi	No	Information sent on 06.06.2018 by e-mail/Speed Post	---
15	23.05.2018	Mr. Somnath Datta, SBI RACPC Durgapur, City Centre, Burdwan, West Bengal-713216	No	Yes, transferred from M/o Finance, Deptt. of Expenditure, New Delhi.	No	Information sent on 29.05.2018 by e-mail/Speed Post.	---
16	23.05.2018	Ms. Goldy, H. No. 300, Talian Wala Mohalla, Sadar Bazar, Sirsa, Haryana	No	Yes, transferred from MoEF&CC, New Delhi.	No	Information sent on 13.06.2018 by Speed Post.	---
17	18.06.2018	Mr. Narendra Lokwani, 226 B Block, Pratap Nagar UIT Colony, Near Kendriya Vidyalaya, Udaipur, Rajasthan	Yes	No	Recd. Online.	Information sent on 21.06.2018 by e-mail/Speed Post. Udaipur-313 001	
18	17.07.2018	Mr. Kash Babu, E – 1 Dum Colony, Gali No. 3, Ibrahim Pur Delhi-110 084	Yes	No	Recd. Online	Information sent on 06.08.2018 by e-mail/Speed Post/Online.	---
19	29.08.2018	Mrs Vinita Farasi, Councellor, District court, Chamber No. 68, IInd Floor, Block No. 6, CJM Compound Dehradun	No	Yes	No	Information sent on 12.08.2018 by Speed Post	
20	04.09.2018	Mr. Manish Tripathi, House No. 38 Kirloskar Layout, Hesearghatta Road, Bangalore, Karnataka.	Yes	No	Recd. Online	Information sent on 26.09.2018 by e-mail/Speed Post and online.	---
21	20.09.2018	Shri Pan Singh Bhakuni, GBPIHED Kosi-Katarmal, Almora	Yes	No	Yes	Information given byhand on 11.10.2018	&&
22	20.09.2018	Mr. Raja, S/o Karupayan, S 67/2, Iyyappa Mandir Madrasi Camp, Jal Vihar Lajpat Nagar, Kabli Hotel, Delhi	Yes	No	Recd. Online	Information sent on 15.10.2018 by e-mail/Speed Post/ Online.	---
23	26.09.2018	Mr. A.K. Singh, Flat No. 301, Jahaji Kothi, Bhikhan Tower, Kankarbagh, Patna, Bihar	Yes	No	Recd. Online	Information sent on 17.10.2018 by e-mail/Speed Post/ Online.	--
24	26.11.2018	Shri Jagdish Chandra S/O Shri Prem Ballabh, Awas Vikas Paryavaran Colony, H.No. 35, Dharanaula, Cheenakhan/Makedi	Yes	No	No	Appeal disposed off on 06.12.2018	--

25	01.10.2018	Mr. Deepak Seth, S-62, Pocket-12, Sector-8, Dwarka, New Delhi-110 077	No	Yes, transferred from MoEF&CC, New Delhi	Recd. Online	Information sent on 30.10.2018 by e-mail/ Speed Post/Online.	---
26	08.10.2018	Ms. Sunita Kumari Meena, D/o Shri Mishri Lal Meena, Room No. 34, Varsha Annexe, Sindhu Guest House, ICAR – Indian Agriculture Research Institute (IARI), New Delhi-110 012	Yes	No	Rs. 10/- IPO	Information sent on 24.10.2018 by Speed Post/ Online.	---
27	15.10.2018	Mr. Kamlesh Tandan, Tandan Traders, Old Chamtari Road, Amha Para Sejbahar Raipur, Chattisgarh	Yes	No	Recd. Online	Information sent on 02.11.2018 by e-mail/ Speed Post/Online.	---
28	15.10.2018	Mr. Kamlesh Tandan, Tandan Traders, Old Chamtari Road, Amha Para Sejbahar Raipur, Chattisgarh	Yes	No	Recd. Online	Information sent on 02.11.2018 by e-mail/ Speed Post/Online.	---
29	15.10.2018	Mr. Rohit Gupta, 12 F Pocket-4, EHS Mix Housing, Mayur Vihar, Phase-3, Delhi	Yes	No	Recd. Online	Information sent on 02.11.2018 by e-mail/ Speed Post/Online.	---
30	16.10.2018	Shri Jagdish Chandra S/O Shri Prem Ballabh, Awas Vikas Paryavaran Colony, H.No. 35, Dharanaula, Cheenakhan/Makedi	Yes	No	Rs 100/- Cash	Information given on 14.11.2018.	&&
31	22.10.2018	Shri Jagdish Chandra S/O Shri Prem Ballabh, Awas Vikas Paryavaran Colony, H.No. 35, Dharanaula, Cheenakhan/Makedi	Yes	No	Rs 100/- Cash	Information given on 13.11.2018.	&&
32	01.11.2018	Shri Jayant Mandal, Krishi Utpadan Mandi Samiti, Kashipur, Mooradabad Road, Udham Singh Nagar-244713, Uttarakhand	Yes	No	Recd. Online	Information sent on 29.11.2018 by Speed Post/ Online.	
33	08.11.2018	Mr. A. Deshmukh, Flat 5, Sector 18, New Panvel, Mumbai-410218, Maharashtra	Yes	No	Recd. Online	Information sent on 06.12.2018 by Speed Post/ Online.	---
34	12.11.2018	Shri Surendra Singh Bisht-Mridul Sandesh, Hindi Biweekly News paper, Village - Poochdi, New Colony, Post Ofice - Ramanagr, District Nainital, Uttarakhand	Yes	No	Rs. 100/- IPO	Information sent on 26.12.2018 by Speed Post	---
35	14.11.2018	Shri Jagdish Chandra S/O Shri Prem Ballabh, Awas Vikas Paryavaran Colony, H.No. 35, Dharanaula, Cheenakhan/Makedi	Yes	No	Rs 100/ cash	Information given on 10.12.2018.	---
36	15.11.2018	Shri Parmod Joshi S/O Shri Balkrishna Joshi, Electronic Media, Hotel Shikhar, Almora, Uttarakhand	Yes	No	Rs 100/ IPO	Information sent on 07.12.2018.	&&
37	17.11.2018	Mr. Rajeev Bhattacharya, 302 Basistha Road Beltola, The Wilderness, Guwahati-781028, Assam	Yes	No	Recd. Online	Information sent on 07.12.2018 by Speed Post.	---

38	29.11.2018	Mr. Deepak Seth, S-62, Pocket-12, Sector-8, Dwarka, New Delhi-110077	Yes	No	Recd. Online	Information sent on 12.12.2018 by Speed Post/ Online.	---
39	29.11.2018	Ms. Sunita Kumari Meena, D/o Shri Mishri Lal Meena, Room No. 34, Varsha Annexe, Sindhu Guest House, ICAR – Indian Agriculture Research Institute (IARI), New Delhi-110012	Yes	No	Rs. 10/- IPO	Information sent on 12.12.2018 by Speed Post/ Online.	---
40	10.12.18	Ms. Kamna Gupta, LIG A 66, Indira Nagar, Banda, UP-210001	No	Yes, transferred from MoEF&CC, New Delhi	Recd. Online	Information sent on 02.01.2019 by Speed Post/ Online.	---
41	14.12.18	Mr. Hira Singh, UDC, GBPIHED, Kosi-Katarmal, Almora, Uttarakhand	Yes	No	Rs. 100/cash	Information given on 26.12.2018.	---
42	26.12.18	Shri Tajendra Singh S/O Shri Kashmir Singh Bedi, News Agency main Road, Bajpur, Udham Singh nagar	Yes	No	Rs. 100/- IPO	Information sent on 22.1.2019 by Speed Post.	---
43	04.01.2019	Ms. Sunita Kumari Meena, D/o Shri Mishri Lal Meena, Room No. 34, Varsha Annexe, Sindhu Guest House, ICAR – Indian Agriculture Research Institute (IARI), New Delhi-110 012	Yes	No	Rs. 10/- IPO	Appeal disposed off on 30.01.2019.	---
44	07.01.2019	Shri Surendra Singh Bisht-Mridul Sandesh, Hindi Biweekly News paper, Village - Poochdi, New Colony, Post Ofice - Ramanagr, District Nainital, Uttarakhand	Yes	No	Rs 100/- IPO	Information sent on January 30, 2019 by Speed Post.	--
45	09.01.2019	Ms. Dipika Rana, D/o Shri Desh Raj Rana, VPO – Sidhbari, Tehsil – Dharamshala, District – Kangra-176 057	Yes	No	Recd. Online	Information sent on 07.02.2019 by Speed Post/ Online.	--
46	11.01.2019	Mr. Kash Babu, E-1, DCM Colony, Gali No. 3, Ibrahim Pur Extn., Delhi-110 084	No	Yes, transferred from MoEF&CC, New Delhi.	No	Information sent on 02.02.2019 by Speed Post/ Online.	--
47	16.01.2019	Mr. Sai, Laya Resource Centre, Plot No. 110, D-No: 5-175/1, Near Senora Beach res, Visakhapatnam, Andhra Pradesh-530 045	Yes	No	Recd. Online	Information sent on 30.01.2019 by Speed Post/ Online.	--
48	22.01.2019	Dr. Ganesh Shanker Srivastava, 56 B, Block-II, National Institute of Health and Family Welfare, Munirka, New Delhi.	Yes	No	Recd. Online	Information sent on 14.02.2019 by Speed Post/ Online.	--
49	30.01.2019	Shri Neeraj Nayal S/O Late Shri Shyam Singh Nayal, Nayal Khola, Almora	Yes	No	Rs. 100/-IPO	Information sent on 12.03.2019 by Speed Post.	--

50	07.02.2019	Shri Divya Prakash C/O Ram Chandra Dairy Wale, Near Harunagala Chauraha (Shiva Medical Store), Harunagla Bilaspur Road, Bareilly, Post - MJP Rohilkhand University, District Bareilly, UP - 243006	Yes	No	Recd. Online	Information sent on 5.03.2019 by Speed Post.	--
51	08.02.2019	Shri Divya Prakash C/O Ram Chandra Dairy Wale, Near Harunagala Chauraha (Shiva Medical Store), Harunagla Bilaspur Road, Bareilly, Post - MJP Rohilkhand University, District Bareilly, UP - 243006	Yes	No	Recd. Online	Information sent on 7.03.2019 by Speed Post.	--
52	13.02.2019	Shri Saurabh Kumar Sahu, New Colony, Dharanaula, Almora - 263601, Uttarakhand	Yes	No	Rs. 100/-IPO	Information sent on 12.03.2019 by Speed Post.	--
53	13.02.2019	Mr. K. Kumar, Roj Kaamgar Shakti Sangthan, RC-1256, Adarsh Nagar, Khoda Colony, Mandir Wala Pushta, NH-24, Ghaziabad, Uttar Pradesh	Yes	No	Recd. Online	Information sent on 13.03.2019 by Speed Post/ Online.	--
54	20.03.2019	Mr. Akshay Mahajan, 57 A, Akashneem Marg, DLF Phase-2, Sector-15, Gurugram-122 002, Haryana	Yes	No	Rec. Online	Information sent on 14.03.2019 by Speed Post/ Online.	--
55	20.03.2019	Mr. Akshay Mahajan, 57 A, Akashneem Marg, DLF Phase-2, Sector-15, Gurugram-122 002, Haryana	Yes	No	Rec. Online	Information sent on 15.03.2019 by Speed Post/ Online.	--
56	26.03.2019	Shri S.P. Nautiyal, H.N. - 4Kali Mandir Enclave, GMS Road Dehradun - 248001, Uttarakhand	Yes	No	Rs. 100/- IPO	Information sent on 01.05.2019 by Speed Post after reciving the photocopy charges.	--

LIST OF SCIENTIFIC & TECHNICAL STAFF (HQRS) as on 31.03.2019

S.N.	NAME	DESIGNATION
1.	Dr. R.S. Rawal	Director
2.	Er. Kireet Kumar	Scientist-G
3.	Dr. R.C. Sundriyal	Scientist-G
4.	Dr. Anita Pandey	Scientist-G
5.	Dr. G.C.S. Negi	Scientist-F
6.	Dr. J.C. Kuniyal	Scientist-F
7.	Dr. Subrat Sharma	Scientist-E
8.	Dr. I.D. Bhatt	Scientist-E
9.	Dr. Paromita Ghosh	Scientist-E
10.	Dr. K. Chandra Sekar	Scientist-E
11.	Mr. Ranjan Joshi	Scientist-E
12.	Dr. S.C. Arya	Scientist-C
13.	Dr. Vasudha Agnihotri	Scientist-C
14.	Dr. Sandipan Mukherjee	Scientist-C
15.	Dr. Mithilesh Singh	Scientist-C
16.	Mr. Asutosh Tiwari	Scientist-C
17.	Dr. Sumit Rai	Scientist-C
18.	Dr. Harshit Pant	Scientist-B
19.	Dr. B.S. Majila	Tech. Gr. IV(4)
20.	Dr. Subodh Airi	Tech. Gr. IV(3)

LIST OF ADMINISTRATIVE, FINANCE/ ACCOUNTS AND SUPPORT STAFF (HQRS)

S.N.	NAME	DESIGNATION
1.	Mr. Anil Kumar Yadav	Administrative Officer
2.	Mr. Surya Kant	Finance Officer
3.	Mr. S.P. Maikhuri	Accounts Officer
4.	Mr L.M.S. Negi	O.S. (Admin)
5.	Mr. S. Higgins	Tech. Gr. III(3)
6.	Mr. Mahesh Chandra Sati	Tech. Gr. IV(2), Lib
7.	Mrs. Sarita Bagdwal	Stenographer
8.	Mr Jagdish Kumar	Stenographer
9.	Mrs Mamta Higgins	O.S.
10.	Mr Heera Singh	U.D.C.
11.	Mr. K.K. Pant	U.D.C.
12.	Mrs. Hema Pandey	U.D.C.
13.	Mr. Atul Bisht	L.D.C.
14.	Mr Chandra Lal	Tech. Gr. II (2)
15.	Mr K.N. Pathak	Tech. Gr. I (4)
16.	Mr Pan Singh	Group 'C'
17.	Mr Nathu Ram	Group 'C'
18.	Smt Ganga Joshi	Group 'C'
19.	Mr. Govind Singh	Driver
20.	Mr. Gopal Singh Bisht	Group 'C'

HIMACHAL REGIONAL CENTRE

S.N.	NAME	DESIGNATION
1.	Dr. S.S. Samant	Scientist-G & Incharge
2.	Er. Rakesh Kumar Singh	Scientist-E
3.	Mrs. Sarla Shashni	Scientist-C
4.	Dr. Renu Lata	Scientist-C
5.	Dr. V.E. Gosavi	Scientist-B
6.	Dr. Kishore Kumar	Tech.-IV(1)
7.	Mr. Daulat Ram	Group 'C'
8.	Mr. Ajay Pawar	Group 'C'

SIKKIM REGIONAL CENTRE

S.N.	NAME	DESIGNATION
1.	Dr. Rajesh Joshi	Scientist-E & Incharge
2.	Dr. Devendra Kumar	Scientist-C
3.	Dr. Sandeep Rawat	Scientist -C
4.	Dr. Mayank Joshi	Scientist -B
5.	Dr. Y.K. Rai	Tech. Gr. IV(3)
6.	Dr. K.S. Gaira	Tech. Gr. IV(1)
7.	Mr. R.K. Das	LDC
8.	Mr. Jagnnath Dhakal	Technical Group I (4)
9.	Mr. P.K. Tamang	Technical Group I (4)
10.	Mr. Musafir Rai	Group 'C'
11.	Mr. Shyambir	Group 'C'

GARHWAL REGIONAL CENTRE

S.N.	NAME	DESIGNATION
1.	Dr. R.K. Maikhuri	Scientist-G & Incharge
2.	Mr. A.K. Sahani	Scientist-D
3.	Mr. Soukhin Tarafdar	Scientist-D
4.	Dr. Arun Kumar Jugran	Scientist-C
5.	Dr. Lakhpat Singh Rawat	Technical Group IV (1)
6.	Mr. D.P. Kumeri	UDC
7.	Mr. M.P. Nautiyal	Tech. Gr. II (2)
8.	Mr. J.M.S. Rawat	Tech. Gr. II (2)
9.	Mr. R.C. Nainwal	Technical Group I (4)
10.	Mr. R.P. Sati	Group 'C'

NORTH-EAST REGIONAL CENTRE

S.N.	NAME	DESIGNATION
1.	Mr. M.S. Lodhi	Scientist-E & Incharge
2.	Dr. K.S. Kanwal	Scientist-C
3.	Dr. Kesar Chand	Scientist -C
4.	Dr. Wishfully Mylliemngap	Scientist-B
5.	Mr. Om Prakash Arya	Tech-IV(1)

DAVER KARNATAK & ASSOCIATES
CHARTERED ACCOUNTANTS

Talla Joshi Khola (Kanoli), Almora
Uttarakhand-263601,05962-230846,+919412045394
206-207. Hari Sadan, 4637/20. Ansari Road, Daryaganj
New Delhi-110002.011-43508411,+919810086211
Karnatakandassociates@gmial.com

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

Opinion

We have audited the financial statements of **G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT** (A Institute of Govind Ballabh Pant Himalaya Paryavaran Evam Vikas Society), which comprise the balance sheet as at March 31, 2019, and the Income & Expenditure Account and Receipt & Payment for the year then ended, and notes to the financial statements, including a summary of significant accounting. In our opinion and to the best of our information and according to the explanations given to us, the aforesaid financial statements give a true and fair view in conformity with the accounting principles generally accepted in India, of the state of affairs of the Company as at March 31st, 2019 and Income over Expenditure for the year then ended

Bases of Opinion

We conducted our audit in accordance with Standards on Auditing (SAs). Our responsibilities under those Standards are further described in the Auditor's Responsibilities for the Audit of the Financial Statements section of our report. We are independent of the Institute (Govind Ballabh Pant Himalaya Paryavaran Evam Vikas Society) in accordance with the Code of Ethics issued by the Institute of Chartered Accountants of India together with the ethical requirements that are relevant to our audit of the financial statements and we have fulfilled our other responsibilities in accordance with these requirements. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our qualified opinion.

Key Audit Matters

Key audit matters are those matters that, in our professional judgment, were of most significance in our audit of the financial statements of the current period. These matters were addressed in the context of our audit of the financial statements as a whole, and in forming our opinion thereon, and we do not provide a separate opinion on these matters. In addition to the matter described in the Basis for Qualified Opinion section we have determined the matters described below to be the key audit matters to be communicated in our report.

Key Audit Matters	Auditor's response
Non	Non

Emphasis of Matters or Other Matter

Interest received from bank is recorded net of TDS & Interest Income is appearing less by the amount of TDS,

As per the letter No. 15/15/2008-CSC of Ministry of Environment, Forest & Climate Change dated 28th June, 2016 "Employees will have to deposit their share of CPF in the corpus fund and all liability will be met by the Institute out of its corpus fund. Liability towards pension trust had not been provided for in the financial accounts.

TDS & GST returns are not produced before us we are not verified the financial records with the returns.

Depreciation on fixed assets has been provided on straight line method as per the rate prescribed in schedule XIV to the company's act 1956, as the Institute is a not a corporate entity policy for charging depreciation should be reviewed the policy should be in consonance with the applicable acts,

DAVER KARNATAK & ASSOCIATES * CHARTERED ACCOUNTANTS * FRN:010196N ALMORA

Responsibilities of Management and Those Charged with Governance for the Financial Statements

The Management is responsible for the preparation of these financial statements that give a true and fair view of the financial position, financial performance, Receipt & Payment of the Institute in accordance with the accounting principles generally accepted in India, including the accounting Standards prescribed by Institute of Chartered Accountants of India. This responsibility also includes maintenance of adequate accounting records in accordance with the provisions of the Act for safeguarding of the assets of the Company and for preventing and detecting frauds and other irregularities; selection and application of appropriate implementation and maintenance of accounting policies; making judgments and estimates that are reasonable and prudent; and design, implementation and maintenance of adequate internal financial controls, that were operating effectively for ensuring the accuracy and completeness of the accounting records, relevant to the preparation and presentation of the financial statement that give a true and fair view and are free from material misstatement, whether due to fraud or error.

In preparing the financial statements, management is responsible for assessing the Institute's ability to continue as a going concern, disclosing, as applicable, matters related to going concern and using the going concern basis of accounting unless management either intends to liquidate the Institute or to cease operations, or has no realistic alternative but to do so.

Those charged with Governance are also responsible for overseeing the Institute's financial reporting process

Auditor's Responsibilities for the Audit of the Financial Statements

Our objectives are to obtain reasonable assurance about whether the financial statements as a whole are free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with SAs will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of these financial statements.

Date: 06.09.2019

Place: Almora

DAVER KARNATAK & ASSOCIATES
FRN:010196N
ALMORA
CHARTERED ACCOUNTANTS

For Daver Karnatak and Associate
(Chartered accountants)

CA. Sanjay Karnatak
FCA .DISA,DIRM (ICAI),LLB
M NO.501670
UDIN 19501670AAAAAO4575

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
BALANCE SHEET AS ON 31ST MARCH 2019

PARTICULARS	SCHEDULE	CURRENT YEAR (`)	PREVIOUS YEAR (₹)
LIABILITIES			
CORPUS / CAPITAL FUND	1	42456716.16	40208702.16
RESERVE AND SURPLUS	2	500857266.72	472081748.42
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	1514044792.88	1120755089.79
TOTAL		**2057358775.76**	**1633045540.37**
ASSETS			
FIXED ASSETS	8	500857266.72	472081748.42
INVEST. FROM EARMARKED/ENDOWMENT FUND	9	32060769.16	32566711.95
INVEST. OTHERS	10	0.00	0.00
CURRENT ASSETS , LOANS, ADVANCES ETC.	11	1524440739.88	1128397080.00
MISCELLANEOUS EXPENDITURE			
TOTAL		**2057358775.76**	**1633045540.37**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES & NOTES ON ACCOUNTS	25		

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

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

DAVER KARNATAK & ASSOCIATES
FRN:010196N
ALMORA
CHARTERED ACCOUNTANTS

DATED : 06.09.2019
PLACE : KOSI- KATARMAL, ALMORA

(DR. R. S. RAWAL)
DIRECTOR

(DR. I.D. BHATT)
D.D.O

06/9/19

(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 2019

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
INCOME			
Income from Sales/Services	12	288976.00	271623.00
Grants/Subsidies(net off exp)	13	463618444.16	395777538.52
Fees/Subscriptions	14	0.00	0.00
Income from Investment	15	0.00	0.00
(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	8121973.00	7458729.92
Other Income	18	5837065.00	8168550.00
Increase (decrease) in stock of Finished goods and work in progress)	19	0.00	0.00
TOTAL (A)		**477866458.16**	**411676441.44**
EXPENDITURE			
Establishment Expenses: a) Institute	20	124898597.00	1204300075.00
b) Projects		44747200.00	40246377.00
c) F.C (Projects)		2861267.00	5020295.00
Administrative Expenses :a) Institute	21	62399276.01	42490886.17
b) Projects (As per Annexure)		211562330.15	159710566.35
c) F.C (Projects)(As per Annexure)		6378918.00	19717808.00
Expenditure on Grants, Subsidies etc.	22	10770856.00	8161531.00
Interest			
Depreciation (Net Total at the year-end-as per Sch. 8)		31404723.48	29443354.48
TOTAL (B)		**495023167.64**	**425220893.00**
Balance being excess of Income over Expenditure (A - B)		17156709.48	13544451.56
Transfer to special Reserve			
Transfer to/ from General Reserve			
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Other Income)		**19941581.48**	**21948106.27**
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Corpus Interest)		**2784872.00**	**8403654.71**
Add: Transferred from General Reserve Fixed Asset Fund		**31404723.48**	**29443354.48**
Interest income of other Saving Accounts.			
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	25		

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

(Sanjay Karnatak)
FCA DISA, DIRM (ICAI)
M.N0.501670

DAVER KARNATAK & ASSOCIATES CA FRN:010196N ALMORA CHARTERED ACCOUNTANTS

DATED : 06 .09.2019
PLACE : KOSI- KATARMAL, ALMORA

(DR. R. S. RAWAL)
DIRECTOR

(DR. L.D. BHATT)
D.D.O

06/9/19

(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 2019

RECEIPTS	CURRENT YEAR	PREVIOUS YEAR	PAYMENTS	CURRENT YEAR	PREVIOUS YEAR
I. Opening Balances			**I. EXPENSES**		
a) Cash in hand	91023.78	65695.72	**a) Establishment Expenses**		
			I) Institute	125808394.00	122124139.99
b) Bank Balances			**b) Administrative expenses**		
			a) Institute	38254167.01	28930287.17
i) In current accounts	0.00	0.00	b) R&D(Rev) expenses	25404982.00	13422870.00
ii) In deposit accounts (Corpus Fund)	5770666.96	43332194.71	c) Payments for current liabilities(gratuity/leave)	0.00	0.00
iii) Savings accounts	173503753.46	448145165.67	**C. Capital expenditure**		
c) Advances & Others	951290838.10	392976876.71	a) Purchase of Fixed Assets	19732896.00	11346961.00
(As per annexure Attached)			b)Expenditure on Capital Work in Progress	27453771.00	23088000.00
F.C. ACCOUNT			c) Acquirement of land (Lease money)		
A) Cash in hand	17846.33	36870.33	**II Payments made against funds for various proj.**		
b) Cash at bank	5809273.66	8487057.27	**Expenditure State govt. projects**		
c)FC Advances	1058177.96	13127678.93	a) Capital	11492046.00	20299697.00
II. Grants Received			b) Revenue:		
a) From Government of India	275000000.00	200000000.00	Establishment exp	39750217.00	39969612.70
i) Institute & IERP			Administration exp	211525952.69	157141340.35
Contribution corpus from CPF	0.00	0.00	**Expenditure FC projects**		
b) From Other agencies	606797265.00	523199894.00	**a) Capital**	1750270.00	105905.00
c) From other sources [from FC]	11830934.81	12538492.58	**b) Revenue:**		
III. Income on Investments from			Establishment exp	3102166.00	4733407.00
a) Corpus Fund(Received from Institute)	7749601.21	7339145.00	Administration exp	5846041.00	19402775.00
IV. Interest Received			**IERP grant released**	10770856.00	8161531.00
a) On Bank deposits savings a/c	17753069.00	12245338.21	**III Investments and deposits made**		
b)On term deposits a/c	0.00	2168742.71	Pension trust (out of corpus fund)	15506465.00	170312760.75
c) Loans, Advances etc.	490860.00	433709.00	**IV Refund of Surplus money/Loans**		
d) Interest income Corpus Fund	245446.00		a) To the Government of India	2684367.00	2787627.50
V. Other Income			b)To Others/ security/ caution money]	6000.00	0.00
Received in Corpus Fund	1067195.00		Refund to MoEF&CC (HBA/MCA)	0.00	9977800.00
(As per annexure Attached)	4958846.00	4483214.00	**V Other payments**		
VI. Amount Borrowed			Other Payment to Instt. FC Proj.	0.00	0.00
VII. Any other receipts.			Unspent Balance (FC)	0.00	3063714.16
			Payment of Current Libilities	0.00	2100.00
			Refund of EMD	474400.00	438000.00
Other Receipt FC a/c			Fund transfar to Corpus fund	7641990.21	7339145.00
a)Performance Guarantee	34600.00	0.00	**VI Closing balances**		
b) Receipts Current Liabilities	0.00	0.00	**a) Cash in hand**	206511.64	91023.78
c) IERP grants refunded by grantee Org.	411186.00		**b) Bank Balance**		
d)Construction Fund			i) In Current account		
e) Corpus Fund FDR'S	0.00	122404578.29	ii) In deposit accounts [Corpus Fund]	2725298.17	5770666.96
f) Caution Money	10500.00	3000.00	iii) In savings accounts	424889948.20	173503753.46
g) Security Deposit	166470.00	46000.00			
h) EMD	331000.00	25500.00	**C) Advances and others**	1081344058.59	951290838.10
i) Royalty	0.00	0.00	**FC Project**		
j) Sales Tax / GST	0.00	25066.00	a) Cash in hand	4976.33	17846.33
k)Service Tax/GST	0.00	2143.00	b) Bank Balance	4625994.18	5809273.66
			c) Advances and others	3386785.25	1058177.96
			Adjustment of previous year closing Advances	0.00	10897108.26
TOTAL	**2064388553.27**	**1791086362.13**	**TOTAL**	**2064388553.27**	**1791086362.13**

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

(Sanjay Karnatak)
FCA DISA, DIRM (ICAI), LLB
M.NO.501670

DATED : 06 .09.2019

DAVER KARNATAK & ASSOCIATES
FRN:018196N
ALMORA
CHARTERED ACCOUNTANTS

(Dr. R. S. RAWAL)
DIRECTOR

(Dr. I.D. BHATT)
D.D.O

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
ANNEXURE FORMING PART OF BALANCE SHEET AS ON 31 MARCH 2019

CURRENT ASSETS

BANK BALANCES (SAVINGS A/C) **ANNEXURE"D"**

PARTICULARS	CURRENT YEAR (₹)
C.B.I Kosi A/c No. 3173366206	31382816.90
S.B.I Almora A/C No. 10861359986	6794482.67
S.B.I Tandong A/c No. 11226047758	1615243.86
S.B.I Kullu A/c No. 10792147561	4601475.81
S.B.I Itanagar A/c No.10940060114	1868190.12
S.B.I Srinagar A/c No. 10972182864	1858581.99
S.B.I Tandong A/c No. 37000934072 (NMHS IHTP DK	4467573.60
C. B. I. Kosi A/c No. 3604013559 (Core Grant New Account)	39930963.00
S. B. I. Kosi A/c No. 36883992887 (NMSHE TF-03 New Account)	4112828.00
S.B.I Srinagar A/c No. 3690636305 (NMHS ST KK)	722014.45
S.B.I Almora A/c No.10861359975 (F.C)	4625994.18
C.B.I Kosi A/c No. 3561532026 (ENVIS New Account)	68171.00
C.B.I. Kosi A/C No. 3530505520 (NMHS-PMU)	308286045.00
S. B. I. Kosi A/c No. 36959540111 (NMHS ST KK)	1647044.00
S. B. I. Kosi A/c No. 36935490949 (NMHS Fellowship)	3155703.30
S. B. I. Kosi A/c No. 36935414822 (NMHS JCK)	4231332.50
S. B. I. Kosi A/c No. 36935498701 (NMHS IHTP GCSN)	917651.00
S. B. I. Kosi A/c No. 36944701949 (NMHS IHTP S. Sharma)	1122753.00
S. B. I. Kosi A/c No. 36944702502 (NMHS IHTP Rajesh Joshi)	616859.00
S. B. I. Kosi A/c No. 36944702987 (NMHS IHTP R. S. Rawal)	2657613.00
S. B. I. Kosi A/c No. 36959556518 (NMHS D. S. Rawat)	2211089.00
S. B. I. Kosi A/c No. 36959540698 (NMHS BSI K. C. Sekar)	345171.00
S. B. I. Mohal A/c No. 36998149642 (NMHS JCK H.P.)	1545964.00
IDBI Itanagar A/c No. 0161104000055514 (NMHS JCK N. E. Unit)	730382.00
Cheque in transit: Regional Centre N.E.	0.00
Regional Centre H.P.	971900.00
Regional Centre Sikkim	1087724.00
Regional Centre Garhwal	0.00
Fund Transfer to Core Grant Account	0.00
	431575566.38

DUE FROM STAFF **ANNEXURE"E1"**

PARTICULARS	CURRENT YR. (₹)
Adv. a/c of Sh. Chandra Lal	10000.00
Adv. a/c of Dr. G.C.S. Negi Sci. G (ENVIS)	25000.00
Total:	**35000.00**

DAVER KARNATAK & ASSOCIATES
FRN:010196N
ALMORA

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DUE FROM OTHERS — **ANNEXURE"E2"**

PARTICULARS	CURRENT YR. (₹)
Adv. a/c of TATA Motors Ltd.	2836.00
Adv. a/c of Meterological Department	8000.00
Adv. a/c of NRSC Hydrabad Proj. 04	24000.00
Adv. a/c of M/s International Trade link	34328.00
Adv. a/c of VPKAS Almora	26560.00
Adv. a/c of STUP Consultant Haldwani	(7435.00)
Adv A/C E.E. RES Almora	1571000.00
Adv. a/c of E. E. CCU N. Delhi	5666158.00
Adv. a/c of NIH Roorkee	100000.00
Adv a/c NICSI New Delhi	35106.00
Employment news New Delhi	48287.00
Adv a/c M/S Sigma Aldrich Chemicals	10590.00
Adv A/C NRSA Hydrabad	35300.00
Adv a/c M/S R.K. Nanda & Sons	28517.00
Adv. a/c of Sh. Manoj Tiwari (Advocate)	20000.00
Adv. a/c of INSA New Delhi	30000.00
Recoverable from Unit	4772.00
Adv. a/c NRSA Hydabad (DST LMS ILTP)	48000.00
Adv. a/c of WWF New Delhi (UNDP CCF PKS N. E. Unit New)	(31930.00)
Adv. a/c of E E. RES Almora (HRDI IDB)	59000.00
Adv a/c of E.E Sikkim (NMSHE-TF-03)	2991000.00
Adv. a/c of NRSC Hydrabad (DST SERB GCSN)	635.00
Adv. a/c of Airport Handling Services (SERB JCK H. P. Unit)	18371.00
Adv a/c of Airport Handling Noida (NMHS-MG- S. Mukherji)	(7788.00)
Adv. a/c of Partners NMHS enclose **Annexure 'X'**	1044304012.05
Adv. a/c of NRSA Hydrabad (ISRO GBP S. Sharma)	350000.00
Adv. a/c of M/s Vankta Enterprises (Cop 11 MoE & F NBA)	7100.00
Adv. a/c Siltep Chemicals Ltd. (Biotech-III)	408.00
Adv. a/c of NRSA Hyerabad (DST KK I)	7400.00
Adv a/c of Forest Research Instt (NMSHE-TF-03)	300000.00
Adv. a/c of NRSC Hydrabad (NMHS IHTP S. Sharma)	121430.00
Adv. a/c of M/s Current Science (NMHS IHTP S. Sharma)	13400.00
Adv. a/c of Indian Institute of Technology (NMHS-ST)	580529.00
Adv. a/c of D. F. O Almora (NMHS-ST)	382914.00
Adv. a/c of Sustainable Dev. Forum NMHS-UBB (RSR)	75000.00
Adv. a/c of Sustainable Dev. Forum (NMHS-IDB)	75000.00
Adv. a/c Forest Vardhanik Uttaranchal (NMHS-IDB)	360000.00
Adv. A/c M/s Moets Catering Services, New Delhi(Mount. Divn.)	42000.00
Adv. a/c NRSC, Hydabad (Mount. Divn.)	73544.00
Adv. a/c IMI New Delhi.(Mount. Divn.)	1000000.00
Adv. a/c Mizoram University (IERP)	300000.00
Adv. a/c IISF Expo 2018 New Delhi.	118000.00
Adv. a/c of Prof. Anil Kumar Raina	375000.00
Adv. a/c of Mahila Haat New Delhi (NMHS-DSR)	239000.00
Adv. a/c of Manoj Kumar Patley (SAC Glacier Phase III)	19677.00
Adv. a/c of H.N.B Gharwal University, Srinagar (ICSSR RKM G. Unit-New)	970822.00
Adv. a/c of M/s Airport Handling (NMSHE TF-03 Old)	230000.00
Adv. a/c of University of Kashmir (NMHS JCK)	2089199.00
Adv. a/c of NEIST, Manipur (NMHS JCK)	1484600.00
Security Deposit CET Sikkim	11000.00
Adv. a/c of D S Bisht (NMHS-DSR)	(40.00)
Security Deposite N.E. Unit	1750.00
	1064247052.05

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SCIENTIFIC ADVISORY COMMITTEE

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Senior Scientist Uppal Road, Hyderabad

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Prof. A.R. Nautiyal
Director
High Altitude Plant Physiology Research
Centre, HAPPRC, H.N.B. Garhwal University,
Srinagar (Garhwal), Uttarakhand

Dr. Kishor Kumar
Chief Scientist and Adviser (E&C)
Geotechnical Engineering Area
CSIR - Central Road Research Institute
Delhi- Mathura Road, New Delhi
Prof. S.C. Rai
Professor & Head
Department of Geography
Delhi School of Economics; University
of Delhi, Delhi

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Salt Lake City, Kolkata, West Bengal
Director/ or his representative

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Forest Research Institute, Dehradun
Institute Faculty

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G.B. Pant Institute of Himalayan Environment
and Development Kosi-Katarmal,
Almora, Uttarakhand

Er. M.S. Lodhi
Scientist - E
G.B. Pant Institute of Himalayan Environment
and Development Nort East Regional Center,
Vivek Vihar Itanagar, Arunanchal Pradesh

Dr. Sarla Sashni
Scientist - C
G.B. Pant Institute of Himalayan Environment
and Development Himachal Regional
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Director
G.B. Pant Institute of Himalayan Environment
and Development Kosi-Katarmal,
Almora, Uttarakhand

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CSIR-National Botanical Research Institute
Rana Pratap Marg, Lucknow

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National Institute of Rural Development
(NIRD) & Panchayati Raj, North Lane,
Jawaharnagar, Khanapara
Guwahati, Assam

Prof. M.C. Nautiyal
Dean, Agriculture & Allied Sciences
High Altitude Plant Physiology
Research Centre, HNB Garhwal University
Srinagar (Garhwal), Uttarakhand

Prof. Dr. J.P. Tamang, FNABS, FNAAS, FIAMS, FBRS
Dean, School of Life Sciences
Professor Department of Microbiology
School of Life Sciences, Sikkim University
(Central University) Tadong, Gangtok, Sikkim

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Department of Botany
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MoEF&CC Representative

Dr. Subrata Bose
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Ministry of Environment, Forest and Climate
Change, Mountain Division,
Indira Paryavaran Bhawan, Jorbagh Road,
Aliganj, New Delhi

Member Secretary (Nominee of the Director, GBPIHED)
Dr. R.C. Sundriyal
Scientist- F
G.B. Pant Institute of Himalayan Environment
and Development
Kosi-Katarmal, Almora, Uttarakhand

G.B. Pant Institute of Himalayan Environment & Development

G.B. Pant Institute of Himalayan Environement and Development (GBPIHED) was established in 1988-89, during the birth centenary year of Bharat Ratna Pt. Govind Ballabh Pant, as an autonomous Institute of the Ministry of Environment, Forest and Climate Change (MoEFCC), Govt. of India. The Institute has been identified as a focal agency to advance scientific knowledge, to evolve integrared management strategies, demonstrate their efficacy for conservation of natural resources, and to ensure environmentally sound management in the entire Indian Himalayan Region (IHR). The Institute has Headquarters at Kosi-katarmal, Almora (Uttarakhand) and five Regional Center, namely, Himachal Regional Center at Mohal (Kullu, HP), Garhwal Regional Center at Srinagar (Garhwal, Uttarakhand), Sikkim Regional Center at Pangthang (Sikkim) and North East Regional Center at Itanagar (Arunachal Pradesh), and Mountain Division Regional Center at MoEFCC New Delhi.

For further information please Contact:
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